MODEL 9307 FOURIER SYNTHESIZER

Instruction Manual

Cat. No. WA-9307-M

PASCO scientific

San Leandro, California 94577

$2.50

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INTRODUCTION

The PASCO Model 9307 Fourier Synthesizer supplies two 440 Hz signals and eight exact harmonics. The unit gives the student complete control over the phase and amplitude of each signal. Any combination of signals can be added together in the summing amplifier for displaying on an oscilloscope and for driving a speaker (such as PASCO Cat. No. WA-9303). With the Fourier Synthesizer, students can experiment with a nearly limitless tange of phenomena from the addition of sine waves to synthesizing pulse waves to examining Gibbs' phenomenon.

PASCO scientific
Model 9307 Fourier Synthesizer

OPERATING INSTRUCTIONS

I. Control Arrangement

The controls and jacks for the Model 9307 Fourier Synthesizer are arranged on the front panel in ten columns. Each column controls one of the Synthesizer's ten channels. The two columns on the left (the number "1" is silkscreened at the top of these columns) control the two channels which produce 440Hz signals. These signals will be referred to as fundamentals. The fundamental controlled by the column on the far left is the first fundamental and the other is the second fundamental. Each of the other eight columns have numbers at the top corresponding to the harmonics they control. For example, the column marked "4" controls the channel which generates a signal with frequency four times the fundamental (i.e. 1760Hz). This signal will be called the fourth harmonic. The column marked "9" controls the ninth harmonic which is a 3960Hz signal.

II. Control Functions

WAVEFORM - The first and second fundamentals each have a series of two slide switches at the top of their control columns. These switches select one of three waveforms. To select a sine waveform, switch the second slide switch to the left. With the second slide switch positioned to the right, the top switch makes the selection between triangular (to the left) and square (to the right) waveforms.

Note: There is no selection of waveform on the second to ninth harmonics. They are all sine waveforms.

PHASE - There are two slide switches and one variable control for adjusting the phase of each signal.

A. 0° - 90°: When switched from the left to the right position, this switch shifts the phase of the signal by 90°. When watching the signal on an oscilloscope, the trace will appear to shift 90° to the right.

B. 0° - 180°: When switched from the left to the right position, this switch shifts the phase of the signal by 180°. When watching the signal on an oscilloscope, the trace will appear to shift 180° to the right.

C. Variable: This control knob is for continuous variation of the signal's phase. When the 0°-90°, 0°-180° Variable controls are used in conjunction with each other, the phase of the original signal can be shifted by any amount from 0° to 360°.

If all the phase control switches are set in the "0" position and all the variable control knobs are set in the "0" position, then all the signals are "in phase". This means that at some point in time all the sine wave signals are simulataneously at their top peaks (depending on how the oscilloscope triggers, all signals may be simultaneously at their bottom peaks). If the signals are displayed on an oscilloscope, then the beginning of the trace (at the left) should start at the top peak of the particular sine wave. Note: See the explanation of the

RESET button below before displaying various signals on the oscilloscope.

AMPLITUDE - This control knob varies the amplitude of the channel's signal. A clockwise rotation increases the amplitude. The amplitude on the fundamentals and second and third harmonics is about 2 volts peak to peak. The remaining harmonics are about one volt peak to peak.

OUTPUT (10K) - Each channel is equipped with a red banana jack which can be connected to an oscilloscope's input (10KΩ or greater) to display each signal separately.

SUMMING AMPLIFIER (IN-OUT) - When the last slide switch in any column is switched to the left, the corresponding signal is connected to the input of the summing amplifier.

SUMMING AMPLIFIER (GAIN, OUTPUT) - The summing amplifier adds all incoming signals together and provides two outputs. The 10K output is for use with an oscilloscope and the 8Ω output includes two red banana jacks. Do not connect either of these jacks to the black grounding jacks on the Fourier Synthesizer.

TRIGGER OUTPUT - The red banana jack in the lower left-hand corner of the front panel provides a trigger source for an oscilloscope. When the oscillscope's external trigger is connected to this jack, the scope will be triggered by a square wave with the same frequency as the fundamental.

GROUND JACKS - The two black banana jacks are connected to the circuit's ground.

ON-OFF - The power switch in the lower lefthand corner turns the unit on and off.

RESET - The red button in the lower righthand corner of the front panel is the reset button. Occasionally transient signals or various sorts of pickup will arbitrarily shift the states of the digital circuitry. In these cases, the phases of the signals from each channel will not line up properly. Pressing the reset button will reset the digital circuitry and immediately align the phases properly. It is good practice to periodically press the reset button to insure that transients are not affecting the phases.

III. OSCILLOSCOPES

The Model 9307 Fourier Synthesizer is designed for use with standard oscilloscopes. To utilize the full potential of the Synthesizer, an oscilloscope with an external trigger should be used. However, many demonstrations are fully effective when using a recurrent sweep scope, A few experiments are even more instructive if, in addition to an external trigger, the oscilloscope has a dual trace (see Experiments Section).

To connect an oscilloscope to the Fourier Snythesizer, first connect one of the GROUND jacks on the Synthesizer to the oscilloscope's ground. Next connect the Synthesizer's TRIGGER OUTPUT jack to the external trigger jack on the scope. Finally, connect the scope's input to any of the

Synthesizer's 10K OUTPUT jacks. If the input connecting cable is not a shielded cable, it should be separated as far as possible from the trigger cable, to reduce AC pickup from the trigger signal.

To get the most out of the various signal displays, connect the trigger on the Synthesizer to the external trigger jack on a triggered scope. If your scope is a recurrent sweep scope, connect the trigger on the Synthesizer to the external sync jack on the scope.

Note on Triggering - If the oscilloscope connected to the Synthesizer is switched to some mode utilizing internal triggering, the Synthesizer phase controls will appear to have no effect on a single channel signal. This occurs because the scope cannot distinguish between different phases of the input signal. However, if two or more channel signals are added together with the Synthesizer and displayed on a scope with internal triggering, a shift in the phase of one of the signals will affect the scope trace. This occurs because the actual shape of the complex signal is changed.

IV. OPERATING PROCEDURE

1. Connect an oscilloscope as explained in Section III.

2. With the oscilloscope turned on, plug the Synthesizer in and switch the power switch to the ON position.

3. Set the oscilloscope sensitivity to about 0.5 volts/cm. If the oscilloscope input is connected to a 10K OUTPUT jack on one channel, turn up the AMPLITUDE on that particular channel until a trace appears on the scope. If the input is connected to the 10K OUTPUT from the summing amplifier, switch one or more channels into the summing amplifier and turn up the AMPLITUDE on those channels until a trace appears on the scope.

4. To use an 8Ω speaker (such as PASCO Cat. No. WA-9303), connect the two leads from the speaker to the two red 8Ω OUTPUT jacks. Switch one or more channels into the summing amplifier. Turn up the AMPLITUDE of those channels as well as the GAIN on the summing amplifier until the signal is clearly heard. The speaker will operate without the oscilloscope connected.

V. OPERATING NOTES

1. If the input cable to the oscilloscope is not properly shielded, or at least separated from the trigger cable, the resulting scope traces may have small spikes and discontinuities. This problem can usually be remedied by shielding the cables. PASCO offers a shielded cable (Cat. No. WA-9305) designed for use with the Fourier Synthesizer.

2. The maximum amplitude obtainable with each channel is scaled down for the upper harmonics. This allows greater accuracy in adjusting the upper hormonics for the very small amplitudes necessary in synthesizing many waveforms.

3. Since the oscillator in the Fourier Synthesizer is crystal controlled, the fundamental frequency is 440Hz to within less than 1%. The harmonics are produced with digital circuitry, and therefore they are essentially 100% accurate relative to the fundamental frequency.

