PE PAIA Electronics
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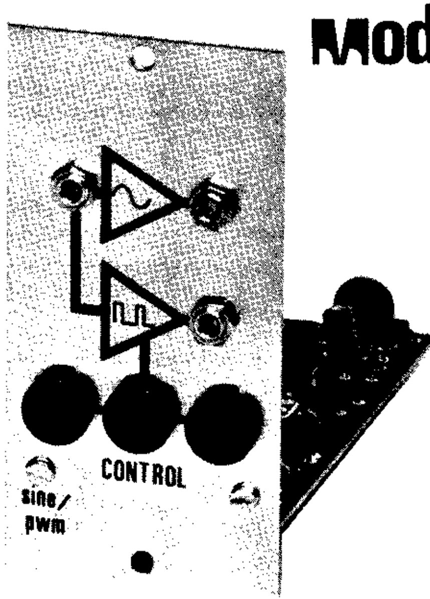
Sine Converter/Pulse Width Modulator



SPECIFICATIONS

Module power requirements:	18v. @ 11ma.
Input impedance:	nominal 47K ohm
Frequency response:	30Hz. to 3kHz.
SINE	
Shaping method:	diode break point
Output impedance:	less than 1K ohm
Output level:	.5v. peak to peak
PULSE	
Control voltage range:	0 to 5v.
Duty factor range:	less than 3% to 50%
Overange:	100%
Output impedance:	less than 1K ohm
Output level:	.5v. peak to peak

The 2720-14 Sine Converter/Pulse Width Modulator accepts at its input a triangular wave with a peak to peak amplitude of 400 to 900 millivolts and at its outputs produces both a sinusoidal waveform and a pulse with voltage controllable duty factor.

A sine wave is the only "pure" tone and as such is appropriate for a number of musical applications either in simulation of natural instrument voices or as a completely electronic sound.

The effect of changing the width of a pulse is to vary both its harmonic structure and the phase relationships of those harmonics. As with other processing modules, voltage control allows automatic time varying timbral changes that would be extremely difficult to produce if only manual control was available.

SOLDERING

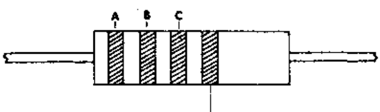
Use care when mounting all components. Use only rosin core solder (acid core solder is never used in electronics work). A proper solder joint has just enough solder to cover the round soldering pad and about 1/16 inch of the lead passing through it. There are two improper connections to beware of: Using too little solder will sometimes result in a connection which appears to be soldered but actually there is a layer of flux insulating the component lead from the solder bead. This situation can be cured by re-heating the joint and applying more solder. If too much solder is used on a joint there is the danger that a conducting bridge of excess solder will flow between adjacent circuit board conductors forming a short circuit. Unintentional bridges can be cleaned off by holding the board up-side down and flowing the excess solder off onto a clean, hot soldering iron.

Select a soldering iron with a small tip and a power rating not more than 35 watts. Soldering guns are completely unacceptable for assembling transistorized equipment because the large magnetic field they generate can damage solid state components.

CIRCUIT BOARD ASSEMBLY

( ) Prepare for assembly by thoroughly cleaning the conductor side of the boards with a scouring cleanser. Rinse the boards with clear water and dry completely.

Begin assembly on the smaller of the circuit boards (B) by installing the fixed resistors. Solder each of the fixed value resistors in place following the parts placement designators printed on the circuit board and parts placement diagram figure 1. Note that the fixed resistors are non-polarized and may be mounted with either of their two leads in either of the holes provided. Cinch the resistors in place prior to soldering by putting their leads through the holes and pushing them firmly against the board; on the conductor side of the board bend the leads outward to about a 45° angle. Clip off each lead flush with the solder joint as the joint is made.



DESIGNATION		VALUE	COLOR CODE A-B-C
( )	R1	6.8K	blue-grey-red
( )	R2	10K	brown-black-orange
( )	R3	47K	yellow-violet-orange
( )	R4	39K	orange-white-orange
( )	R5	150K	brown-green- yellow
( )	R6	330K	orange-orange-yellow
( )	R7	680K	blue-grey-yellow
( )	R8	680K	blue-grey-yellow
( )	R9	150K	brown-green-yellow
( )	R10	1.8 meg	brown-grey-green
( )	R11	680K	blue-grey-yellow

Up to this point all components have been non-polarized and either lead could be placed in either of the holes provided without affecting the operation of the unit. Electrolytic capacitors are polarized and must be mounted so that the "+" lead of the capacitor goes through the "+" hole in the circuit board. In the event that the "-" lead of the capacitor rather than the "+" lead is marked it is to go through the unmarked hole in the circuit board.

