PAIA Electronics
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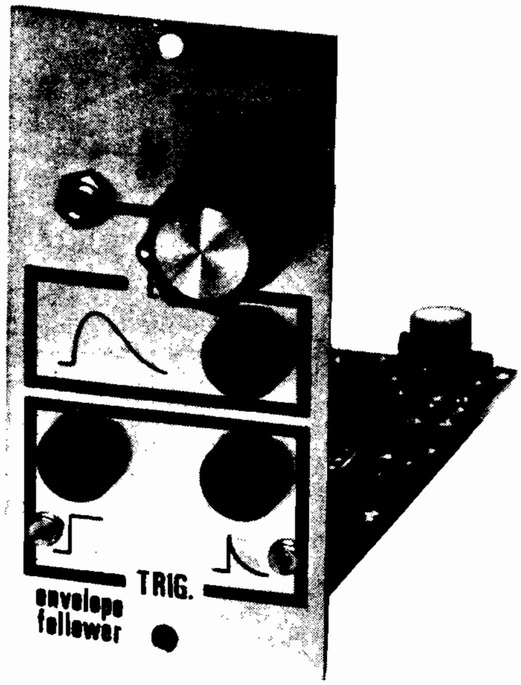
2720-11

# Envelope Follower/Trigger




SPECIFICATIONS

| | |
|---|---|
| Module Power Requirements: | -9v. @ 6.5 ma.<br>-9v. @ 7.5 ma. |

ENVELOPE

| | |
|---|---|
| Input impedance: | 47K ohms |
| Output impedance: | 150 ohms short circuit protected |
| RMS Transfer gain: | min. 29 db.<br>max. 60 db. |
| Output level: | 0 to - 5v. |
| Max. overange: | 60% |

TRIGGER

| | |
|---|---|
| Outputs: | step and pulse |
| Amplitude: | -5v. |
| Output impedance | 10K ohms |

The biggest problem associated with using the 2720 series modules to process the outputs of conventional musical instruments is the elimination of the triggering functions that are ordinarily provided by the keyboard. Without these triggering functions much of the automation that makes a synthesizer a practical reality is lost.

The 2720-11 Envelope Follower/Trigger overcomes this problem by converting the amplitude contour of any instrument into a high level control voltage and providing step and pulse trigger outputs derived from the instrument's output.

## SOLDERING

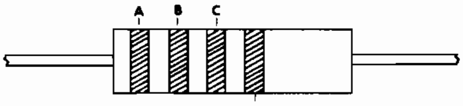
Use care when mounting all components. Use only rosin core solder ( acid core solder is never used in electronics work. ) A proper solder joint has just enough solder to cover the round soldering pad and about 1/16 inch of the lead passing through it. There are two improper connections to beware of: 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 board with a scouring cleanser. Rinse the board with clear water and dry completely.

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. Save the lead clippings for use as jumpers in later steps.




silver or gold disregard this band

| | DESIGNATION | VALUE | COLOR CODE A-B-C |
|---|---|---|---|
| ( ) | R1 | 47K | yellow-violet-orange |
| ( ) | R2 | 270K | red-violet-yellow |
| ( ) | R3 | 100 ohm | brown-black-brown |
| ( ) | R4 | 39K | orange-white-orange |
| ( ) | R5 | 39K | orange-white-orange |
| ( ) | R6 | 39K | orange-white-orange |
| ( ) | R7 | 18K | brown-grey-orange |
| ( ) | R8 | 220K | red-red-yellow |
| ( ) | R9 | 22K | red-red-orange |
| ( ) | R10 | 100K | brown-black-yellow |
| ( ) | R11 | 22K | red-red-orange |
| ( ) | R12 | 68K | blue-grey-orange |
| ( ) | R13 | 33K | orange-orange-orange |
| ( ) | R14 | 15K | brown-green-orange |
| ( ) | R15 | 33K | orange-orange-orange |
| ( ) | R16 | 100 ohm | brown-black-brown |
| ( ) | R17 | 100 ohm | brown-black-brown |
| ( ) | R19 | 2200 | red-red-red |
| ( ) | R20 | 1800 | brown-grey-red |

( ) Using the excess leads clipped from resistor installation form and install the four wire jumpers indicated by the solid lines printed on the circuit board and shown in the parts placement diagram figure 1.

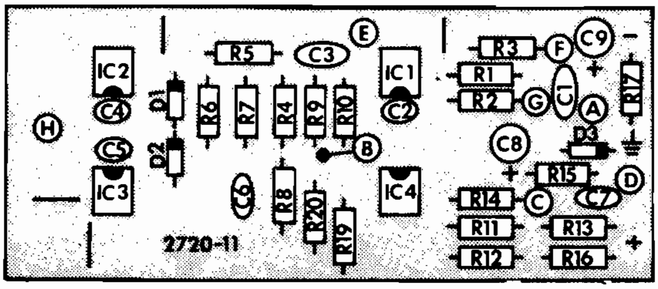



Figure 1 Parts Placement Diagram

Install the ceramic disk and mylar capacitors. The ceramic disks without exception have their value marked on the body of the part but the mylar capacitors may be color coded as shown below:

| DESIGNATION | | VALUE | COLOR CODE A-B-C |
|---|---|---|---|
| ( ) | C1 | .1 mfd. mylar | brown-black-yellow |
| ( ) | C2 | 100 pf disk | |
| ( ) | C3 | .1 mfd. mylar | brown-black-yellow |
| ( ) | C4 | 100 pf disk | |
| ( ) | C5 | 100 pf disk | |
| ( ) | C6 | .05 mfd. disk | |
| ( ) | C7 | .01 mfd. disk | |


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.

