PAIA **1500A**

PHLANGER

The **PAIA Phlanger** uses a state-of-the-art analog delay line in conjunction with ancillary circuitry to provide an exact duplication of the classic flanging effect which previously was achieved using two tape recorders running out of sync. A wide range of additional user controls provides capabilities for many extra uses including rotating speaker simulation, chorusing, vibrato, and increasing the stereo or quad depth of a mono signal. Provisions are included for use of external voltage control such as foot pedals and switches, or interfacing with music synthesizers.

SPECIFICATIONS

Maximum input voltage:	.5 volts peak-to-peak
Input to Output Gain:	Unity (minimum)
Delay Time Range:	.5 to 10 milliseconds
Voltage Control Inputs:	0 to 5 volts
Power Requirement:	110 volts AC

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 connection 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 upside 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 of 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 the circuit board for assembly by thoroughly cleaning the conductor side with a scouring cleanser. Rinse the board with clear water and dry completely. Solder each of the fixed resistors in place following the parts placement designators printed on the circuit board and the assembly drawing 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 circuit 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 EXCESS CLIPPED OFF LEADS FOR USE AS JUMPERS IN LATER STEPS.

Silver or gold - disregard this band.

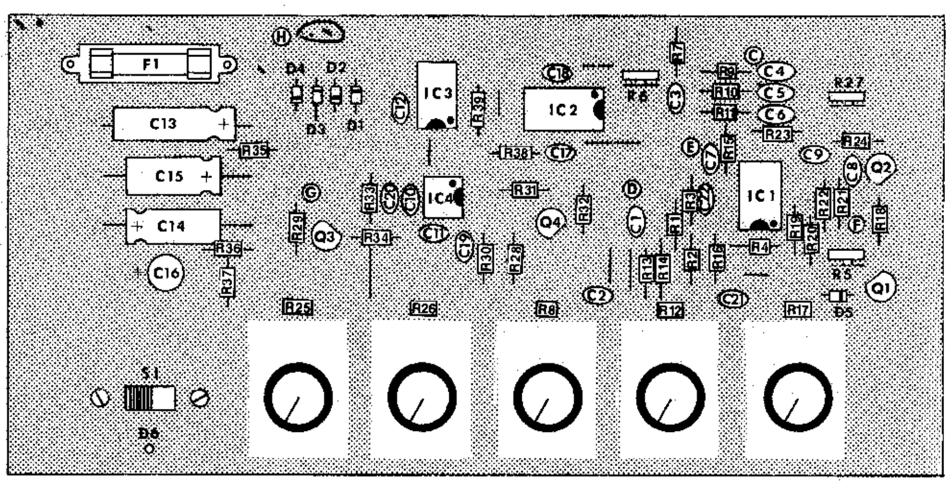


Figure 1 - Circuit Board Parts Placement

	DESIGNATION	VALUE	COLOR CODE A-B-C
( )	R1	470K	yellow-violet-yellow
( )	R2	470K	Yellow-violet-yellow
( )	R3	470K	yellow-violet-yellow
( )	R4	470K	yellow-violet-yellow
( )	R7	2.7K	red-violet-red
( )	R9	82K	grey-red-orange
( )	R10	82K	grey-red-orange
( )	R11	100K	brown-black-yellow
( )	R13	470K	yellow-violet-yellow
( )	R14	220K	red-red-yellow
( )	R15	680K	blue-grey-yellow
( )	R16	470K	yellow-violet-yellow
( )	R18	100K	brown-black-yellow
( )	R19	3.9 meg	orange-white-green
( )	R20	2.2 meg	red-red-green
( )	R21	470K	yellow-violet-yellow
( )	R22	680K	blue-grey-yellow
( )	R23	220K	red-red-yellow
( )	R24	33K	orange-orange-orange
( )	R28	3900 ohm	orange-white-red
( )	R29	22K	red-red-orange
( )	R30	100K	brown-black-yellow
( )	R31	33K	orange-orange-orange
( )	R32	2.7K	red-violet-red
( )	R33	1800 ohm	brown-grey-red
( )	R34	10K	brown-black-orange
( )	R35	100 ohm	brown-black-brown
( )	R36	470 ohm	yellow-violet-brown
( )	R37	3900 ohm	orange-white-red
( )	R38	10 ohm	brown-black-black
( )	R39	10 ohm	brown-black-black

( ) Using the excess wire clipped during resistor installation, form and install the eight jumpers as indicated by the solid lines in figure 1 and printed on the circuit board.