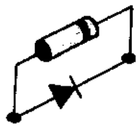
Note that the operating voltage (v.) specified for a capacitor is the minimum acceptable rating. Capacitors supplied with specific kits may have a higher voltage rating than that specified and may be used despite this difference. For instance, a 100 mfd. 25v. capacitor may be used in place of a 100 mfd. 10v. capacitor without affecting the operation of the circuit.

Install the electrolytic capacitor on the smaller (B) circuit board.

DESIGNATION		VALUE
( )	C1	10 mfd. 15v.

Diodes are polarized components and must be properly oriented in order to operate properly. Polarization of the part will be indicated by a colored band on one end of the part. The orientation method is related to the schematic symbol used on the circuit board in the drawing below. Diodes are heat sensitive and may be damaged if allowed to get too hot while soldering. To be on the safe side heat sink during soldering by grasping the lead being soldered with a pair of needle nose pliers at a point between the circuit board and the body of the part.

DESIGNATION		TYPE NO.
( )	D1	1N914
( )	D2	1N914
( )	D3	1N914
( )	D4	1N914
( )	D5	1N914



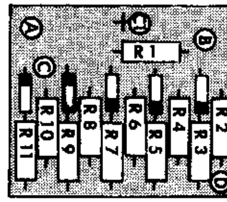


Figure 1

In the following steps wires will be soldered to the "B" circuit board that in later steps will connect with points on the larger "A" circuit board. At each step prepare the wire by cutting it to the specified length and stripping 1/4 inch of insulation from each end. "Tin" each end of the wire by twisting the exposed strands tightly together and melting a small amount of solder into the wire.

Using the wire provided make the following connections to the smaller "B" circuit board.

( ) a 1 1/2 inch length to point "A"
( ) a 2 1/4 inch length to point "B".
( ) a 4 1/2 inch length to point "C".
( ) a 5 inch length to point "D".

THIS COMPLETES ASSEMBLY OF THE 2720-14B CIRCUIT BOARD. TEMPORARILY SET THE BOARD ASIDE AND PROCEED WITH THE ASSEMBLY OF THE LARGER "A" CIRCUIT BOARD.

Following the directions given for resistor installation on the "B" circuit board, install the fixed resistors on the "A" board as follows:

DESIGNATION		VALUE	COLOR CODE A-B-C
( )	R13	680K	blue-grey-yellow
( )	R14	680K	blue-grey-yellow
( )	R15	150K	brown-green-yellow
( )	R16	10K	brown-black-orange
( )	R17	220K	red-red-yellow
( )	R18	10K	brown-black-orange
( )	R19	680 ohm	blue-grey-brown
( )	R20	27K	red-violet-orange
( )	R21	33K	orange-orange-orange
( )	R22	33K	orange-orange-orange
( )	R23	33K	orange-orange-orange
( )	R24	56K	green-blue-orange
( )	R25	10K	brown-black-orange
( )	R26	330 ohm	orange-orange-brown
( )	R27	1K	brown-black-red
( )	R28	1K	brown-black-red
( )	R29	270 ohm	red-violet-brown
( )	R30	2.2K	red-red-red
( )	R31	2.2K	red-red-red

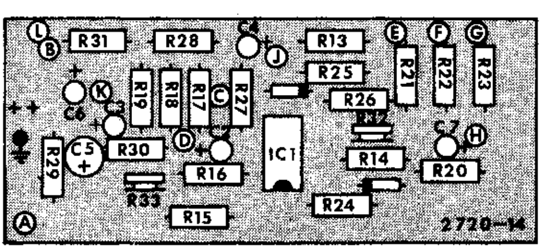


Figure 2

Following the directions given for capacitor installation on the "B" board, install the electrolytic capacitors on the "A" board as follows:

DESIGNATION		DESCRIPTION
( )	C2	2.2 mfd. 6v.
( )	C3	2.2 mfd. 6v.
( )	C4	2.2 mfd. 6v.
( )	C5	100 mfd. 15v.
( )	C6	2.2 mfd. 6v.
( )	C7	2.2 mfd. 6v.

Following the directions given for diode installation on the "B" board, install the diodes on the "A" circuit board as follows:

DESIGNATION		TYPE NO.
( )	D6	1N914
( )	D7	1N914

Mount the integrated circuit. Note that the orientation of the integrated circuit is keyed by a notch at one end of the case which aligns with the semi-circular key on the designator printed on the circuit board. Use particular care when installing this part, like any other semi-conductor it is heat sensitive and should not be exposed to extraordinarily high soldering temperatures. Make sure that the orientation is correct before soldering, once the unit is in place it cannot be removed without destroying it.