4. It is good practice to periodically hit the RESET button to avoid any problems due to transient signals. Any other load on the power line, such as an electric typewriter or other appliance, can produce transients as it is switched on or switched off. These transients can sometimes affect the digital circuitry and alter phase relationships.

5. The summing amplifier introduces a 180° phase shift. Hence, the the 10K output before the summing amplifier is 180° out-of-phase with the 10K output after the summing amplifier.

VI. CIRCUIT DESCRIPTION:

The PASCO Model 9307 Fourier Synthesizer uses digital synthesis circuitry to generate two 440Hz signals and eight exact harmonics by dividing down a master frequency. The master oscillator is crystal-controlled and produces a square wave signal of 4.4352Hz. This square wave signal is then divided down using D-type TTL flip-flops. For example, in order to get the eighth harmonic, the 4.4352Hz square wave is first divided by 5, then by 7, then by 3, once again by 3, then by 2, and finally by 2 again. The final signal is 3520Hz.

Division by two is easily accomplished with one flip-flop, and consequently division by any power of two is accomplished with the required string of flip-flops. Division by other integers can be done by using several flip-flops to form a counter which resets at the required count. For example, to divide by 5, three flip-flops are used to form a counter. By connecting the outputs, pre-set input, and reset inputs, in the appropraite way, the counter can be made to start over after reaching 5. Consequently, the final output signal frequency is one-fifth the input signal's frequency.

After dividing by some number other than a power of two, the output signal is not always a symmetric wave. In order to make the signal symmetric it is necessary to divide by two. In the case of the eighth harmonic the first division by two is used to make the signal symmetric. In the circuitry for each harmonic as well as the fundamentals, there is a final division by two in order to give exact 90° and 180° phase shift. These shifts are accomplished by switching between various outputs on the flip-flop.

All the digital circuitry is susceptible to transients. Consequently there is a manual reset button which clears all the flip-flops. Also, there is an automatic reset which clears all the flip-flops for a short time after the power is turned on. This automatic reset is merely a RC circuit which sets the level for a Schmidt trigger. The trigger shunts all the logic resets to ground for a short time after the power is initially turned on.

After a square wave of the proper frequency is produced via digital circuitry, the signal is then integrated by an RC circuit to produce a triangular waveform. This waveform is then fed into an active filter tuned to the given frequency. The filter shapes triangular wave into sine wave. Another RC network provides continuous phase shift of at least 90° and then the signal is fed into a buffer amplifier Finally there is a summing amplifier and an audio amplifier. The audio amplifier utilizes two LM-380 integrated circuits in a push-pull configuration.

The power supply for the Model 9307 Fourier Synthesizer is built around two 3-terminal regulated chips and a full-wave bridge rectifier.

EXPERIMENTS

The precision Fourier Synthesizer is especially designed and calibrated to eliminate much of the tedious adjustment that is often necessary in wave experiments. Once the phase relationships between channels have been set, they remain fixed. Moreover, when all the phase controls are in their zero position, all signals are "in phase". This means that if each of the signals is displayed on an oscilloscope (which is triggered by the positive slope of the trigger signal), then the left starting point of the trace begins at a peak of the signal (see Figure 1). If we think of a vertical line at the left starting point of the trace as the Y-axis, and a horizontal line through the middle of the trace as the X-axis, then the trace will resemble the graph of a cosine curve. If the oscilloscope triggers on the negative slope of the trigger signal, then the trace will resemble the graph of the minus cosine curve. If any of the signals appears out-of-phase with the rest, hit the RESET button to bring it in phase.

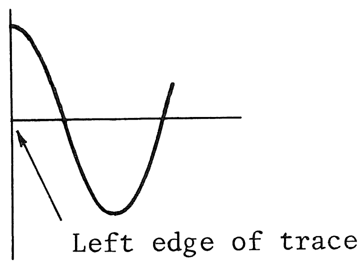


Figure 1

Before beginning any experiment, it is convenient to first switch the 0-180° phase switch to the zero position, then switch the 0-90° phase switch to the zero position, and finally set the variable phase control knob to the zero position. Then a signal from any channel will resemble a cosine curve (with some scale factor) when displayed on an oscilloscope with a coordinate system as discussed above.

1. Addition of Sine Waves (Same Frequency).

Connect an oscilloscope to the Synthesizer with the input cable connected to the 10K OUTPUT after the summing amplifier. Turn on the Synthesizer and zero all the phase controls. Switch the first fundamental into the summing amplifier with all the other channels switched out. Select the sine waveform with the slide switches and adjust the oscilloscope until a clear trace appears on the screen. Adjust the signal's amplitude for a convenient value.

Now switch out the first fundamental and switch in the second fundamental. Adjust the amplitude until it equals the amplitude of the first fundamental. If all the phase controls have been zeroed, the two fundamentals should be in phase. (Remember that in order to observe phase relations, you must connect the external trigger or external sync on your oscilloscope to the Synthesizer's trigger output.) The two signals in phase have been added together and the oscilloscope displays the resulting waveform. Note the amplitude. Again add the two sine waves, but adjust them so that they have different amplitudes. Note the resulting amplitude.

It may be conceptually more instructive if the traces being added together resemble the graph of sine curves when viewed in the coordinate system mentioned in the introduction to this EXPERIMENTS section. To do this, merely shift the phase of the two fundamentals by 90° with the appropriate switch. Then the traces will start out like a sine curve starts out from the origin (see Figure 2).

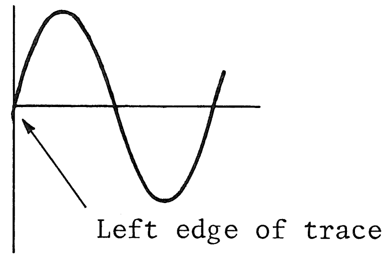


Figure 2

With both signals added together, slowly change the phase of the second fundamental with the VARIABLE phase control. Watch the change in the resulting waveform. What happens when the signals are 180° out of phase? By switching each fundamental in separately and then together, make a chart noting amplitude and phase of the separate signals and the signal resulting from addition of the two. Connect the speaker to hear the signals before and after addition.

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

2. Addition of Sine Waves (Different Frequencies).

When adding two sine waves of different frequencies, the relationship between phase difference and wave shape gives direct information on the laws of sine wave addition.

Connect an oscilloscope to the Synthesizer with the input cable connected to the 10K OUTPUT after the summing amplifier. Switch the first fundamental into the summing amplifier and select the sine waveform. Shift the phase of the signal by 90° so that the trace resembles the graph of a sine curve when viewed in the coordinate system mentioned above. Adjust the amplitude to a convenient level.

Now switch out the first fundamental and switch in the second harmonic. Shift the phase of the signal by 90° so that is resembles a sine curve in the coordinate system mentioned above. Adjust the amplitude until it is one-half the amplitude of the first fundamental.

Switch in the first fundamental and observe the resulting waveform. This waveform represents the graph of $\sin\theta + \frac{1}{2} \sin 2\theta$.

By adjusting their phases by steps of 90°, both the first fundamental and second harmonic can be put in one of four postions - sin, cos, -sin, -cos. The resulting sixteen combinations of the two components results in four distinct waveforms. Make a chart showing phase relation and the resulting waveform. With a little more experimenting, some of the basic trigonometric addition formulas can be derived.

3. Beats.

When two waves of relatively similar frequencies interfere, the amplitude of the resulting waveform varies sinusoidally. These variations of amplitude are called "beats" and occur at a frequency equal to the difference of the two original frequencies.