( ) Locate the IC connector pins provided with this kit and using a pair of diagonal cutters clip the carrier to form two rows of eight (8) pins each. Refer to figure 2.

( ) Install and solder the two rows of IC connector pins at the IC-2 position. NOTE: These pins should be installed with their carriers to the inside. Refer to figure 2. As each row of connector pins is installed use a pair of needle nose pliers to break away the carrier. DO NOT INSTALL IC-2 AT THIS TIME.

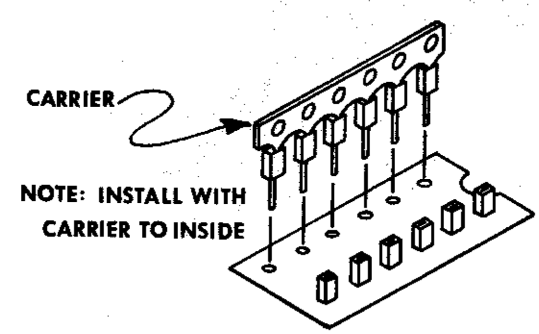
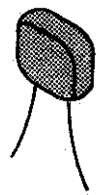


Figure 2 - Installation of IC Connector Pins

Install the ceramic disk and polyester capacitors. Without exception the values will be marked on the body of the part.

DESIGNATION	VALUE
( ) C1	.05 mfd. ceramic disk
( ) C2	.05 mfd. ceramic disk
( ) C3	.05 mfd. ceramic disk
( ) C4	100 pf. ceramic disk
( ) C5	100 pf. ceramic disk
( ) C6	100 pf. ceramic disk
( ) C7	.05 mfd. ceramic disk
( ) C8	.1 mfd. polyester
( ) C9	500 pf. ceramic disk
( ) C10	15 pf. ceramic disk
( ) C11	.001 mfd. ceramic disk
( ) C12	.01 mfd. ceramic disk
( ) C17	.05 mfd. ceramic disk
( ) C18	.05 mfd. ceramic disk
( ) C19	.01 mfd. ceramic disk
( ) C20	.01 mfd. ceramic disk
( ) C21	.1 mfd. polyester
( ) C22	15 pf. disk


ceramic disk capacitor

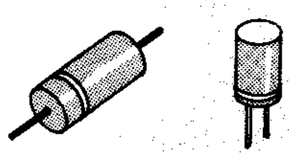

polyester capacitor

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 on the circuit board. In the event that the "-" lead of the capacitor is marked it is to go through the unmarked hole in 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. 25 v. capacitor may be used in place of a 100 mfd. 16 v. capacitor without affecting the operation of the circuit.

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

DESIGNATION	DESCRIPTION
( ) C13	1000 mfd. 10 v.
( ) C14	250 mfd. 10 v.
( ) C15	250 mfd. 10 v.
( ) C16	100 mfd. 10 v.

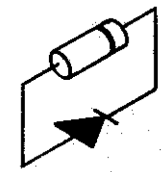


Install the transistors. Orient as illustrated in figure 1 and the parts placement designators printed on the circuit board. All semiconductors are heat sensitive and may be damaged if allowed to get too hot while soldering. To be on the safe side, heat sink each transistor lead during the soldering operation by grasping it with a pair of needle nose pliers at a point between the circuit board and the body of the transistor.

DESIGNATION	TYPE NO.
( ) Q1	2N5139
( ) Q2	2N5129
( ) Q3	2N5139
( ) Q4	2N5139

Install the diodes. Like transistors, diodes are heat sensitive and the precautions listed for transistor installation apply here also. The physical appearance of the diode is related to the schematic representation in the drawing below.