DESIGNATION		TYPE NO.
( )	IC-1	LM-3900 Quad Norton Amplifier

Install the trimmer potentiometers. These parts will either be marked with their value or will be separately bagged.

DESIGNATION		VALUE
( )	R32....................	50K trimmer
( )	R33	10K trimmer

In each of the following steps wires will be soldered to the "A" circuit board which will later connect to the front panel jacks. Refer to the wire preparation instructions (covered during assembly of the "B" circuit board) and make the following connections to the "A" board.

( ) a 1 1/4 inch length to point "E"
( ) a 1 1/2 inch length to point "F"
( ) a 2 1/4 inch length to point "G"
( ) a 4 inch length to point "J"
( ) a 6 1/2 inch length to point "K"
( ) a 6 1/2 inch length to point "L"

( ) Cut a 1 1/4 inch length of the hollow plastic tubing provided and slip it over one lead of the 39K resistor (orange-white-orange) R12. Approximately 1/4 inch of the resistor lead should extend beyond the tubing. Insert this lead through circuit board point "H" and solder.

ASSEMBLY OF THE "A" PRINTED CIRCUIT BOARD IS NOW COMPLETED. SET IT ASIDE UNTIL CALLED FOR LATER IN THE INSTRUCTIONS AND PROCEED WITH FRONT PANEL ASSEMBLY.

Place the front panel face down on a soft rag during front panel assembly operations to prevent marring the finish.

( ) Place a black pin jack (J4) in the hole provided as shown in figure 5. and fasten it in place with a tinnerman nut as shown in detail figure 3. Press the tinnerman nut down firmly.

( ) In a similar manner mount black pin jack J5.

( ) In a similar manner mount black pin jack J6.

( ) Mount the miniature phone jack J1 to the front panel and orient it in the position shown in figure 5. Fasten it in place by putting the notches on the nut in the jaws of a small pair of diagonal cutters and carefully tightening the nut, using the cutters as a spanner.

( ) In a like manner mount phone jack J2.

( ) In a like manner mount phone jack J3.

( ) Using the bare wire provided make connections between the bottom lugs (ground) of the miniature phone jacks J1, J2 and J3 as shown in figure 5. The wire need only be passed through the ground lug of J2; a tight crimp connection is not necessary. Solder the wire at J1 and J2 but DO NOT SOLDER TO J3 AT THIS TIME.

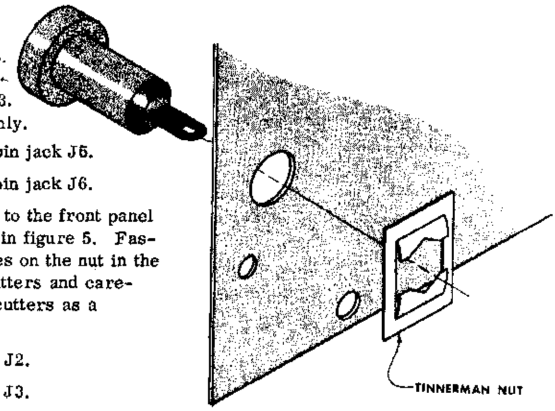


Figure 3

THE FRONT PANEL MAY NOW BE BOLTED ONTO THE CIRCUIT BOARD AS FOLLOWS:

( ) Fasten the two "L" brackets to the front panel using one 4-40 X 1/4" machine screw and one 4-40 nut on each bracket. Note that the unthreaded hole on the "L" bracket is used in this operation.

( ) Fasten the circuit board to the front panel "L" brackets by passing two 4-40 X 1/4" machine screws up through the holes in the circuit board and threading them into the threaded holes in the "L" brackets. Securely tighten all screws.

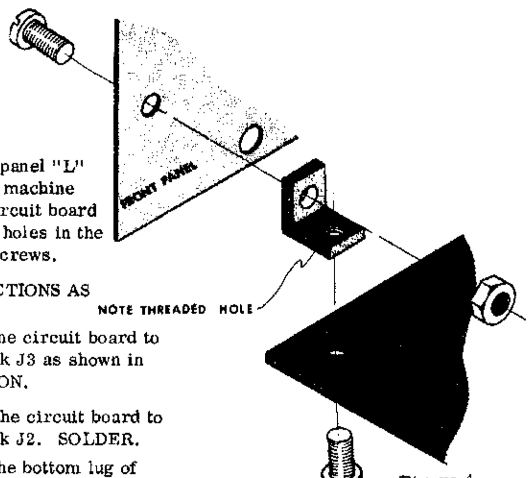


Figure 4

MAKE THE FINAL FRONT PANEL CONNECTIONS AS FOLLOWS:

( ) Connect the wire from point "J" on the circuit board to the center lug of miniature phone jack J3 as shown in figure 5. SOLDER THIS CONNECTION.