With the Fourier Synthesizer, it is easy to demonstrate beats. Connect an oscilloscope to the 10K OUTPUT after the summing amplifier on the Synthesizer. Switch in the eighth harmonic and adjust the amplitude to a convenient value. Switch out the eighth harmonic, and switch in the ninth harmonic. Adjust the amplitude until it equals the amplitude of the eighth harmonic. Now switch in both the eighth and the ninth harmonics. Determine the frequency and amplitude of the beats by examining the waveform on the oscilloscope. Repeat the procedure using different amplitudes on the eighth and ninth harmonics. Try producing beats with the sixth and eighth harmonics.

NOTE: Your ear will have difficulty discerning the beats produced by two harmonics, since the resulting tones will seem to be "in harmony".

4. Fourier Analysis.

Joseph Fourier discovered that periodic functions can be represented as an infinite sum of sine and cosine functions. Moreover, each of these sine and cosine functions represent the harmonics (i.e. their frequency is an integer times some constant) of some fundamental. Consequently, complex waveforms can be built up by adding certain harmonics of the proper amplitude and phase.

The square wave for example, can be synthesized by adding the odd-numbered harmonics in the proper proportions. Connect an oscilloscope to the 10K OUTPUT after the summing amplifier. Since phase relationships are very important in Fourier synthesis, always adjust the phase of each signal with respect to the coordinate system mentioned in the introduction to this section. Switch in the fundamental, adjust its amplitude to a convenient value, and note that the scope trace resembles a cosine curve when viewed in the coordinate system which has the Y-axis at the left starting point of the trace. Now switch out the fundamental and swich in the third harmonic. Adjust its amplitude to 1/3 the amplitude of the fundamental. Shift its phase by 180° so that it resembles the minus cosine curve. Continue by adding the fifth harmonic with 1/5 the amplitude of the fundamental. The fifth harmonic should resemble a cosine curve (with a different scale factor than the fundamental). The seventh harmonic should resemble a minus cosine curve with 1/7 the amplitude of the fundamental. Finally the ninth harmonic should resemble a cosine curve with 1/9 the amplitude of the fundamental.

Now switch in the fundamental and third harmonic together. The composite waveform should resemble a cosine curve with a small indentation at the peaks and depths. Switch in the fifth, seventh, and ninth harmonics. The final composite waveform should resemble a square wave. More harmonics are necessary to make an accurate square wave. If all the phase controls were originally zeroed, the square wave should be fairly symmetric. However, since the variable phase controls are fairly sensitive, it may be necessary to make fine phase adjustments to get a proper square wave. To make these adjustments, switch the fundamental and third harmonic in together. Adjust the variable phase of the third harmonic until the trace is symmetric with the indentation in the middle of the wave's peak. Then switch in the fifth harmonic and adjust its phase to again perserve the symmetry of the wave. Continue for all the harmonics.

The table below gives the harmonic makeup of some common periodic waves. The coefficient in front of the "s" (sine waveform) or "c" (cosine waveform) represents the relative amplitude. For example, when building a sawtooth wave, the second harmonic should resemble a minus sine curve with an amplitude which is 50% of the fundamental's amplitude.

	Harmonics								
Waveform	Fundamental (1)	2	3	4	5	6	7	8	9
Square	+100 c	0	-33 c	0	+20 c	0	-14 c	0	+11 c
Triangular	+100 c	0	+11 c	0	+ 4 c	0	+ 2 c	0	+1.2 c
Sawtooth	+100 s	-50 s	+33 s	-25 s	+20 s	-17 s	+14 s	-12.5 s	+11 s
Train of pulses	+ 20 c	+20 c	+20 c	+20 c	+20 c	+20 c	+20 c	+20 c	+20 c
Rectified cosine	+100 c	-20 c	+8.3 c	-4.8 c	+3.3 c	-2.1 c	+1.3 c	-1.2 c	+.9 c
Parabola	+100 c	+25 c	+11 c	+6.7 c	+ 4 c	+ 3 c	+ 2 c	+1.5 c	+1.2 c

* c = cosine
s = sine

In the above table, the phase of the harmonics in building a square wave are referenced to the cosine function. Suppose we used sine curves instead of cosine curves. That is, we add a sine curve, then the third harmonic with phase resembling a minus sine curve, then the fifth harmonic with phase resembling the sine curve, etc. Is the result the same? Explain.

5. Gibbs' Phenomenon.

As more and more harmonics are added together in the Fourier Synthesis of a square wave, the composite wave approaches a square waveform, but there are definite "overshoots" on the leading and trailing edges of the wave. Gibbs noticed 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 of harmonics increases. This phenomenon is easily explained mathematically and is dealt with in the more advanced text on Fourier analysis.

Synthesize the square wave as outlined in the preceding Fourier Analysis section. As each harmonic is added in, measure the amount of overshoot and the width of the peaks. Repeat the procedure when synthesizing a sawtooth waveform. Check the other common periodic waves for overshoots.

6. Music:

Tones produced by musical instruments are examples of complex periodic waves. We often describe various musical tones in a more or less subjective manner with words like mellow, tinny, round, brassy, etc. These differences in quality are due primarily to the presence of various harmonics (often called overtones). A different distribution of intensities among the harmonics results in a tone of a different quality. Of course, in some musical instruments the situation is not quite so simple. Even if the same instrument is used to play two different scale tones, the harmonic makeup of the tones can vary markedly. Moreover, the various vibration modes of the instrument may give rise to frequencies other than the main fundamental and its harmonics. In cases such as this, the "pitch" of the tone is hard to define and often differs from the fundamental or its harmonics.

With the Fourier Synthesizer we can further examine the connection between wave shape and tonal quality. Connect an oscilloscope to the 10K OUTPUT after the summing amplifier on the Synthesizer and connect a speaker between the 8Ω OUTPUT and GROUND. Switch in the first fundamental. Adjust the AMPLITUDE and GAIN until the waveform is seen and heard. Now switch from the sine waveform to the square waveform and readjust the amplitude to equal that of the sine waveform. Note the difference in tonal quality. Switch to the triangular waveform and again note the quality difference.

Next switch in the first fundamental in the sine waveform mode and switch in the second harmonic. Vary the amplitude of the second harmonic and listen for quality changes in the resulting tone. Vary the phase of the second harmonic and again listen for quality changes. Try to correlate wave shape to the tonal quality. Switch out the second harmonic and switch in one of the higher harmonics (leave the first fundamental switched in). Adjust the amplitude and phase of the higher harmonic and note quality changes. Do phase changes of the higher harmonics affect the tone much?

Many physics texts give sample sound spectra of various musical instruments. By adjusting the Synthesizer for the various harmonic intensities given in these spectra, we can synthesize musical tones. The table below gives the relative amplitudes for the harmonics present in several musical tones. Use the oscilloscope to adjust the amplitude of each harmonic, then add them all together with the summing amplifier. Listen to the resulting waveform. Vary the phases and note any changes in the tonal qualities.

Sound Spectra of some Musical Instruments

	Harmonics								
	Fundamental (1)	2	3	4	5	6	7	8	9
Violin	100	47	20	10	35	10	-	-	-
Clarinet	100	56	10	5	15	30	45	30	20
Piano	100	25	30	20	15	5	-	-	-

NOTE: Using PASCO's Model 9302 Waveform Analyzer we can determine the relative intensities of harmonics in any musical tone. Then using the data we can synthesize the original tone.