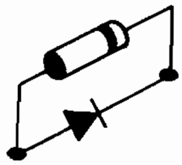
Note that the operating voltage (v.) specified for a capacitor is the minimum acceptable rating. Capacitors supplied with specific kits may have a higher voltage rating than that specified and may be used despite this difference. For instance, a 100 mfd. 25v. capacitor may be used in place of a 100 mfd.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

Mount the following electrolytic capacitors and solder them in place. The values, voltage rating and polarization are marked on the body of the part.

| DESIGNATION | | VALUE |
|---|---|---|
| ( ) | C8 | 100 mfd. 10v. |
| ( ) | C9 | 100 mfd. 10v. |

Install the diodes D1 through D3. The diodes are polarized components and must be properly oriented in order to operate properly. Polarization of the part will be indicated either by a colored band on one end of the part or by the bullet shape of the case. These two orientation methods are 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 the soldering operation 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 |



Mount the integrated circuits. Note that the orientation of the integrated circuits 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. The orientation notch may be replaced with a circular recess in some of these parts. 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 | 748 op-amp |
| ( ) | IC-2 | 748 op-amp |
| ( ) | IC-3 | 748 op-amp |
| ( ) | IC-4 | 748 op-amp |

In the following steps wires will be soldered to the circuit board that in later steps will connect with the front panel controls. 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 circuit board.

( ) a 7 inch length to point "A".
( ) a 3 1/2 inch length to point "B".
( ) a 4 inch length to point "C".
( ) a 4 1/2 inch length to point "D".
( ) a 4 inch length to point "E".
( ) a 5 1/4 inch length to point "F".
( ) a 5 inch length to point "G".
( ) a 2 3/4 inch length to point "H".

THIS COMPLETES ASSEMBLY OF THE 2720-11 CIRCUIT BOARD. Temporarily put the circuit board aside and proceed to the front panel assembly.

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

( ) Place the red pin jack (J2) in the hole provided as shown in figure 4 and fasten in place with a tinnerman nut as shown in detail figure 2. Press the tinnerman nut down firmly.

( ) In a similar manner mount red pin jack J3.

( ) In a similar manner mount red pin jack J4.

( ) Mount the miniature phone jack (J1) to the front panel in the position shown in figure 4. Orient the jack as shown and fasten in place with the nut provided. Carefully tighten the nut by putting the points of the jaws of a pair small diagonal cutters into the notches in the nut and using the cutters as a spanner.

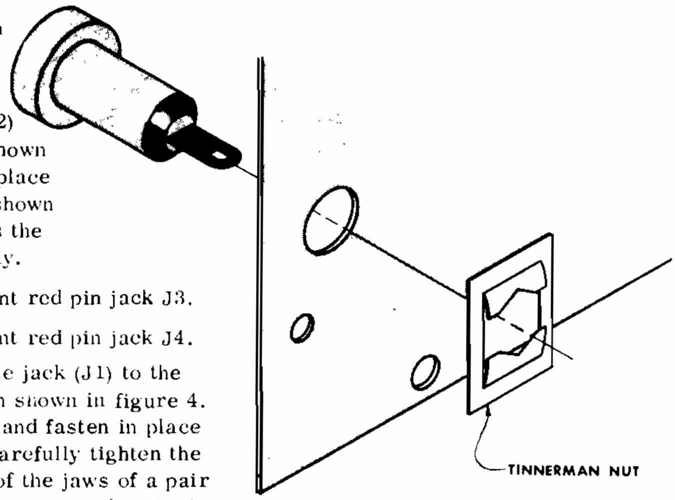


Figure 2 Pin jack mounting detail

( ) Mount the 5K linear taper potentiometer R18 in the position shown in figure 4. Use two 3/8 inch nuts, one behind the front panel as a spacer and the second on the front side of the panel to secure the pot. Adjust the rear nut so that none of the threaded shaft of the control is exposed when the front nut is tightened down. This will allow the control knob which will be mounted in a later step to seat as closely as possible to the panel. Orient as illustrated.

THE FRONT PANEL MAY NOW BE BOLTED TO 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 a 4-40 X 1/4" machine screw up through the holes in the circuit board and threading them into the threaded holes in the "L" brackets. Securely tighten all screws.