( ) Connect the wire from point "K" on the circuit board to the center lug of miniature phone jack J2. SOLDER.

( ) Connect the wire from point "L" to the bottom lug of J3 (ground) as shown in figure 5. SOLDER THE TWO WIRES CONNECTED TO THIS LUG.

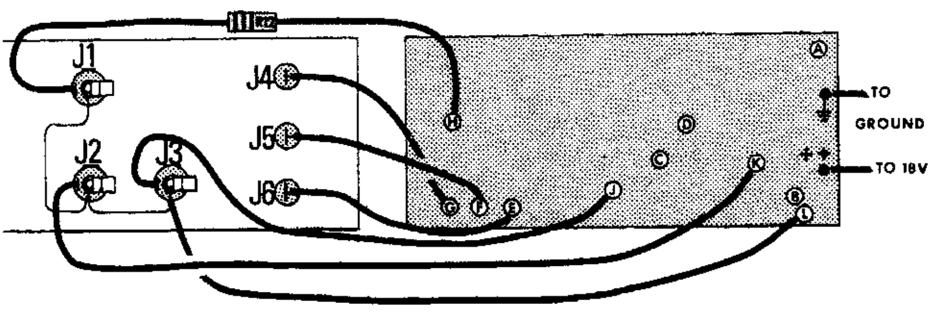


Figure 5

( ) Route the three wires just installed so that they run along the circuit board and up the front panel. Dress then as closely as possible to both the front panel and circuit board (for appearance).

( ) Cut a 1 1/4 inch length of the hollow plastic tubing provided and slip it over the remaining lead of fixed resistor R12. Approximately 1/4 inch of the lead should extend beyond the tubing. Connect this lead to the center lug of J1. SOLDER THIS CONNECTION. Dress the resistor against the front panel.

( ) Connect the wire from point "E" on the circuit board to pin jack J6 as shown in figure 5. SOLDER THIS CONNECTION.

( ) Connect the wire from point "F" on the circuit board to pin jack J5. SOLDER THIS CONNECTION.

( ) Connect the wire from point "G" on the circuit board to pin jack J4. SOLDER THIS CONNECTION.

THIS CONCLUDES FRONT PANEL WIRING. PROCEED WITH THE MOUNTING AND INTERCONNECTION WIRING OF THE TWO CIRCUIT BOARDS AS FOLLOWS:

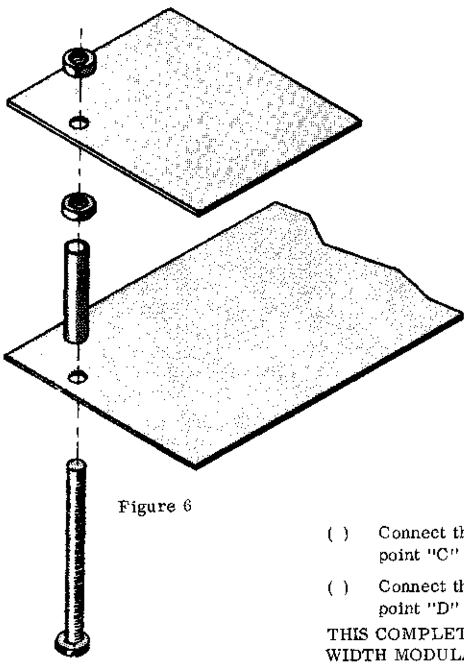


Figure 6

( ) Pass a 4-40 X 1 1/2 machine screw through the hole by the "ground" power connection on the larger board with the head of the bolt on the foil side of this circuit board. Slip the 3/4" spacer over the bolt.

( ) Thread a 4-40 nut onto the bolt and tighten. this secures the spacer assembly. Slip the end of the bolt through the hole on the smaller circuit board. Thread a 4-40 nut onto the bolt and tighten to secure the smaller circuit board

In the following steps the wires that were previously connected to the "B" board will be connected to the corresponding points on the "A" board. As the wire. are installed route them over the <u>rear</u> edge of the smaller circuit board down to the rear edge of the "A" board and then across the board to the proper point.

( ) Connect the wire from point "A" on the smaller circuit board to point "A" on the larger board. SOLDER THIS CONNECTION

( ) Connect the wire from point "B" on the smaller circuit board to point "B" on the larger board. SOLDER THIS CONNECTION

( ) Connect the wire from point "C" on the smaller circuit board to point "C" on the larger circuit board. SOLDER.