Although the Fourier Synthesizer is properly adjusted to reproduce the harmonic makeup of a particular musical instrument, the resulting synthesized tone may not sound exactly like the given musical instrument. This may be due to the effect of attack and decay on musical tones. When a piano and violin produce the same tone, their attacks are markedly different. In the piano the particular string is struck with a hammer, whereas on the violin the string is vibrated by rubbing it with a bow. Hence, both tones have different qualities. Similarly, the way musical tones die out or decay affects their overall tonal qualities. The Fourier Synthesizer does not reproduce these various attacks and decays but, rather, synthesizes the harmonic make-up of musical tones.

7. Lissajous Figures.

The Model 9307 Fourier Synthesizer is a convenient unit for demonstrating Lissajous Figures. To use the synthesizer for these demonstrations, connect the ground jack of an oscilloscope to a ground jack on the synthesizer. Next connect the vertical input of the scope to one of the output jacks <u>before</u> the synthesizer's summing amplifier. Finally connect the scope's horizontal input to another output jack before the summing amplifier.

If the vertical and horizontal inputs are connected to the outputs of the first and second fundamentals, and if both fundamentals are in the "sin" or "cos" mode, then the resulting Lissajous Figure is an ellipse. Vary the phase of the second fundamental and note the changing orientation of the ellipse. Correlate the phase difference between the fundamentals with the ellipse orientation. Vary the amplitude of both signals and note the results.

Try different waveforms, such as triangular and square waves, on the vertical and horizontal inputs. Next put a sine wave fundamental on the vertical input and one of the harmonics on the horizontal. Again vary phase and amplitude and note the different figures. With this data explain how to tell which harmonic is used by looking at the resulting figure.

To produce even more complex Lissajous figures, connect either the horizontal or vertical input of the scope to the output jack after the Synthesizer's summing amplifier. Then switch in as many harmonics as desired. This will produce a complex signal at one of the scope inputs. Connect the other input to a single channel as before.

8. Strange Traces to Generate Student Interest.

The Fourier Synthesizer is capable of generating many odd waveforms. The student will undoubtedly find the resulting oscilloscope traces extremely facinating. These strange waveforms can be used to generate student interest or to test his understanding (by asking the student how the scope trace was formed). The following traces may prove useful in these areas.

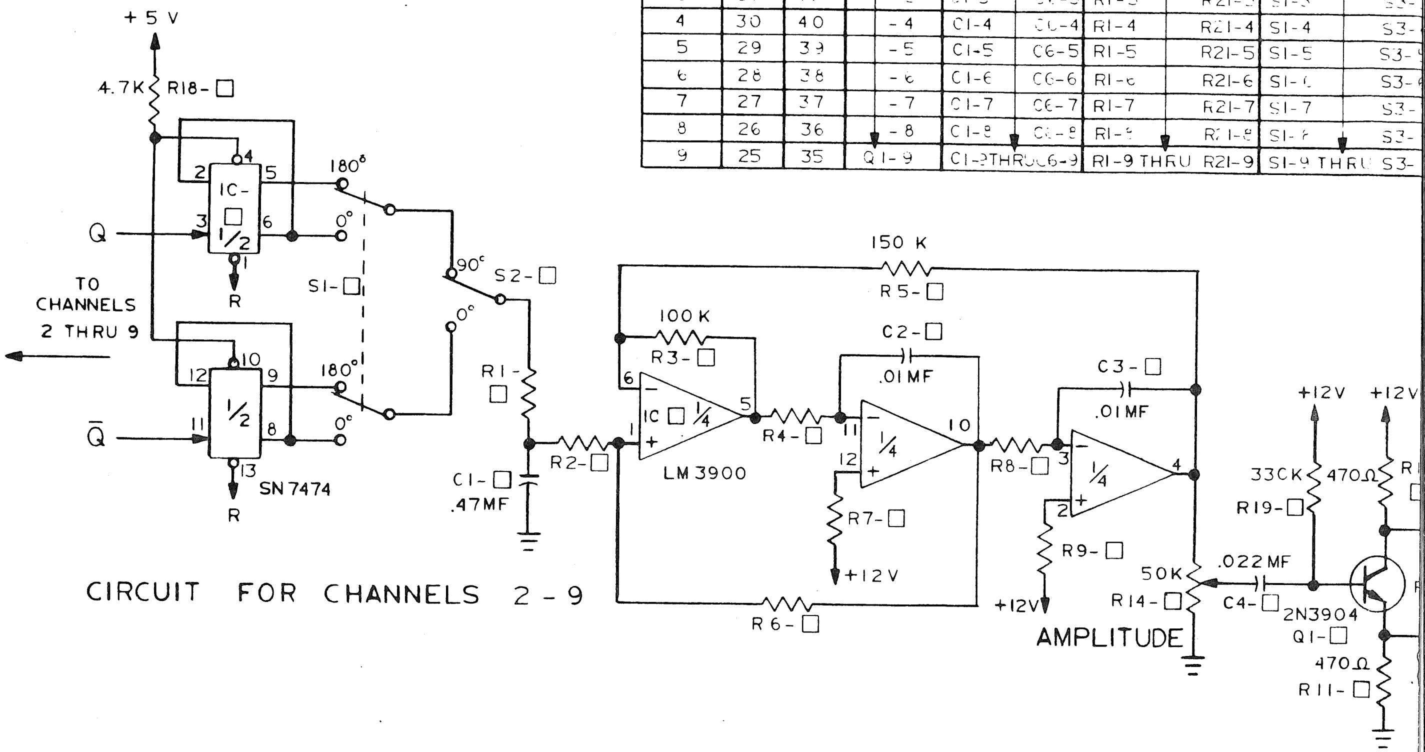
A. Braces: Add the first fundamental in the sine waveform mode and the second fundamental in the triangular waveform mode. Adjust their amplitudes to be equal and adjust the phase until both signals are 180° out of phase.

B. Design with V's: Repeat the procedure in A. above with the first fundamental in the square waveform mode.

C. Disjointed Sine Wave: Add the first fundamental in the square waveform mode and the second fundamental in the sine waveform mode. Adjust the phase until both signals are in phase. The amplitude of the square wave should be much less than that of the sine wave.