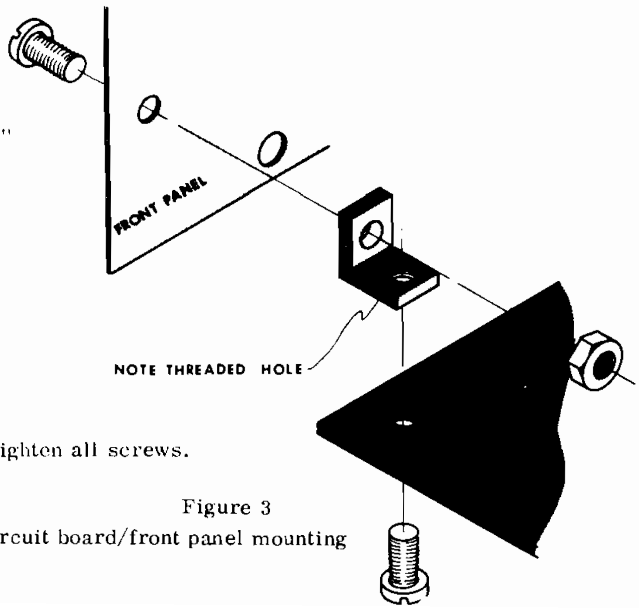


Figure 3
Circuit board/front panel mounting

MAKE THE FINAL FRONT PANEL CONNECTIONS AS FOLLOWS:

( ) Solder the wire coming from circuit board point "A" to the center lug (#2) of miniature phone jack J1 as shown in figure 4.

( ) Solder the wire coming from circuit board point "B" to pin jack J2.

( ) Solder the wire coming from circuit board point "C" to pin jack J3.

( ) Solder the wire coming from circuit board point "F" to the center lug (#2) of R18 as shown in figure 4.

( ) Solder the wire coming from circuit board point "D" to pin jack J4.

( ) Solder the wire coming from circuit board point "E" to lug #3 of R18 as shown in figure 4.

( ) Solder the wire coming from circuit board point "G" to lug #1 of R18.

( ) Solder the wire coming from circuit board point "H" to lug #3 of miniature phone jack J1 as shown in figure 4.

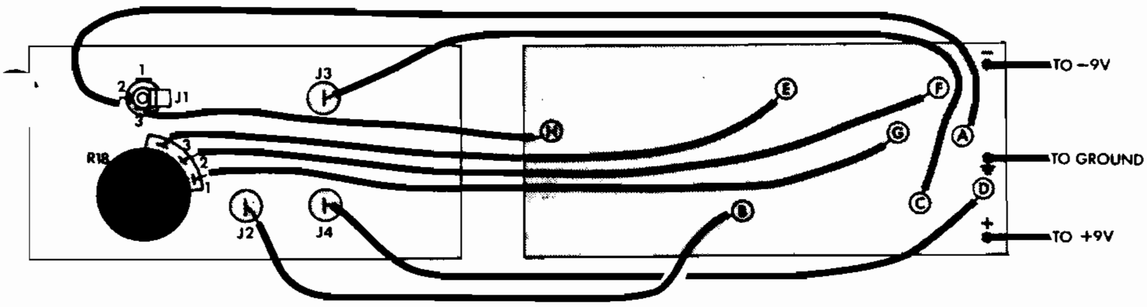



Figure 4 Front panel wiring

( ) Rotate the shaft of the sensitivity control R18 fully counter-clockwise as viewed from the front of the panel and install the control knob so that it points to the "7 O'clock" position of an imaginary clock face. Tighten the set-screw to secure the knob.

Note that 3 "flea" clips have been included in the parts bag. Using a pair of needle nose pliers push these three pins into the "+", "⏚" and "-" power supply holes in the end of the circuit board. These pins provide connecting points for the power supply leads.

THIS COMPLETES ASSEMBLY OF THE 2720-11 ENVELOPE FOLLOWER MODULE.

## TESTING

There are no internal adjustments to make to the 2720-11 and the testing procedure is accordingly simplified. The only test equipment required will be a Volt-Ohm Meter (VOM) and an amplitude variable audio signal generator ( the 2720-2 VCO triangle output run through the attenuator provided on the 2720-7 Power Supply will do nicely).

Connect a power supply (2720-7 Power Supply Module or other suitable supply such as two 9v. batteries) to the power connections on the rear edge of the circuit board; "+" to +9v., "-" to -9v. and ground to ground. With no signal applied to the input of the module use the VOM to make sure that there is no voltage present at either the envelope or pulse trigger outputs. Similarly, check for voltage at the step trigger output. It will be normal to find a very small negative or positive voltage at the step output but it should be less than 1 volt.

Next apply the amplitude variable signal source to the miniature phone jack input on the front panel of the module. Set the signal generator for approximately 440 Hz. (concert A) and set the Envelope Follower sensitivity control fully counter-clockwise. With the VOM connected to the envelope output pin jack observe that as the amplitude of the signal source is varied between 0 and .5v. peak to peak (the max. output of the 2720-2 VCO is .5v. peak to peak) the voltage at the output varies between 0 and 5v. ±20%. Connect the VOM to the step trigger output and slowly increase the amplitude of the input signal until the instant a voltage appears at this output. The voltage at the step output should be 5v. ±10% and the voltage at the envelope output should be 3v. ±10%.

Once again connect the VOM to the step output jack and slowly reduce the amplitude of the input signal until the instant the step output returns to 0 volts. Once again read the envelope output voltage and observe that it is 2v. ±10%.