( ) Connect the wire from point "D" on the smaller circuit board to point "D" on the larger circuit board. SOLDER.

THIS COMPLETES ASSEMBLY OF THE SINE CONVERTER/PULSE WIDTH MODULATOR.

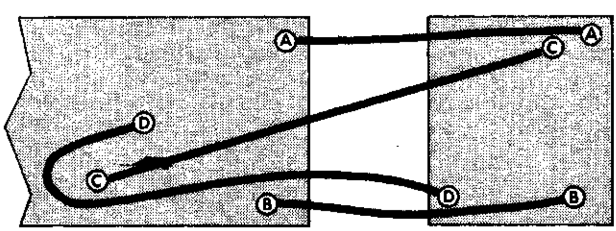


Figure 7

TESTING AND CALIBRATION

The only equipment required to test the 2720-14 Sine Converter/Pulse Width Modulator is the gear you will be using it with anyway - A source of .5v. peak to peak triangle waves (2720-2 VCO or other) and an amplifier.

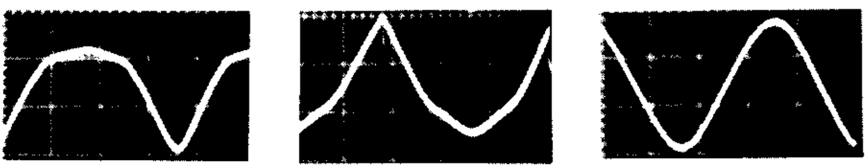
Connect a power supply (2720-7 power supply or other suitable power source) to the power connections on the rear edge of the circuit board: "++" to +18v. and ground to ground. Jumper the output of the triangle source to the input jack on the 2720-14 front panel and jumper the pulse output to the high (line) level input of a hi-fi or instrument amplifier.

Turn on the power and allow a couple of minutes for voltages to stabilize. NOTE: the first time the power is applied to the unit it may be necessary to let the module sit for 15 or 20 minutes to allow the numerous electrolytic capacitors to "form". This should be necessary only the first time that power is applied.

Ground one of the Sine/PWM modules control voltage inputs by connecting it to the 0 to 5v. bias supply pin jack of the 2720-7 power supply and turning the bias source control knob fully counter-clockwise. Using the second bias source apply a constant control voltage to the VCO corresponding to about middle C (1.25v. for a calibrated VCO). Turn the adjusting disk of the "pulse" trimmer (R32) fully counter-clockwise, there should be no sound from the module at this point.

Slowly advance the adjusting disk of the "pulse" trimmer in a clockwise direction until you first hear the familiar whine of a narrow pulse waveform, then stop.

Disconnect the amplifier from the pulse output of the module and re-connect it to the sine wave output. You should hear a tone at this output and as the "sine" trimmer R33 is turned the timbre of the tone should change. Some point in the rotation of this trimmer should produce a tone that is noticeably more "mellow" than other settings. This is the proper setting for this control. If an oscilloscope is available it can be used to confirm that this setting produces the best sine wave. Figure 8 (a), (b) and (c) show oscilloscope traces corresponding to the symmetry trimmer being set too far counter-clockwise, too far clockwise, and correctly, respectively.



(A) (B) (C)

Figure 8

Setting the sine wave symmetry may have caused the pulse output to change slightly so once again connect the pulse output jack to the input of the amplifier, rotate the "level" trimmer R32 counter-clockwise until the pulse output stops (if it hasn't already) then advance this control in a clockwise direction until the pulse can just be heard.

Remove the ground jumper from the control voltage input pin jack. Since the control voltage summation for this input is a passive network removing the ground will cause the pulse width to increase slightly and you should be able to hear this as an increased "fullness" of the sound. If an oscilloscope is available you can connect it to the pulse output and observe this increase in pulse width. Connect a control voltage input source (2720-7 bias supply or other) to one of the control voltage inputs and observe that as the control voltage increases up to about 5v. the sound becomes progressively more "full". An oscilloscope may also be used to verify that increasing control voltages increase the width of the pulse and that the duty factor of the pulse reaches 50% (square wave) when the control voltage is at 5v. (± 10%). Similarly, test the other two control voltage inputs.

As a final test, ground one of the control voltage inputs as discussed earlier and listen to the pulse output as the frequency of the VCO is varied over its entire range. If at any frequency the sound of the pulse drops out, advance the "pulse" trimmer slightly until the sound returns.

USING THE 2720-14 SINE CONVERTER/PWM

The only compromise with performance made in this module is the use of a passive summing network for the pulse width modulator's control voltage inputs. The reasoning here was the same as on other modules that utilize passive summation, the process is not critical enough to justify the added cost of an active summer.