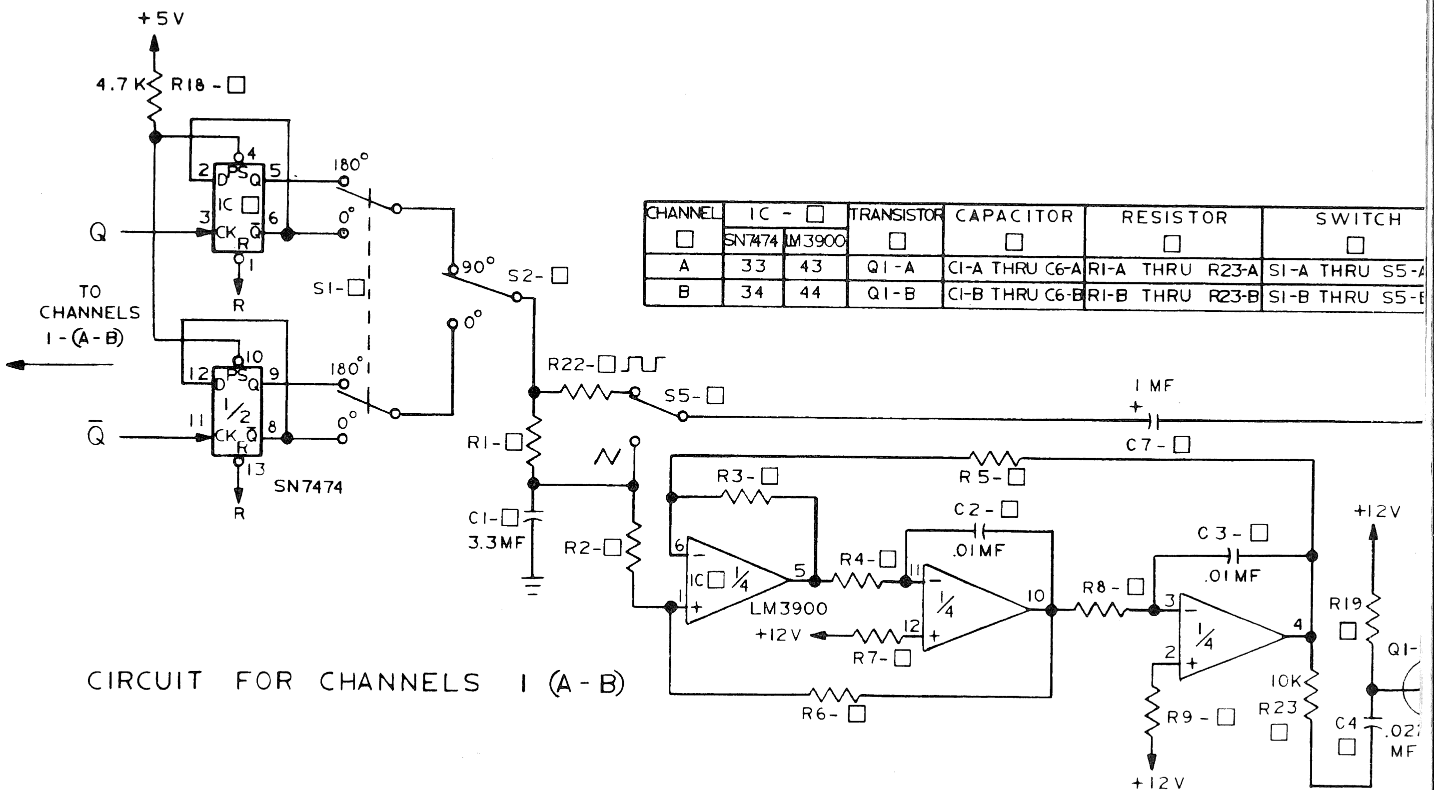
D. Figure "8": Connect the Synthesizer to the oscilloscope for displaying a Lissajous Figure. Connect the first fundamental (in the sine waveform mode) to the horizontal input and the second harmonic to the vertical input. With the amplitudes of both signals approximately equal, adjust the phase of the second harmonic until the Figure "8" is centered.

CHANNEL ☐	IC - ☐ SN7474	IC - ☐ LM3900	TRANSISTOR ☐	CAPACITOR ☐		RESISTOR ☐		SWITCH ☐	
2	32	42	Q1-2	C1-2 THRU C6-2		R1-2 THRU R21-2		S1-2 THRU S3-2	
3	31	41	-3	C1-3	C6-3	R1-3	R21-3	S1-3	S3-
4	30	40	-4	C1-4	C6-4	R1-4	R21-4	S1-4	S3-
5	29	39	-5	C1-5	C6-5	R1-5	R21-5	S1-5	S3-
6	28	38	-6	C1-6	C6-6	R1-6	R21-6	S1-6	S3-
7	27	37	-7	C1-7	C6-7	R1-7	R21-7	S1-7	S3-
8	26	36	-8	C1-8	C6-8	R1-8	R21-8	S1-8	S3-
9	25	35	Q1-9	C1-9 THRU C6-9		R1-9 THRU R21-9		S1-9 THRU S3-	

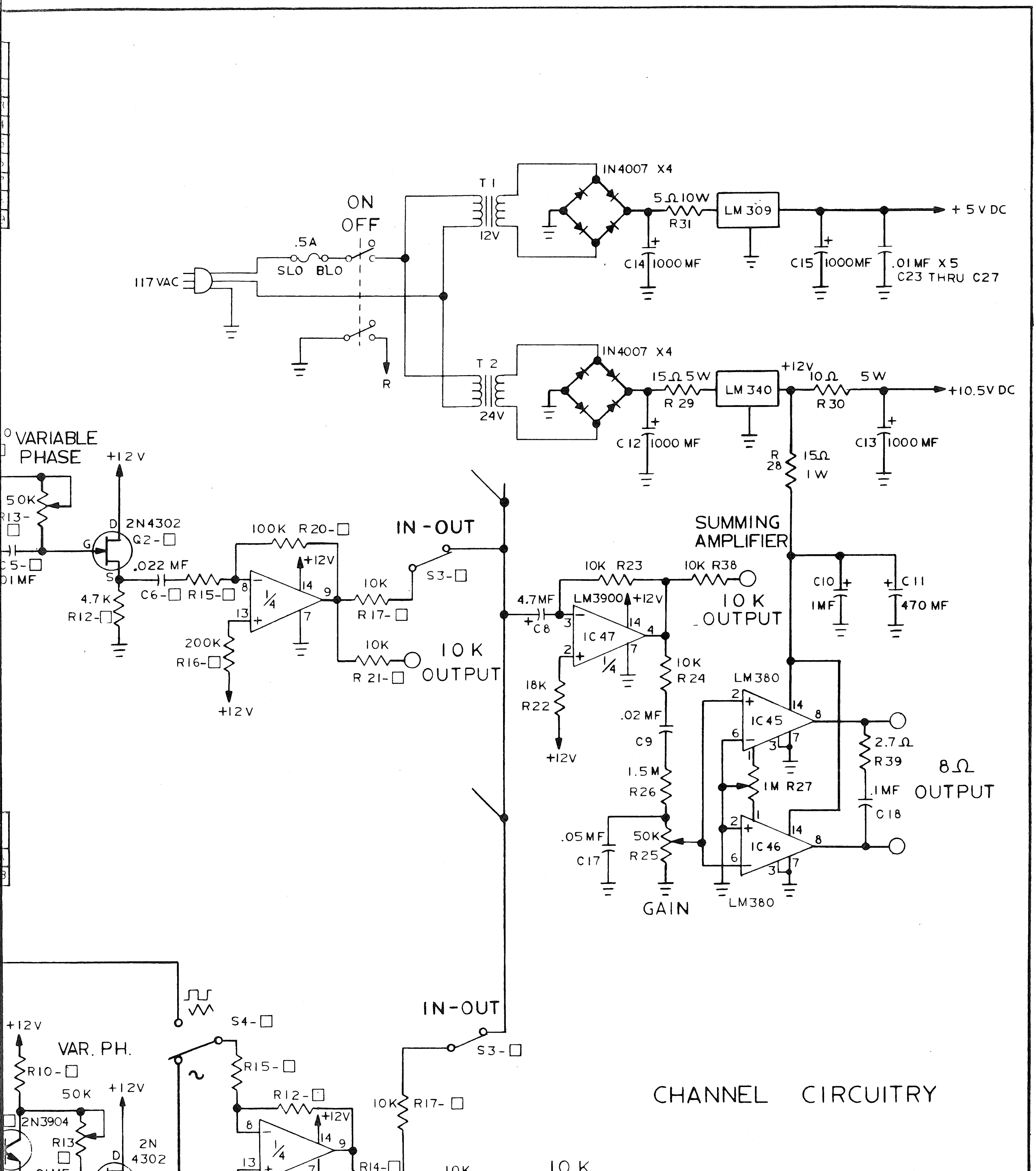


CIRCUIT FOR CHANNELS 2 - 9

CHANNEL ☐	IC - ☐ SN7474	IC - ☐ LM3900	TRANSISTOR ☐	CAPACITOR ☐	RESISTOR ☐	SWITCH ☐
A	33	43	Q1-A	C1-A THRU C6-A	R1-A THRU R23-A	S1-A THRU S5-A
B	34	44	Q1-B	C1-B THRU C6-B	R1-B THRU R23-B	S1-B THRU S5-B