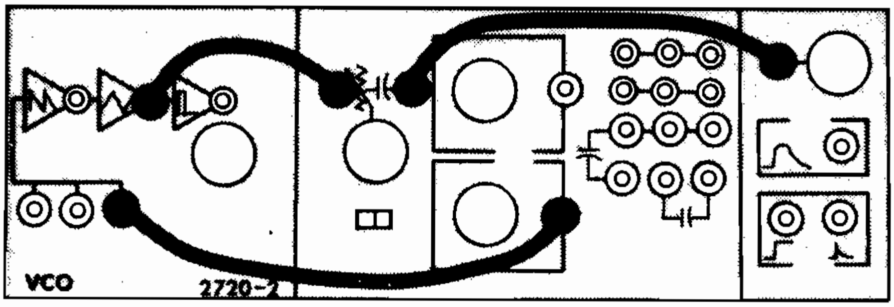



Figure 5 Testing connection using VCO and Power Supply

With the VOM still connected to the envelope output and the sensitivity control fully counter-clockwise, set the amplitude of the signal source for a reading of .25v. on the meter. Observe that by rotating the sensitivity control clockwise the envelope output voltage can be raised to 7v. or greater.

The affirmative completion of this testing sequence assures that the module is functioning in accordance with the original design parameters.

USING THE 2720-11 ENVELOPE FOLLOWER/TRIGGER

Our first two comments regarding the use of the Envelope Follower don't relate directly to this module but they are so important that it won't hurt to stress them by putting them ahead of everything else.

The inputs to the 2720 series processing modules (amplifiers, filters, etc.) must always be a.c. coupled to whatever signal source is being used. When the various modules are simply feeding each other this requirement is taken care of by the capacitively coupled outputs of the modules themselves, but when a conventional instrument is being used as a feed for the system the coupling capacitor must be externally supplied. Isolated capacitors are provided as part of the patch panel associated with the 2720-7 Power Supply for just this purpose. The input to the Envelope Follower is d.c. isolated by its own internal coupling capacitor.

Secondly, the 2720 series modules are designed to work at a nominal signal level of 500 mv. For most electronic pianos, organs, guitars, etc. this level is ideal but there may be instances where the signal level from the instrument to be modified is either too high or too low. Too high a signal level will cause the familiar "fuzz" of harmonic distortion and may be cured by padding down the output of the instrument with a suitable voltage divider ( the attenuator of the 2720-7 can be used ). Too low a signal level will show up as an excessively noisy system ("pops" as the VCA works or the hiss of input noise from the filters). The only satisfactory solution to this problem is to either tap the signal from a higher level point in the instrument's audio system (in the case of electronic instruments) or pre-amplify the signal if the instrument has only a pickup output. In the PAIA line, the 2720-12 Inverter Buffer has provision for use as a suitable pre-amplifier for most applications.

OPERATION OF THE CONTROLS IS AS FOLLOWS:

INPUT The miniature phone jack in the upper left hand corner of the panel provides a moderated impedance, capacitively coupled input to the system.

SENSITIVITY The sensitivity potentiometer is in the upper right hand corner of the module. At the extreme counter-clockwise limit of the rotation of this control a 500 mv. peak to peak input to the module will produce a 5 volt DC level at the envelope output jack. Maximum sensitivity transforms a 15mv. signal to a 5 volt envelope output.

ENVELOPE The red pin jack on the middle right hand edge of the front panel provides a 0 to 5v. control voltage that is proportional to the amplitude contour of the input signal.

STEP TRIGGER The red pin jack in the lower left hand corner of the module front panel provides access to a trigger circuit that switches from 0 volts to 5 volts when the voltage at the envelope output jack exceeds 3 volts. Envelope output must fall below 2 volts for the trigger circuit to re-set.

PULSE TRIGGER  The red pin jack in the lower right hand corner of the module provides access to a positive-going, short duration, 5 volt pulse that is formed whenever the step pulse output transitions to its high output state. The re-setting of the step trigger does not appear at this output.

It would be impossible to list all of the applications of the Envelope Follower but to get started we'll look at a couple of the more striking and easy to produce effects.

The way in which the amplitude contour (envelope) of an instrument builds up and dies away is called dynamics and this single characteristic contributes more to the recognizability of an instrument than any other. It stands to reason, then, that if we want to completely alter the sound of an instrument the logical place to start is with the envelope. The electronic gadgets that perform this modification are - for some reason - commonly called timbre gates and figure 6 shows some of the 2720 series modules arranged to produce this effect.