Sine shaping is by means of non-linear feedback network around one of the amplifier stages with the network being of the "diode break-point" type. When fully expanded on an oscilloscope this type of waveshapeing can be seen to break the waveform into several straight line segments which when taken together approximate a sine wave. Since the break-points are for all practical purposes discreet they do tend to introduce higher order harmonics that would not be present in a pure sine wave but the added harmonics are typicly at such a low level in relation to the fundamental that they are inaudible.

Operation of the input and output jacks are as follows:

INPUT The miniature phone jack in the upper left hand corner of the module provides a moderate input impedance input to the module that is to be connected to a source of triangle waves. For best operation the amplitude of the triangle wave input source should be between .4 and .9v. peak to peak.

SINE OUTPUT The miniature phone jack in the upper right corner of the module provides a low impedance output of .5v. peak to peak sine waves.

PULSE OUTPUT The miniature phone jack on the right edge in the middle of the panel provides a low impedance output of variable duration pulses.

CONTROL The three black tip jacks along the lower edge of the front panel provide for voltage control of the width of the pulse available at the pulse output jack. Nominal range of these inputs is from ground to 5v. corresponding to duty factors variable from less than 3% to 50% respectively. Control voltages below ground will turn off the pulse. Control voltages greater than 5v. will not harm the module and will cause the duty factor of the output to be greater than 50%.

In use you should consider this module to be simply a part of the VCO - merely expanding the versatility of an already present waveform (pulse) and adding another waveform not previously available (sine).

As has been mentioned several times before, a sine wave is the basic building block of any imaginable waveform. It is a pure tone that contains no harmonics.

Only a couple of natural instruments come even close to having a sinusoidal output. The flute is one, and the synthesizer can produce flute sounds simply by running the sine output through the VCA for envelope shaping and then out to the amplifier. Attack and decay times of the function generator controlling the VCA should be set moderately short to properly simulate the envelope of a natural instrument. Bass, conga, bongo, tom-tom; Any drum that doesn't have provisions for snare are also for all practical purposes a very damped (rapidly decaying) sine wave. By using the same circuit that produces the flute (but with shortest possible attack and moderate decay) we can also produce drum sounds. Whereas a step is the appropriate trigger for the sustain produced by a flute, a pulse trigger is needed for the percussive envelope of the drums - otherwise, they're the same.

PULSE

As the duty factor (ratio of "on" time to total period) of a pulse changes a number of relatively complicated, and musicly interesting, things happen to the harmonic content.

As pulse duration becomes shorter the amplitude of the fundamental decreases while the amplitudes of the higher order harmonics increases. At the same time there is a relative phase shift between the harmonics that produces an almost unbelievable electronic sound.

Just as an initial experiment, try running the pulse output directly to an amplifier input and pitching the VCO from the keyboard. Vary the PWM control inputs from a low frequency, more or less sinusoidal control voltage (about 3Hz.; the 2720-5 control oscillator is the logical choice). As the control voltage cycles up and down and the duration of the pulses increases and decreases the biggest effect you will notice is the phase shift. Since this is the major effect produced by a rotating speaker you will hear a sound that you would almost swear is coming from one of these mechanical vibrato devices.

Any control voltage source can be used to vary the pulse width and interesting effects can be produced by using the function generator to sweep the pulse width up as the gain of the VCA is being varied. The pulse width and center frequency of the band-pass filter may be varied simultaneously for other effects.

You will notice from the specifications at the front of this manual and from the calibration procedure that the maximum duty factor of the pulse is 50% at the nominal maximum control voltage of 5v. and that the unit is capable of 100% over-range. These two facts are significant enough to warrant further comment.

Under ordinary circumstances you will not need duty factors greater than 50% because above that point you are simply inverting the pulse and your ears aren't capable of distinguishing a positive-going pulse from a negative-going one. A pulse with a 10% duty factor sounds the same as one with a 90% duty factor.

If for some reason you decide that you need to use a 0 to 5v. control voltage to transition smoothly from a low duty factor to one that approaches 100% it is a simple matter to apply the voltage to two of the control inputs simultaneously. The result of this connection is an apparent doubling of the applied control voltage; 5v. applied to two inputs sums to the equivalent of 10v. applied to a single input.

Control voltage summation and the equivalency of reciprocal duty factors allows some other interesting tricks. Let's suppose that you're designing a sound that requires pulse duration to decrease while the control voltage for some other parameter is increasing. The first arrangement that comes to mind would be to use an inverter to reverse the control voltage before it is applied to the pulse width inputs. This would work, but there's an easier way. Since the ear is unable to distinguish whether a pulse's width is increasing or decreasing from 50% we need only sum a constant 5v. into the first control input of the modulator while running the time varying control voltage into one of the other two. The effect of this is to set the duty factor at 50% for zero output from the time varying source with duty factor increasing as the time varying control source rises toward 5v. This sounds the same as going from 50% toward 0.