CIRCUIT FOR CHANNELS 1 (A-B)



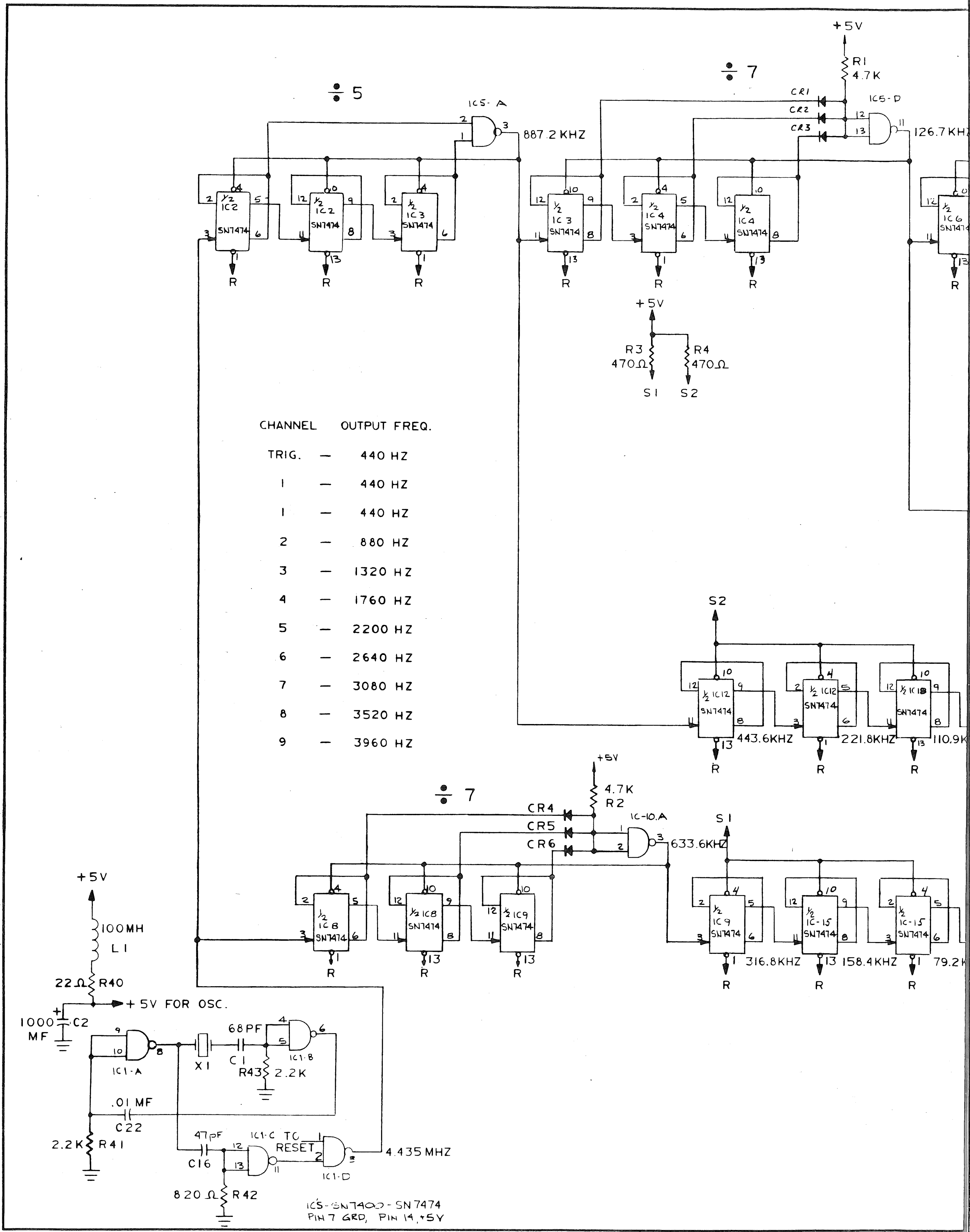
CHANNEL CIRCUITRY

PASCO scientific CALIFORNIA, U.S.A.

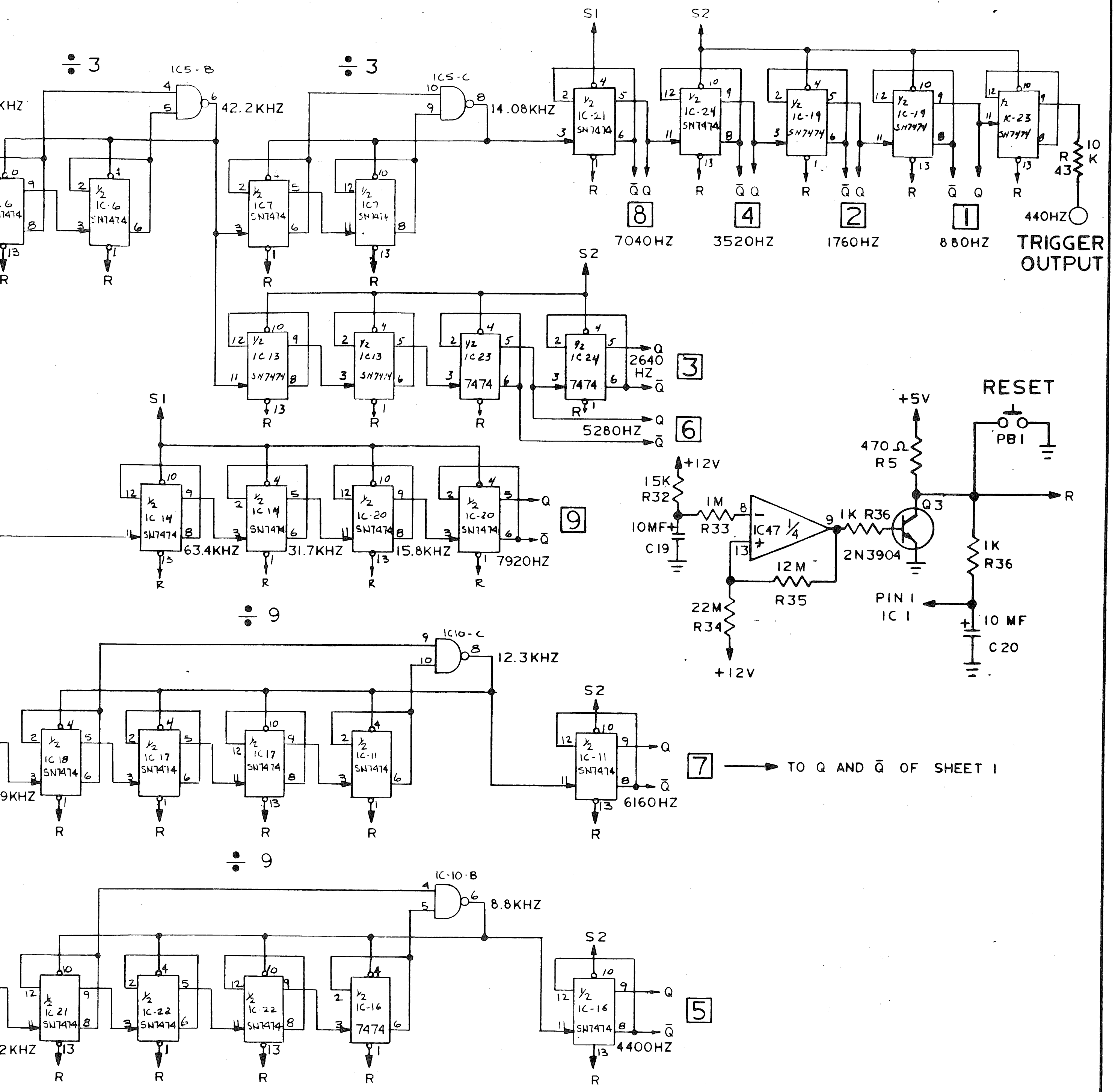
SCALE	FOURIER SYNTHESIZER
DWN BY SWD	
DATE 1-19-5	
APP'D BY	PROD I.D. 9307
DATE	DWG LIST NO ———

DRAWING NUMBER D-005-00253-B SHEET 1/2

SIZE SERIAL NO. CLASS REV.