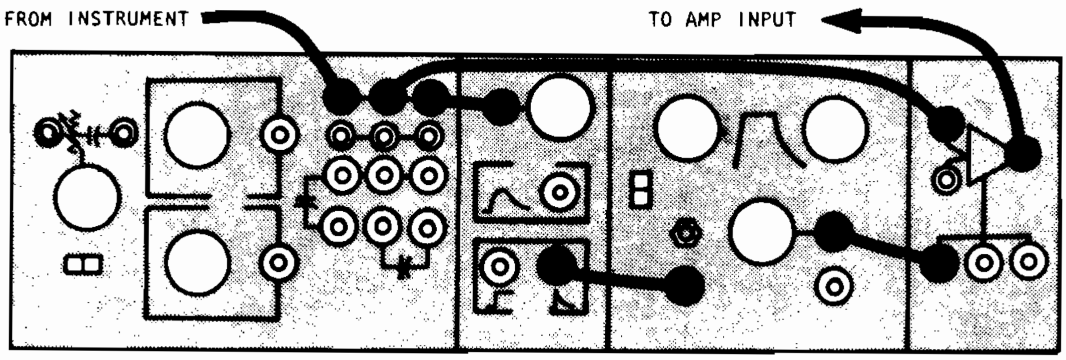



Figure 6  Using Function Generator and VCA to produce timbre gate

The reasoning behind this arrangement is relatively simple; each note played on the instrument causes the Envelope Follower to generate a pulse that triggers the Function Generator which in turn produces a new envelope with independently adjustable attack and decay times. The Function Generator controls the gain characteristics of the VCA so that the new envelope is imparted to the original signal. Some of the effects that can be produced using this configuration are:

PERCUSSION GUITAR - This is really a misnomer since guitar is already a percussion instrument but the meaning is that the normally long decay of the instrument is cut short by cranking back on the function generator's decay control. The effect is somewhat like deadening the strings but none of the harmonics are lost, as they are when the strings are deadened.

ATTACK DELAY - In the same way that the normally long decay of an instrument can be cut short using the decay control of the Function Generator; the rapid attack of percussion instruments can be slowed using the attack control. The effect is amazingly like a recording of the instrument being played in reverse.

PERCUSSION EFFECTS - Many of the older electronic organs that are popular with jazz and rock musicians are not equipped with the gradual decay required for true percussion effects. With a timbre gate these effects are simply a matter of selecting tne attack and decay times that suit the sound required. Other instruments that are not normally percussion (flute, saxophone, etc.) can also be revoiced.

In any effect there the dynamics of an instrument are to be modified there are two points that should be kept in mind. First, the timbre gate doesn't add to the signal, it just takes away. Because of this, decay times cannot be any longer than the natural decay, or maximum possible sustain time of the instrument. In particular, if you're generating percussion for an organ the note that you're playing must be held down through the entire cycle of the Function Generator so that a tone will be available for the whole envelope.

Secondly, there must be a short re-set time between notes during which the envelope output falls below the lower threshold of the internal triggering circuit. This sounds like a bigger problem than it really is because in most cases the sensitivity control of the Envelope Follower can be set so that the module triggers only on the initial attack of the instrument. In fact, a number of interesting effects can be produced by purposely setting the sensitivity so that only accented notes cause the module to trigger. Further information on the use of the Function Generator is contained in the instruction manual for that module and in the booklet "Using the PAIA 2720 Synthesizer".

The VCA is of course not the only module that can be driven with the output of the Function Generator and for some really strange sounds you can try working the VCA and one of the filters at the same time. Also don't overlook biasing the modules by summing in a constant voltage, using this trick the VCA can be set so that it is always passing some signal but adds a real percussive punch to the initial attack.

In many instances it's not really necessary to go through the Function Generator, the envelope output can be used directly. Figure 7 shows an arrangement that produces an auto-mute effect. As the output of the instrument rises and falls it causes the center frequency of the band-pass filter to sweep up and then back down again.

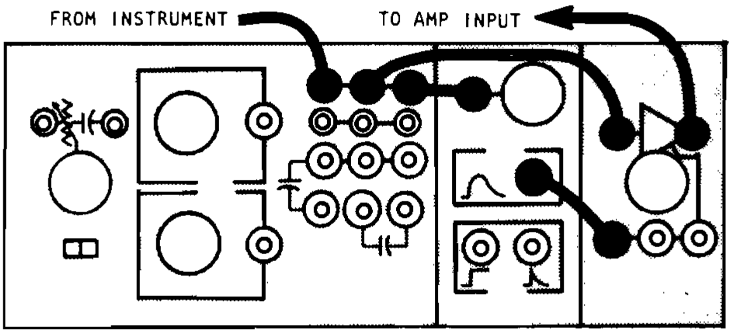



Figure 7 An Auto-mute connection using Band-pass Filter

In other applications the output of one instrument can be used to control the mixing of that instrument with a second instrument. For example, using an arrangement similar to figure 7 but with the VCA in place of the VCF one of the amplifier inputs can be used for the instrument while the second is connected to the noise output of the 2720-5 Control Oscillator/Noise Source. The result of this connection is a steam-like noise mixed in with the sound of the instrument.

## ABOUT ENVELOPE RIPPLE

The time constants associated with the filtering of the envelope output have been carefully selected for an optimum compromise between response time and ripple content ("ripple" refers to the amount of signal that is able to pass through the filter and appear as an a.c. component superimposed on the d.c. output level. As the frequency of the input signal increases less ripple is produced.) The ripple will only be of concern in applications which employ the envelope output directly as a control voltage and will appear as a sound similar to the fuzz of harmonic distortion. It will be particularly noticeable on modules which have a low rejection ratio between audio input and control voltage ( such as the 2720-3 series filters). In some cases ripple provides a very strange effect of its own; as, for example, the envelope - with ripple - driving a filter provides a very spaced-out phaser effect. In cases where the ripple is undesirable it may be eliminated (at the expense of slightly slower rise times) with an external low-pass filter section such as the one shown in figure 8.