2720-14 DESIGN ANALYSIS

The circuitry of the 2720-14 is designed around an integrated circuit quad current differencing amplifier package. The schematic of this circuit is shown in figure 10.

When a triangular waveform is applied to the input of the module it is buffered and amplified by the first of the gain blocks in the package before being applied to the pulse width modulator and sine converter. The trimmer in the input of this first stage (R32) allows the gain of the stage to be varied to compensate for level differences of the signal source.

The pulse width modulator is essentially a summing comparator. The current produced by the voltage appearing across R20 (the triangular output of the first amplifier) is added to the sum of the currents produced by the control voltages that appear across R21, R22 and R23. This total current flow into the inverting ("-") input of the second amplifier in the IC package is compared to the reference current flowing into the non-inverting ("+") input through R25. As long as the reference current into the input is greater than the total current flowing into the "-" input the output of the amplifier stays high. Resistor values are selected so that for a small part of each cycle of the triangle the current into the "-" input exceeds the reference current causing the output to switch low, thereby producing a very narrow output pulse for zero control voltage. As the control voltages begin to rise from ground, the total current into the "-" input of the amplifier increases causing progressively lower points on the triangle to switch the comparator. Since points further down the sides of the triangle are further apart the net result is a pulse whose width increases proportional to increases in control voltage.

As the comparator switches on and off it in turn switches the third amplifier in the package which inverts the pulse (not that this affects the sound) and serves to square up the rise and fall times. The diodes D6 and D7 serve the dual function of clamping the outputs at about 1v. thereby restricting the maximum rise and consequently the effect of amplifier slew rate on the final pulse, as well as providing biasing current to the inverting inputs of the amplifiers at times that they would otherwise be reverse biased (If the inverting inputs are allowed to reverse bias it fouls up the internal biasing system.)

The sine shaper is a classic non-linear feedback type with a diode break point feedback loop. Here we are approximating a sine wave with a series of straight line segments as shown in figure 9. Assume for a moment that we begin watching the sine converter at a point in time when the input triangle is ramping down from the mid-point of the waveform. Amplifier #4 is arranged in an inverting configuration so as the input is heading down the output is heading up. At the mid-point of the waveform all of the diodes in the sine converter (D1-D6) are reverse biased so that the only element in the feed-back loop is R17 and this resistor alone determines the gain of the stage and consequently the rate at which the output voltage of the amplifier increases. This corresponds to line segment #1 in the figure. Eventually the output voltage reaches the point at which it is greater than the voltage at the junction of the voltage divider consisting of R6 and R7. At this point diode D1 forward biases and parallels R7 with R17 resulting in lower gain and a new line segment with a slower rate of increase than the previous segment (segment #2). As the output voltage increases further it eventually reaches the point at which D2 is forward biased thereby paralleling R5 with R7 and R17 resulting in another new line segment with an even lower slope (#3). Finally, D3 forward biases adding R3 to the network resulting in line segment #4. On the way back down the diodes are progressively reverse biased resulting in the reverse sequence of line segments. As the output signal passes through its mid-point and heads lower D4 and D5 are sequentially forward biased resulting in line segments #5 and 6 respectively. Ordinarily there would be a 7th break point and line segment but since the bottom edge of the triangle produced by our VCO is rounded anyway it is unnecessary in this application.