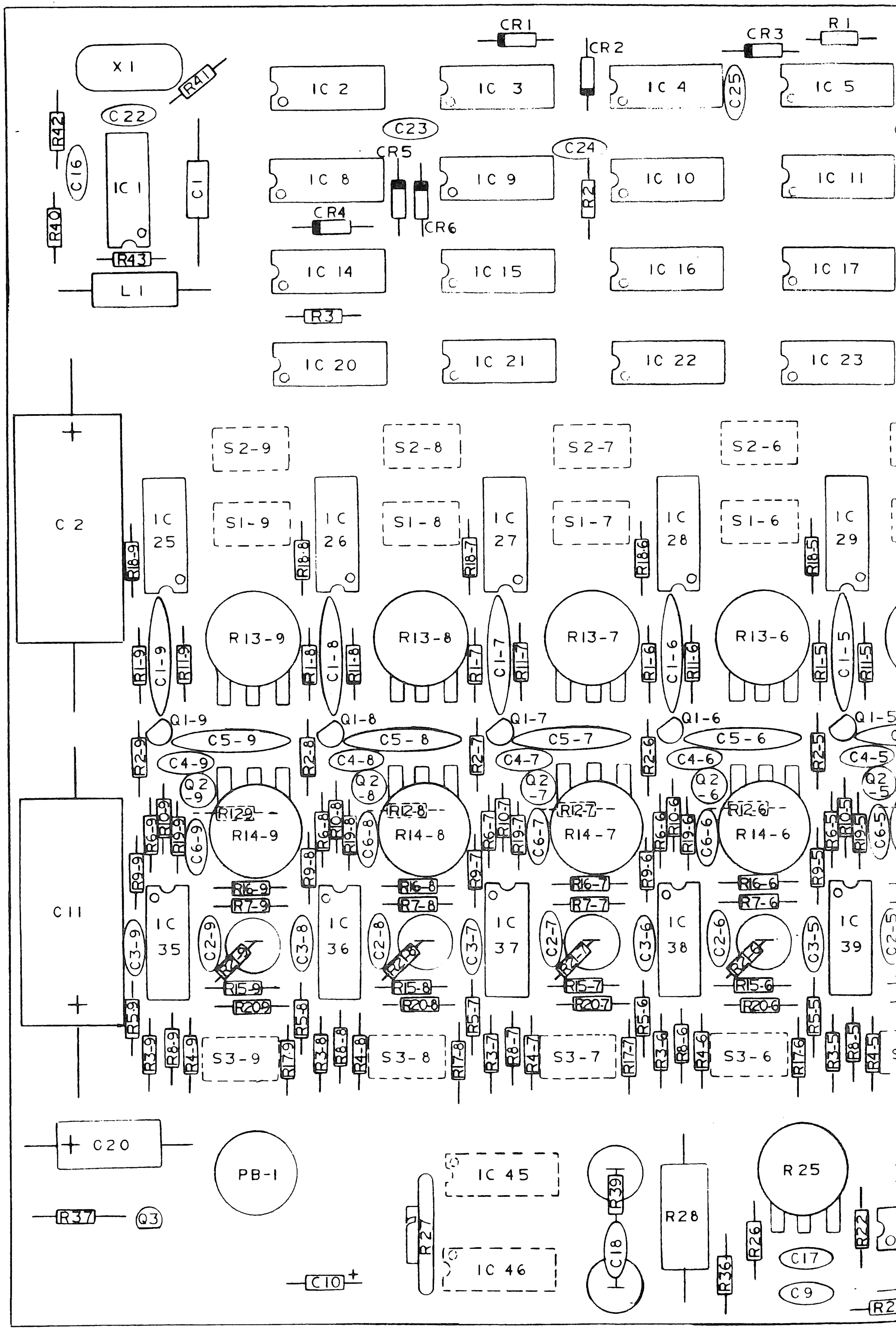
CHANNEL		OUTPUT FREQ.
TRIG.	—	440 HZ
1	—	440 HZ
1	—	440 HZ
2	—	880 HZ
3	—	1320 HZ
4	—	1760 HZ
5	—	2200 HZ
6	—	2640 HZ
7	—	3080 HZ
8	—	3520 HZ
9	—	3960 HZ