DESIGNATION	TYPE NO.
( ) D1	1N4001
( ) D2	1N4001
( ) D3	1N4001
( ) D4	1N4001
( ) D5	1N914



Install the light emitting diode (LED). Note that the LED is inserted from the conductor side of the board. The same precautions for the installation of transistors and diodes apply here also. Before installing the LED melt a small amount of solder onto each LED soldering pad. This will allow the LED to be soldered into place as quickly as possible with a minimum of heat buildup. Note that the LED must be installed with the banded lead on the pad marked "+".

DESIGNATION	TYPE NO.
( ) D6	MLS-750

Install the trimmer potentiometers.

DESIGNATION	TYPE NO.
( ) R5	500K
( ) R6	1K
( ) R27	500K

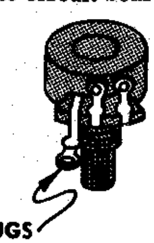

trimmer potentiometer

( ) Melt a small amount of solder onto each of the fifteen (15) potentiometer soldering lug pads. This will aid in soldering the potentiometer lugs to the pads as the potentiometers are installed.

Install the potentiometers. Note that before installation each potentiometer should have its soldering lugs bent as shown in figure 3. This will allow the potentiometer lugs to mate up with their soldering pads as the potentiometers are installed. Solder the lugs directly to the pads.

Mount each potentiometer using two of the 3/8-inch nuts provided, one behind the circuit board as a spacer, and the second on the front side to secure the potentiometer. Adjust the rear nut so that none of the threaded shaft 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 circuit board.