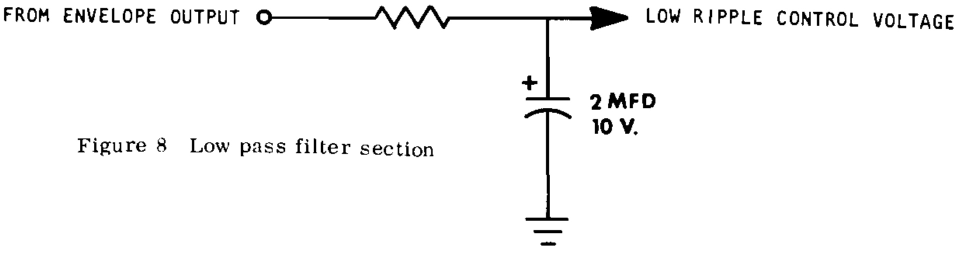



Figure 8 Low pass filter section

In practice this filter section is most easily formed using the capacitors that are already a part of the 2720-7 Power Supply. Two special jumpers will be required; one terminated on both ends with pin plugs but with a 2.2K ohm resistor installed as shown and the second

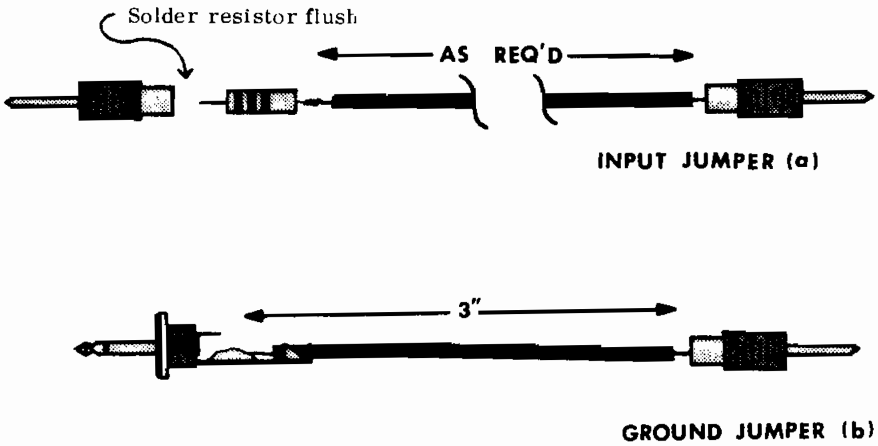



Figure 9 Jumpers for low pass filter

terminated on one end by a pin plug and on the other by a miniature phone plug. Notice that the purpose of the second jumper is to allow for the grounding of a pin jack and consequently the wire at the phone plug end connects to the ground side of the plug. Using these jumpers the low pass filter can be arranged as shown in figure 10.

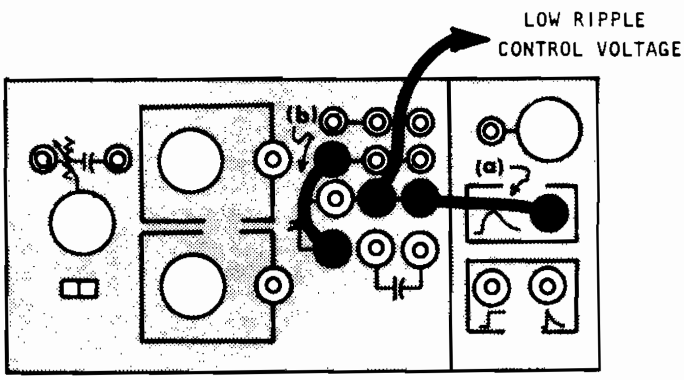



Figure 10 A low-pass filter using special jumpers and Power Supply patch panel.

DESIGN ANALYSIS

For ease of analysis the circuit can be broken down into three essentially independent sections; an input amplifier, full wave rectifier and a Schmitt trigger.

Signals applied to the input jack J1 are amplified by operational amplifier IC-1. Gain of this stage is variable from 15 db. to 34 db. depending on how much of the output signal is tapped off by potentiometer R18 and applied to the feed-back resistor R2. The output of this amplifier drives the precision full wave rectifier.