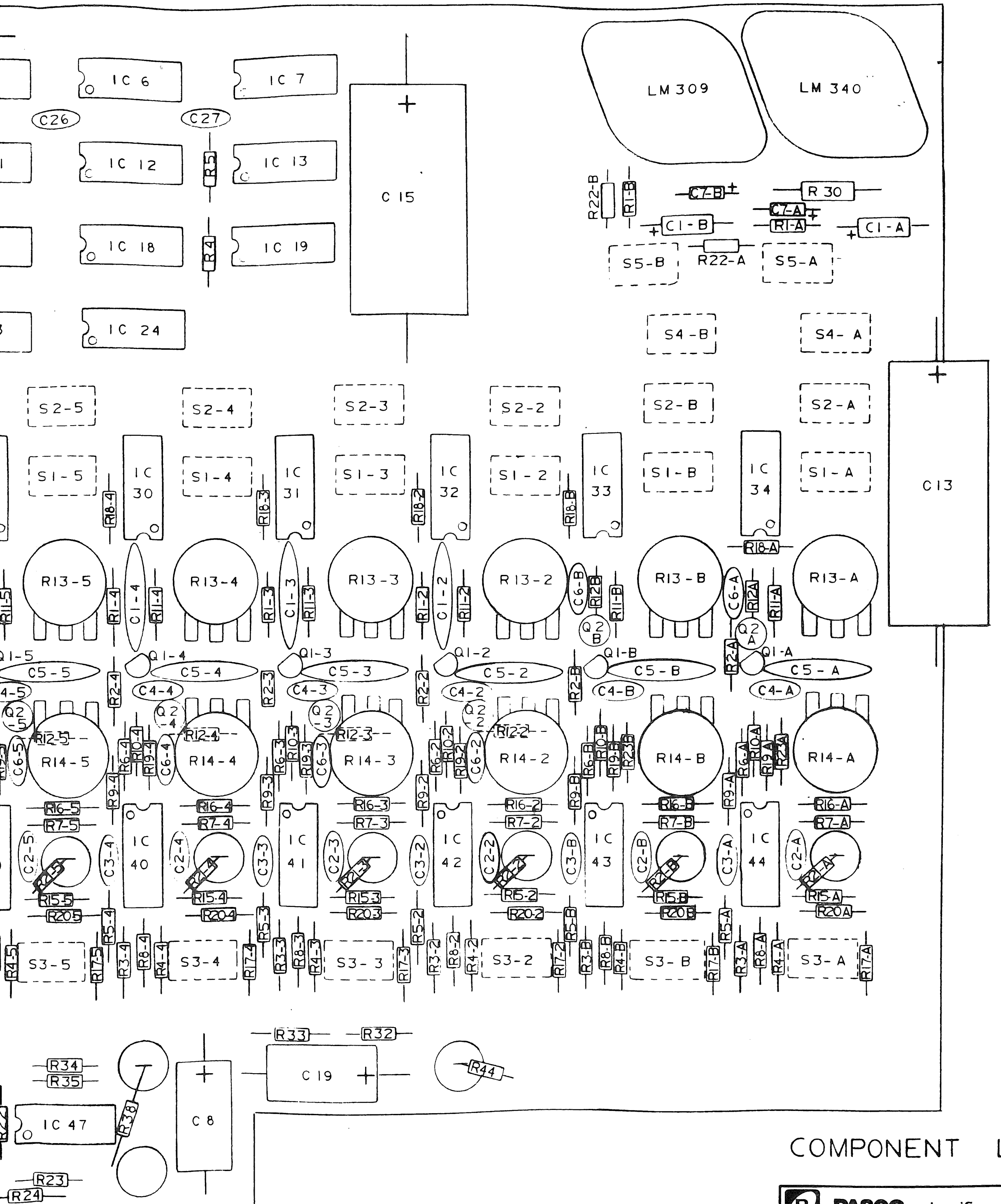
DIGITAL CIRCUITRY

PASCO scientific CALIFORNIA, U.S.A.

SCALE:	FOURIER SYNTHESIZER
DWN BY: SWD	
DATE 1-19-5	
APP'D BY:	PROD I.D. 9307
DATE	DWG LIST NO ——
DRAWING NUMBER	D-005-00253-B
SHEET	2/2


X1
R41
C22
R42
C16
IC 1
C1
R40
R43
L1
CR1
CR2
CR3
R1
IC 2
IC 3
IC 4
C25
IC 5
C23
CR5
C24
IC 8
IC 9
IC 10
IC 11
R2
CR4
CR6
IC 14
IC 15
IC 16
IC 17
R3
IC 20
IC 21
IC 22
IC 23
C 2
S2-9
S2-8
S2-7
S2-6
S1-9
S1-8
S1-7
S1-6
IC 25
IC 26
IC 27
IC 28
IC 29
R18-9
R18-8
R18-7
R18-6
R18-5
R13-9
R13-8
R13-7
R13-6
R1-9
C1-9
R11-9
R1-8
C1-8
R11-8
R1-7
C1-7
R11-7
R1-6
C1-6
R11-6
R1-5
C1-5
R11-5
Q1-9
Q1-8
Q1-7
Q1-6
Q1-5
C5-9
C5-8
C5-7
C5-6
R2-9
R2-8
R2-7
R2-6
R2-5
C4-9
C4-8
C4-7
C4-6
C4-5
Q2 -9
Q2 -8
Q2 -7
Q2 -6
Q2 -5
R12-9
R12-8
R12-7
R12-6
R14-9
R14-8
R14-7
R14-6
R10-9
R6-9
R19-9
C6-9
R6-8
R10-8
R19-8
C6-8
R6-7
R10-7
R19-7
C6-7
R16-6
R10-6
R19-6
C6-6
R6-5
R10-5
R19-5
C6-5
R9-9
R9-8
R9-7
R9-6
R9-5
C11
R16-9
R7-9
R16-8
R7-8
R16-7
R7-7
R16-6
R7-6
IC 35
IC 36
IC 37
IC 38
IC 39
C3-9
C2-9
C3-8
C2-8
C3-7
C2-7
C3-6
C2-6
C3-5
C2-5
R15-9
R20-9
R15-8
R20-8
R15-7
R20-7
R15-6
R20-6
R5-9
R5-8
R5-7
R5-6
R5-5
R3-9
R8-9
R4-9
S3-9
R17-9
R3-8
R8-8
R4-8
S3-8
R17-8
R3-7
R8-7
R4-7
S3-7
R17-7
R3-6
R8-6
R4-6
S3-6
R17-6
R3-5
R8-5
R4-5
C20
PB-1
IC 45
R39
R28
R25
R37
Q3
R27
C18
R26
R22
C17
IC 46
R36
C10
C9

COMPONENT S



COMPONENT LOCATION

PASCO scientific CALIFORNIA, U.S.A.

SCALE	FOURIER SYNTHESIZER		
DWN BY SWD			
DATE 2-28-5			
APP'D BY	PROD I D 9307	DWG LIST NO ———	DRAWING NUMBER D-003-00253-B
DATE			SHEET 1/1

SIZE SERIAL NO CLASS REV

SILE

Parts List

Most component values are included on the schematics contained in the appendix. Those values that are not there are included in the tables below. When reordering parts other than resistors and capacitors, include the PASCO stock number. In either case, indicate that the part is a replacement for a component in the Model 9307 Fourier Synthesizer. If possible, include the schematic number (e.g. R2-3) when designating some part.

Resistors

All resistors are 1/4 watt, carbon composition unless otherwise noted on the schematics.

The following table gives resistor values for circuitry special to each channel.

Schematic No.	Channel									
	A	B	2	3	4	5	6	7	8	9
R1-	1.5K	1.5K	3.9K	6.8K	3.3K	4.7K	3.6K	3.9K	4.7K	4.7K
R2-	330K	330 K	240K	100K	330K	150K	150K	470K	100K	100K
R3-	100K →									
R4-	33K	33K	18K	12K	8.2K	6.8K	6.8K	4.7K	4.7K	3.9K
R5-	150K →					180K	100K	150K	100K	100K
R6-	240K	240K	470K	470K	1M	2M	3.3M	820K	680K	680K
R7-	1M →									
R8-	33K	33K	18K	12K	8.2K	6.8K	6.8K	4.7K	4.7K	3.9K
R9-	1M →									
R10-	1K	1K	470 →							
R11-	1K	1K	470 →							
R12-	4.7K →									
R13-	50K Potentiometer →									
R14-	50K Potentiometer →									
R15-	Factory Select Value →									
R16-	1M	1M	240K →							
R17-	10K →									
R18-	4.7K →									
R19-	330K →									
R20-	270K	270K	150K	100K	100K	100K	100K	100K	150K	150K
R21-	10K	10K	10K	10K	10K	10K	39K	39K	10K	10K
R22-	330K	330K								
R23-	10K	10K								

Capacitors

Value	Type	Schematic Nos.
.022MF	Ceramic	C6-2 to C6-9 C4-A to C4-9

4.7MF	25V. Electrolytic	C8
10MF	35V. Tantalum	C19 C20
1MF	35V. Tantalum	C7-A C7-B C10
3.3MF	35V. Tantalum	C1-A C1-B
.01MF	Ceramic	C5-A to C5-9 C22 to C27
.01MF	Mylar	C2-A to C2-9 C3-A to C3-9
.1MF	Ceramic	C6-A C6-B C18
.47MF	Ceramic	C1-2 to C1-9
68pF	Polystyrene	C1
47pF	Ceramic	C16 C17
1000MF	25V Electrolytic	C11 to C15 C2
.05MF	Ceramic	C9

Semiconductors

Industry No.	Schematic Nos.	PASCO Stock No.
2N4302	Q2-A to Q2-9	422-004
2N3904	Q1-A to Q1-9 Q3	420-002
1N4151	CR1 to CR6	414-001
SN7474	IC2 to IC4 IC6 to IC9 IC11 to IC34	430-018
SN7400	IC1 IC5 IC10	430-017
LM3900 (MC3401)	IC35 to IC44 IC47	430-007
LM380	IC45 IC46	430-004

Potentiometers
50K Panel Pot PASCO Stock No.: 140-013

Crystal
4.4352Hz PASCO Stock No.: 318-001

Choke
100mH PASCO Stock No.: 310-001

Switches
Power switch PASCO Stock No.: 511-005
Slide switch PASCO Stock No.: 512-007