DESIGNATION	VALUE
( ) R8	500K
( ) R12	500K
( ) R17	500K
( ) R25	75K
( ) R26	5K



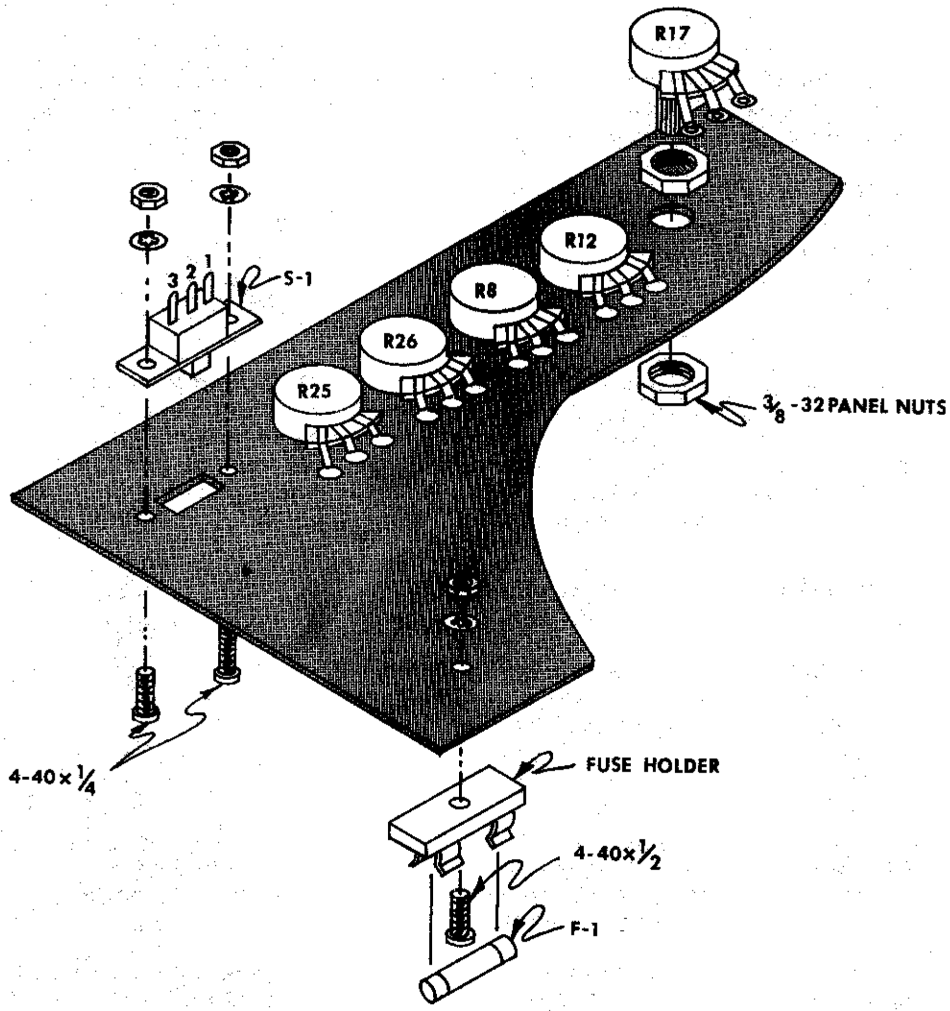


Figure 3 - Potentiometers, Switch, and Fuse Block Mounting Detail

( ) Using two (2) 4-40 X 1/4-inch machine screws, two (2) #4 internal lock washers, and two (2) 4-40 machine screw nuts install the slide switch S-1 as shown in figure 3.

( ) Using one (1) 4-40 X 1/2-inch machine screw, one (1) #4 internal lock washer, and one (1) 4-40 machine screw nut install the fuse holder as shown in figure 3.

( ) Using two (2) lengths of excess wire saved from the resistor installation make the connections between the fuse holder solder lugs and the circuit board.

( ) Install the fuse in the fuse holder.

In the following steps wires will be soldered to the circuit board which will in later steps connect to various switches and jacks. At each step prepare the wire by cutting it to the specified length and, unless otherwise noted, stripping 1/4-inch of insulation from each end of the wire. "Tin" each end by twisting the exposed strands tightly together and melting a small amount of solder into the wire.

( ) Turn the circuit board copper side up and solder a 2-inch length of insulated wire to the pad marked "A".

( ) Solder the remaining end of the wire installed in the previous step to lug #1 of S-1. Refer to figure 3.

( ) Solder a second 2-inch length of insulated wire to the circuit board pad marked "B".

( ) Solder the remaining end of the wire installed in the previous step to lug #2 of S-1. Refer to figure 3.

Turn the circuit board component side up and using the remaining insulated wire make the following connections.

( ) A 7-inch length to point "C".
( ) A 8-1/4-inch length to point "F".
( ) A 7-inch length to point "G".
( ) A 7-1/2-inch length to point "H".

( ) Locate the co-axial cable provided and cut an 8-inch length.

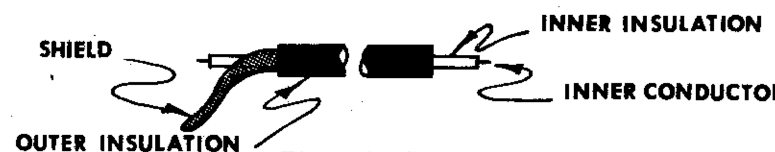


Figure 4 - Co-ax Detail

( ) Referring to figure 4, prepare one end of the co-axial cable by stripping away 3/4-inch of the outer insulating sleeve to expose the shielding wire. Using a pencil, or other pointed object, carefully unbraid the shielding wire and pull to one side. Twist the shield tightly together and "tin". Cut the exposed inner conductor to a length of 1/2-inch. Strip away 1/4-inch of the inner conductors insulating sleeve, and twist and "tin" the exposed strands.

( ) Prepare the remaining end of the co-ax by stripping away 1/2-inch of both the outer insulating sleeve and the shielding wires. Strip away 1/4-inch of the exposed inner insulating sleeve, and twist and "tin" the exposed inner conductor. Connect this end of the co-axial cable to circuit board point "D".

( ) Prepare the remaining length of co-axial cable in exactly the same manner as described in the steps above. Connect the end with the shielding wire removed to circuit board point "E".

Install the integrated circuits. Note that the orientation of the integrated circuits is keyed to the notch at one end of the case which aligns with the semicircular key on the designators printed on the circuit board. Use particular care when installing these parts. Like any other semiconductor they are heat sensitive and should not be exposed to extraordinarily high soldering temperatures. Make sure that the orientation is correct before soldering. Once these parts have been installed they cannot be removed without destroying them.