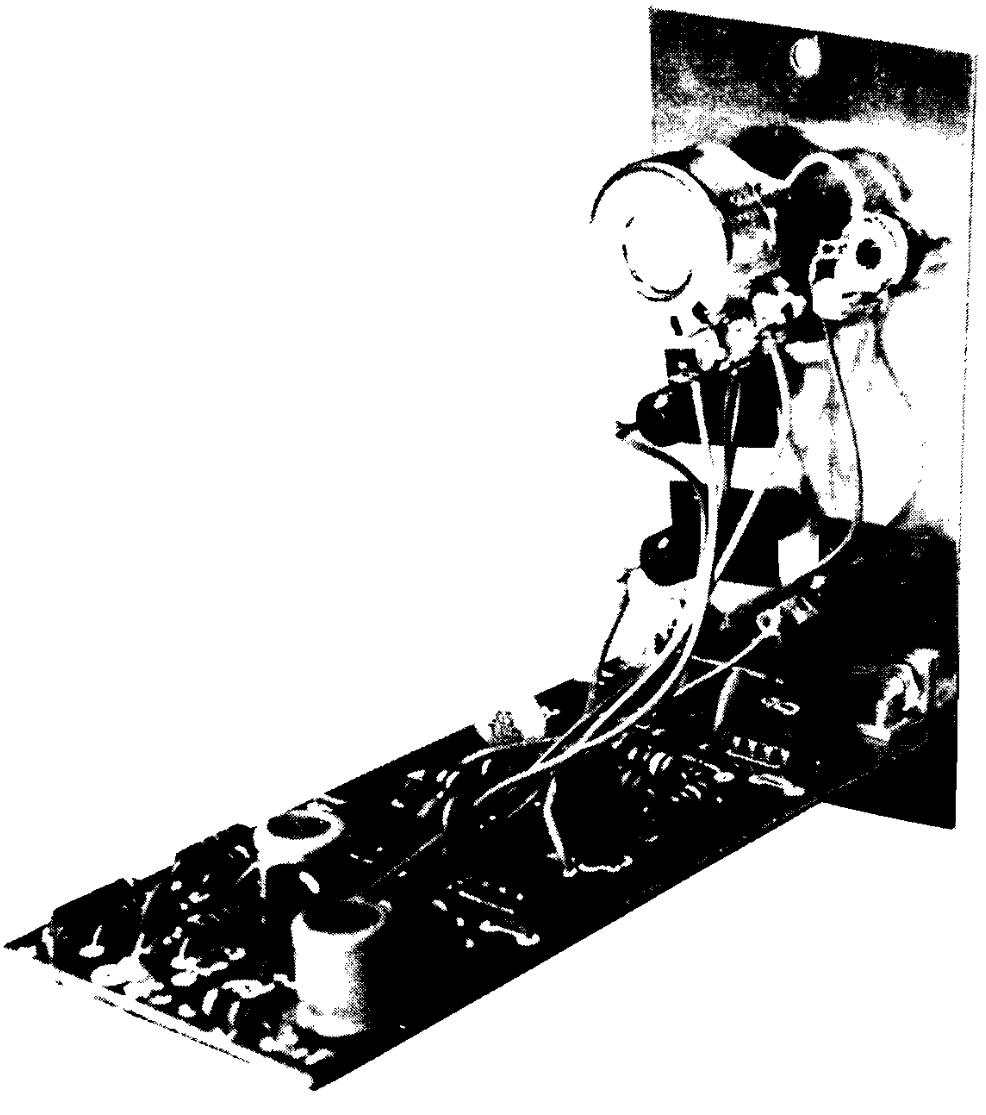
Input signals to the rectifier are applied simultaneously to the inverting inputs of both IC-2 (by way of R5) and IC-3 ( by R4 ). Assuming that the input is a sine wave, negative half-cycles applied to the inverting input of IC-2 cause the output of this amp to try to drive positive. As soon as the output reaches a voltage above ground that is equal to the forward voltage drop of D1 that diode begins to conduct and clamps the output at that voltage. At the same time diode D2 reverse biases and isolates the output of IC-2 from the rest of the circuit so that there is no input to IC-3 through R7. The input through R4 causes the output of IC-3 to go positive.

For positive half-cycles of the input the output of IC-2 goes negative which reverse biases D1 (thereby eliminating it from the circuit) and forward biases D2. In this condition there are two inputs to IC-3; a positive input through R4 and an equal magnitude ( because of the ratio of R6 to R5 ) but inverted input supplied by the output of IC-2. These two inputs are summed together and if R7 and R4 - the summing resistors - were equal values the inputs would cancel completely. But since the value of R7 is approximately half that of R4 the net result is a positive voltage at the output of IC-3. The ratio of R8 to R4 and R7 provides additional gain in the rectifier while C6 produces a low-pass response that averages the output. The rectifier output is available on the front panel as a control voltage proportional to the amplitude of the low level input envelope and is also applied to the Schmitt trigger built around IC-4.

The design of the trigger circuit is in most respects a common type with the input signal applied through R9 to the non-inverting input of the op-amp where it is compared with the reference voltage produced at the junction of the voltage divider R12 and R13. Positive feed-back for hysteresis is supplied by R10. Trigger points are set at approximately 3 volts for the high threshold and 2 volts for the low threshold.

It is desirable that the step output be close to ground when the trigger is "off", but a normal Schmitt configuration would produce an output near the negative supply voltage. There are a number of ways that a diode could be used to clamp the output at ground but all of them draw unnecessarily large amounts of current. Returning the negative supply pin of IC-4 to ground won't work; since the maximum output swing of an op-amp is limited to something less than the supply voltages, the "off" state of the trigger would be several volts positive. For these reasons the negative supply of IC-4 is derived from the voltage divider consisting of R19 and R20 and is set to be below ground by a voltage corresponding to the difference between the maximum output swing and supply.