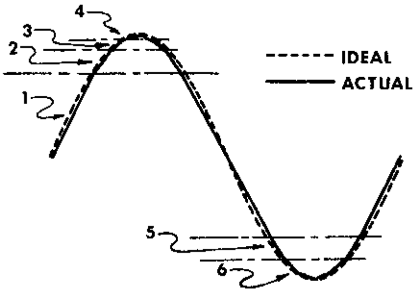
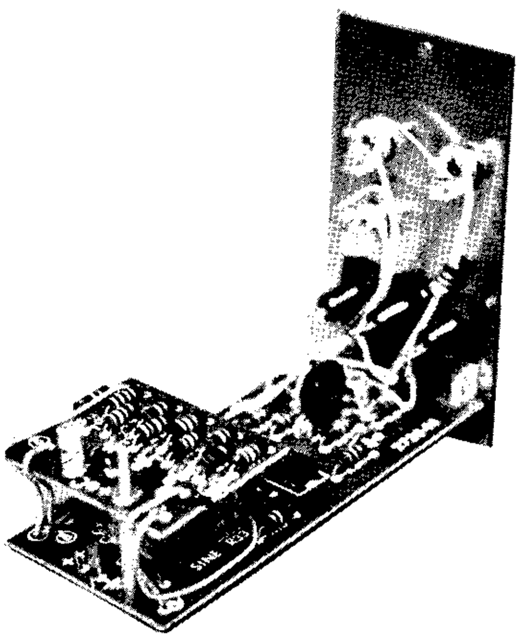
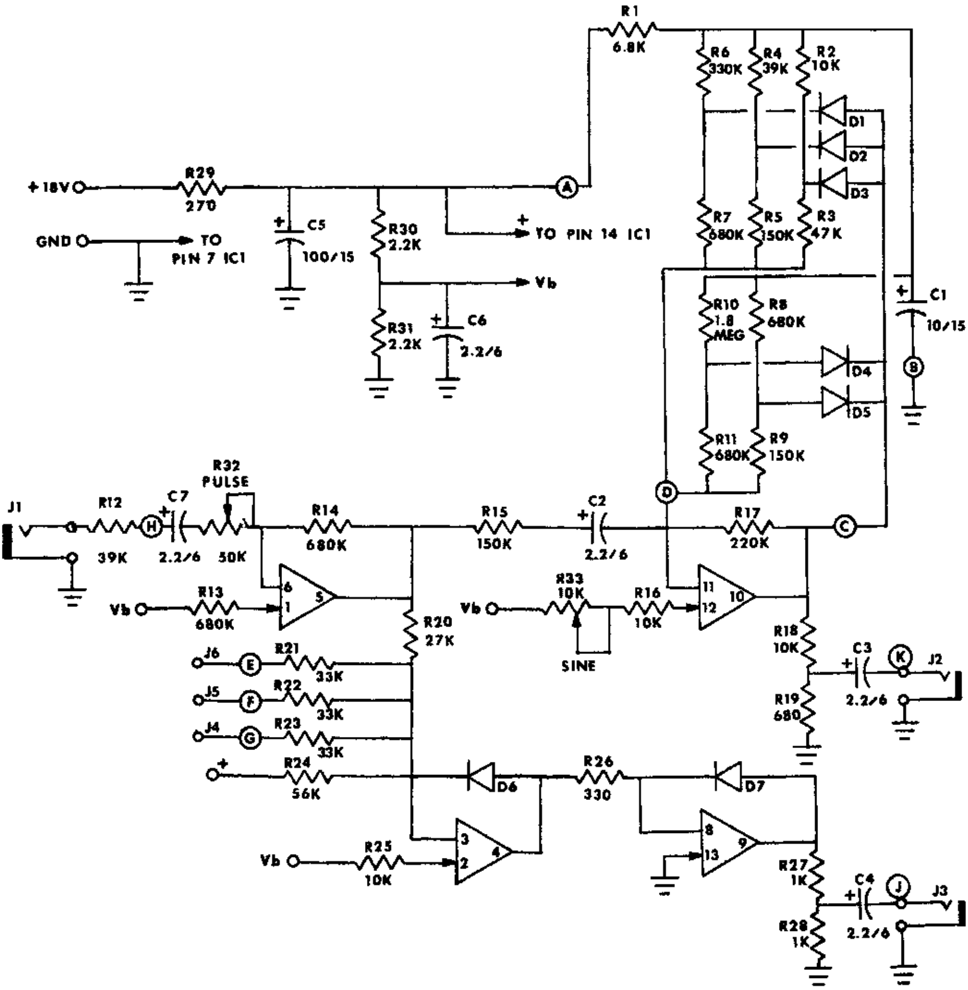


Figure 9




R1
6.8K
R6
330K
R4
39K
R2
10K
D1
D2
D3
+18V
R29
270
A
GND
TO
PIN 7 IC1
C5
100/15
R30
2.2K
TO PIN 14 IC1
R7
680K
R5
150K
R3
47K
Vb
R31
2.2K
C6
2.2/6
R10
1.8
MEG
R8
680K
C1
10/15
D4
B
D5
R11
680K
R9
150K
R32
PULSE
J1
R12
39K
H
C7
2.2/6
50K
R14
680K
R15
150K
C2
2.2/6
D
R17
220K
C
R13
680K
R33
10K
SINE
R16
10K
R20
27K
R18
10K
C3
2.2/6
K
J2
J6
E
R21
33K
J5
F
R22
33K
J4
G
R23
33K
R19
680
R24
56K
D6
R26
330
D7
R25
10K
R27
1K
C4
2.2/6
J
J3
R28
1K