DESIGNATION	TYPE NO.
( ) IC1	LM-3900 or CA-3401 Quad Norton amp
( ) IC4	NE-566 High frequency VCO

WARNING: CMOS CIRCUITS

The remainder of the integrated circuits used in this kit are Complementary Metallic Oxide Semiconductors (CMOS). While state of the art internal protection is provided, these circuits are still susceptable to damage from STATIC ELECTRICITY. You should not experience any difficulties if you observe the following precautions:

1) The circuits are supplied to you inserted in blocks of conductive foam. Leave them in these blocks until you are ready to install the part.
2) Do not install the parts in sequence other than that called for in the instructions.
3) Do not wear synthetic (e.g. nylon) clothing while handling these parts.
4) A three wire grounded soldering iron is ideal but if you don't have one your present iron may be used by allowing it to heat, then UNPLUGGING it during the actual soldering operation. Before soldering and after unplugging, touch the tip of the iron momentarily to the ground screw of an electrical outlet to drain static charges.

DESIGNATION	TYPE NO.
( ) IC3	CD-4013 Dual D Flip-Flop
( ) IC2*................	SAD-1024 Analog Shift Register

*Note: When installing this part make certain that all pins have mated up with the IC connectors.

( ) Locate the transformer and clip the two black primary wires to a length of 4 inches. Strip away 1/4-inch of insulation and twist and "tin" the exposed strands.

( ) Clip the two white and one red secondary wires to a length of 4 inches. Strip away 1/4 inch of insulation and twist and "tin" the exposed strands.

( ) Solder the two black primary transformer wires to the two holes marked T1-PRI on the circuit board. Either wire may be soldered in either of the two holes provided.

( ) Solder the two red secondary wires into the holes marked T1-SEC on the circuit board. Once again, these two wires may be soldered into either of the holes provided.

( ) Solder the remaining white secondary center tap wire in the hole marked T1-CT.

Proceed with the final case assembly.

( ) Using the nut provided, mount the 1/4-inch phone jack J-1. Orient as illustrated in figure 5.

( ) In a similar manner mount the 1/4-inch phone jack J-2. Orient as illustrated.

( ) In a similar manner mount the 1/4-inch phone jack J-3. Orient as illustrated.

( ) In a similar manner mount the 1/4-inch phone jack J-4. Orient as illustrated.

( ) In a similar manner mount the 1/4-inch phone jack J-5. Orient as illustrated.

( ) Using a 7-1/2-inch length of bare wire provided make the connections between the ground lugs of J-1, J-2, J-3, J-4, and J-5. Refer to figure 5. At J-2, J-3, and J-4 this wire need only be passed through the hole in the lug. A tight crimp connection is not necessary. Solder the wire at J-3, J-4, and J-5 only. DO NOT SOLDER AT J-1 AND J-2 AT THIS TIME.

( ) Using two (2) 4-40 X 1/4-inch machine screws, two (2) #4 internal lock washers, and two (2) 4-40 machine screw nuts mount the transformer to the case bottom as shown in figure 6.

( ) Turn the case top upside down on a soft rag to prevent marring the finish, then run the line cord through the hole provided in the case top and solder to the circuit board at the points marked LINE. Note: Either of the wires of the line cord may be installed in either of the two holes provided.

( ) Locate the rubber extrusion provided and cut a length 8-3/4-inches.

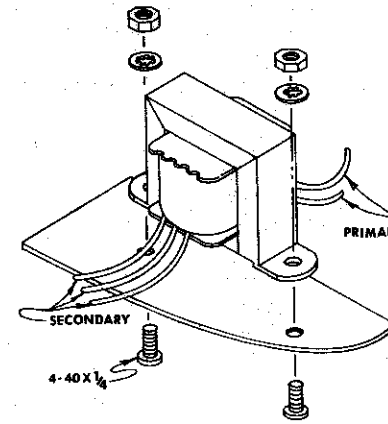


Figure 6 - Transformer Mounting

( ) Slip the extrusion just cut over the front edge of the circuit board.