The output step of the Schmitt trigger is attenuated by the voltage divider R14 and R15 and made available on the front panel. The pulse trigger is formed from the voltage step by the differentiating action of C7 and diode D3 is provided to clamp negative pulses to ground.



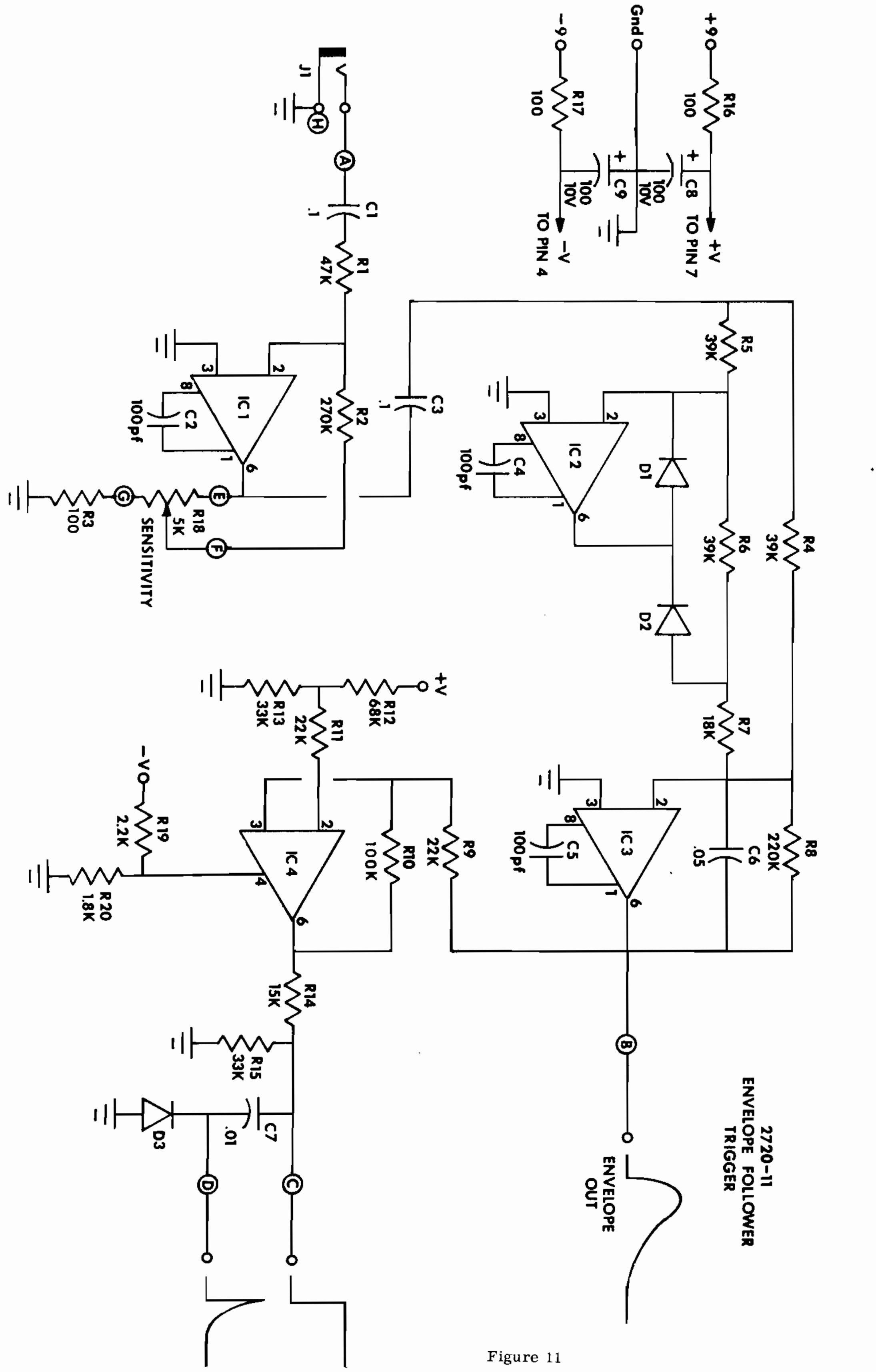

2720-11
ENVELOPE FOLLOWER
TRIGGER
ENVELOPE OUT
SENSITIVITY
+9
Gnd
-9
TO PIN 7
TO PIN 4
+V
-V
R16 100
R17 100
C8 100 10V
C9 100 10V
J1
C1 .1
R1 47K
R2 270K
C3 .1
C2 100pf
IC1
R3 100
R18 5K
R5 39K
R6 39K
R4 39K
IC2
C4 100pf
D1
D2
R7 18K
R8 220K
C6 .05
IC3
C5 100pf
R12 68K
R13 33K
R11 22K
R10 100K
R9 22K
IC4
R19 2.2K
R20 1.8K
R14 15K
R15 33K
C7 .01
D3

Figure 11