( ) Using four (4) #4 X 3/8-inch self tapping screws and four (4) rubber feet attach the case bottom to the wood ends making sure that the circuit board slips into the groove in the wood ends and is pulled up flush with the front lip of the case bottom as shown in figure 7.

Make the final wiring connections. Note: The following steps will be most easily accomplished if the case top is oriented as shown in figure 5.

( ) Connect the wire coming from circuit board point "G" to lug #1 of J-3. SOLDER.

( ) Connect the wire coming from circuit board point "F" to lug #1 of J-4. SOLDER.

( ) Connect the wire coming from circuit board point "C" to lug #1 of J-5. SOLDER.

( ) Connect the wire coming from circuit board point "H" to lug #2 of J-1. DO NOT SOLDER.

( ) Connect the inner conductor of the co-axial cable coming from circuit board point "D" to lug #1 of J-1. SOLDER.

( ) Connect the shield from the co-ax in the above step to lug #2 of J-1. SOLDER THREE WIRES.

( ) Connect the inner conductor from the co-axial cable coming from point "E" to lug #1 of J-2. SOLDER.

( ) Connect the shield from the co-ax in the above step to lug #2 of J-2. SOLDER TWO WIRES.

( ) Using the wire tie provided bundle and tie all wires coming from the circuit board except the line cord.

( ) Fold the molded strain relief provided over the line cord at a point approximately four inches from the circuit board. While squeezing the strain relief with a pair of pliers, insert it into the hole provided from the outside of the case top. Insert the strain relief until it locks into place.

( ) Rotate all potentiometer shafts fully counter-clockwise.

( ) Before installing the knobs align the pointer on top of each knob so that it points to the seven o'clock position of an imaginary clock. Push the knobs onto their shafts firmly.

You are now ready to proceed to the testing and calibration section.

TESTING AND CALIBRATION

Before applying power to the Phlanger, double check your work for cold solder joints, solder bridges, and correct parts values and placement. Set the three trimpots to the midpoint of their rotation. Set all potentiometers fully counter-clockwise, except R26 (Center) which should be set fully clockwise. Plug the line cord into a wall outlet and slide the power switch S1 to the right. Power indicator LED D6 should be glowing. Apply a signal to the input (J1) with a maximum signal level of .5 volts peak-to-peak. Feed the output signal (J2) to the high level input of a guitar amp or hi-fi system. The normal signal should now be passing through the unit. Turn the Mix control (R12) to maximum. Adjust Bias trimpot (R5) until the signal is passed with minimum clipping (distortion). If you have access to an oscilloscope, view the signal at the wiper of Balance trimmer R6. Set the scope controls so you can see the high frequency signal which is superimposed on the audio signal. Adjust the Balance trimmer to minimize this high frequency signal. Visually, it will appear that there are two identical audio signals at different DC levels. At some point near the middle of R6 rotation, the two traces will converge into one. This is the proper setting. If you do not have access to a 'scope, leave R6 at approximate midrotation and proceed.

With the delay section properly trimmed, set Mix control R12 to the middle of it's range. Decrease the setting of Center control R26 and listen for the filtering effect dropping to the lower frequency range. When Center is at minimum, advance the Accent control R8 to maximum. You will hear the increased resonance ("hollowness") of the filter, and again sweeping the Center control R26 through it's range will produce a much more pronounced flanging effect. With the Center control at maximum, advance the Span control R25 to maximum. The internal low frequency oscillator will be sweeping the flanging effect. At the "bottom" of each sweep you may hear a short "wheep" or squeal. Adjust Peak trimmer R27 until this sound is heard, and then return the trimmer to the point at which the "wheeps" do not occur. While the internal oscillator is sweeping the effect, advance Speed control R17 and notice that the flanging speed increases from approximately one sweep every five seconds to about one cycle per second. At this point all calibration has been made, and you can proceed to the Final Case Assembly.

( ) Cut the remaining length of rubber extrusion to a length of 8-3/4-inches and slip over the front edge of the case top.

( ) Using four (4) #4 X 3/8-inch self tapping screws install the case top as shown in figure 5.

THIS COMPLETES ASSEMBLY OF THE 1500 PHLANGER.

THE BACKGROUND OF FLANGING

Flanging is a musical effect which has recently caught the eye (ear?) of nearly every musician. Despite the current onslaught of phasers and flangers, the effect has been around since Phil Spector first used it musically on Tony Fisher's 1958 recording of "The Big Hurt". Until the technological advances of the '70's came about, the effect was produced using two identical tape recordings played simultaneously and mixed together. While the recorders were running, the playback speed of one of the recorders was decreased slightly by pressing a finger against the capstan or the flanges of the tape reels. Hence, the name flanging. As the recorder was slowed down more and more, an increasing time delay between the two signals occurred. When mixed together, any frequencies which were 180 degrees out of phase with themselves were cancelled. Similarly, those frequencies whose phase relationships coincided were reinforced. This caused a complex series of signal peaks and notches to occur across the audio spectrum. As the time delay increased, the cancellation notches moved farther down into the audio frequencies, causing a dramatic swirling or "turning inside out" sound. When the effect had extended to low frequencies, the other recorder was slowed down to cause the effect to sweep up until the two signals were once again in sync, and there were no audible cancellation frequencies. As you can see, the effect was cumbersome and time consuming to achieve, and could only be done in the studio.

In the early '70's widespread use of op-amp circuitry and active filters stimulated the development of all-pass filters. This circuit will cause the output to be shifted in phase by some amount depending on the center frequency of the filter and the frequency of the input signal. When several identical all-pass filters are connected in series with some means of varying the center frequencies of all filters simultaneously, large phase shifts can be obtained throughout the audio spectrum. The shifted signal, when mixed with the original input signal, causes a series of notches to occur at octavely related frequencies. This development excited musicians, as they could now have a low cost portable means of achieving an effect similar to flanging. But, those who had heard or worked with flanging knew that phasing wasn't the same sound. It isn't as deep and rich, it doesn't "roll" as much as flanging. Time delay is the only way to get the full complement of HARMONICALLY related notches needed for flanging.

Around 1974, MOS charge coupled devices were perfected and released as solid state image sensors for video cameras. Engineers soon realized that the same type of circuitry could be used to construct an analog shift register or audio delay circuit. The job which formerly caused audio engineers to pull their hair out is now reduced to the use of a few IC's!

USING THE PHLANGER

Operation of the Phlanger controls is as follows:

POWER- When slid to the right, this switch will apply power to the circuit. The LED below the switch should glow when power is applied.

SPAN- This control determines the amount of low frequency oscillator signal that is used to sweep the flanging effect. With the control at minimum, very little sweep oscillation occurs and the Center control has the most effect. As the Span control is increased, the sweeping effect will grow wider both above and below the initial setting of the Center control. At maximum, the Center control will be disabled and the low frequency oscillator will be sweeping the flanging effect across it's entire range.

CENTER- This control can be thought of as a "manual" flanging control, or as an initial delay time adjustment. Both are correct. When the Span control is at minimum, the Center control becomes effective. With the Center control at minimum, the initial delay time is at maximum or about 10 milliseconds. This corresponds to the flanging notches being at their lowest frequency setting. As the Center control is advanced, delay time is decreased until, at maximum control setting, it is about .5 milliseconds.

ACCENT- The Accent control determines the gain of a feedback loop around the analog delay IC. This, like the "Q" control on active filters, causes a resonance to occur at a frequency whose period is equal to the time delay introduced by the analog delay line IC. The resultant effect is an increased depth, or "hollowness" in the flanging effect.

MIX- Mixing capabilities allow selecting only normal signal, only the delayed signal, or any blend of the two. This allows for various depths of flanging effects, and gives access to the straight delayed signal which can be used for many striking effects which will be discussed later.

SPEED- Speed adjustment will vary the rate at which the flanging effect is automatically swept when the Span control is advanced. At minimum Speed setting, very slow sweep rates are obtained (about one cycle every five seconds). As the control is advanced, the speed will increase to about one cycle per second.

The rear panel jacks are to be used as follows:

INPUT- The signal source is fed to the input jack. To avoid nonlinearities in the delay circuit, input level must be restricted to .5 volts peak-to-peak maximum. This leaves plenty of headroom for most instruments and line signals.

OUTPUT- Signals from this jack are fed to the amplifier. Output level will be approximately equal to the original input level.

CENTER- Remote voltage control of the initial delay time is possible with this jack. When using the remote jack, the front panel Center control MUST be set to maximum. Then, as a source of 0 to 5 volts is applied to the tip connection of the jack, the delay time will extend to maximum.

SPEED- As with the Center jack, this jack allows remote voltage control of the flanging sweep rate. Again, the voltage should be applied to the tip connection of the jack, but voltages as high as 9 volts can be used if desired. Maximum effect will be derived from the remote jack if the front panel Speed control is set to minimum, however other settings of the Speed control can be used if less range is desired.

CANCEL- This jack allows for use of a foot switch to eliminate the delayed portion of the output signal. When the foot switch shorts the tip and shaft connections of this jack, the delayed signal will stop, and if the Mix control is set to less than maximum, the normal signal will continue to pass.

The obvious use for a flanger is to duplicate the effect of tape reel flanging. This "classic" sound is obtained when a 50/50 mix of normal and delayed signal is used. Accent should be set to minimum, and sweep rate and span can be set as desired. To achieve the more pronounced flanging effect of the '70's, the Accent control can be advanced to the desired amount of depth.

During the design process we found that the addition of a few extra controls added a high degree of versatility to the Phlanger. When the unit is considered as a general purpose time delay, many other effects can be obtained which initially aren't as obvious, and can't be accomplished with a basic flanger.

When the clock speed of the Phlanger is changing, the signal at the output of the delay line exhibits a slight pitch shift. If, for example, the clock speed is continually increasing, the audio signal will be sampled into the delay line at one rate but will be sampled out at a faster rate. Thus, the input frequency will be shifted up by an amount dependent on the rate of increase of the clock frequency. Similarly, when the clock rate is continually decreasing the input signal will show a decrease in frequency as it leaves the delay line. Using this phenomenom, we can generate quite a few unusual effects.

Periodic pitch shifting is known as vibrato. With the Phlanger Mix control at maximum (for 100% delayed signal) the Span control can be advanced to create a vibrato effect. The sharp switching of the internal triangle wave may produce too harsh an effect for some, but the Span control can be set to minimum, and an external sine wave applied to the Center jack. The PAIA 2720-5 Control Oscillator synthesizer module is well suited to this application. The external sine wave will produce the familiar smooth vibrato usually associated with organs. Vibrato isn't a radical new effect, as most guitars, organs, and synthesizers have provisions for this effect. But now you can have vibrato wherever you want it. Imagine vibrato on a recording of a grand piano, a choir, or on chimes. Or if you are recording several instrumental tracks and later decide that there should have been vibrato on the saxophone, you can easily process the saxophone track through a modulated delay line during mixdown rather than rerecording the entire track.

Another unique application of the Phlanger is generation of stereo or quad motion effects from a mono signal. See figure 9. For this effect, the original signal is fed to the input of one amp AND to the Phlanger input. The Phlanger output is then fed to the remaining amp. Control settings on the Phlanger are the same as for vibrato effects, except with a slower rate. When a signal with complex harmonic structure is fed through this system, some frequencies will be ~~emitted~~ from the speakers in phase with each other. The apparent source of the sound will be between the two speakers. Other frequencies will have enough phase difference between the two sources to cause a psychoacoustical image to one side of center. The amount of location shift is related to the amount of phase difference between the two sources. When the delay time is changing, different frequencies will tend to move across the stereo field at different rates and depths. This effect is quite dramatic, but is even better in a quad system where opposite corners are fed with the former stereo outputs. The sound source appears to float and drift above your head, not unlike sitting in the middle of a rotating speaker system used with organs. To generate a quad signal from a stereo source, a separate Phlanger could be used for each side with the normal signals feeding the front speakers and the delayed signals feeding the rear speakers. The two Phlangers could be run independently, causing apparently random motion around the room; or using the voltage controlled center inputs, a common control source could be used for synchronized frequency motion between the front and rear of the room.

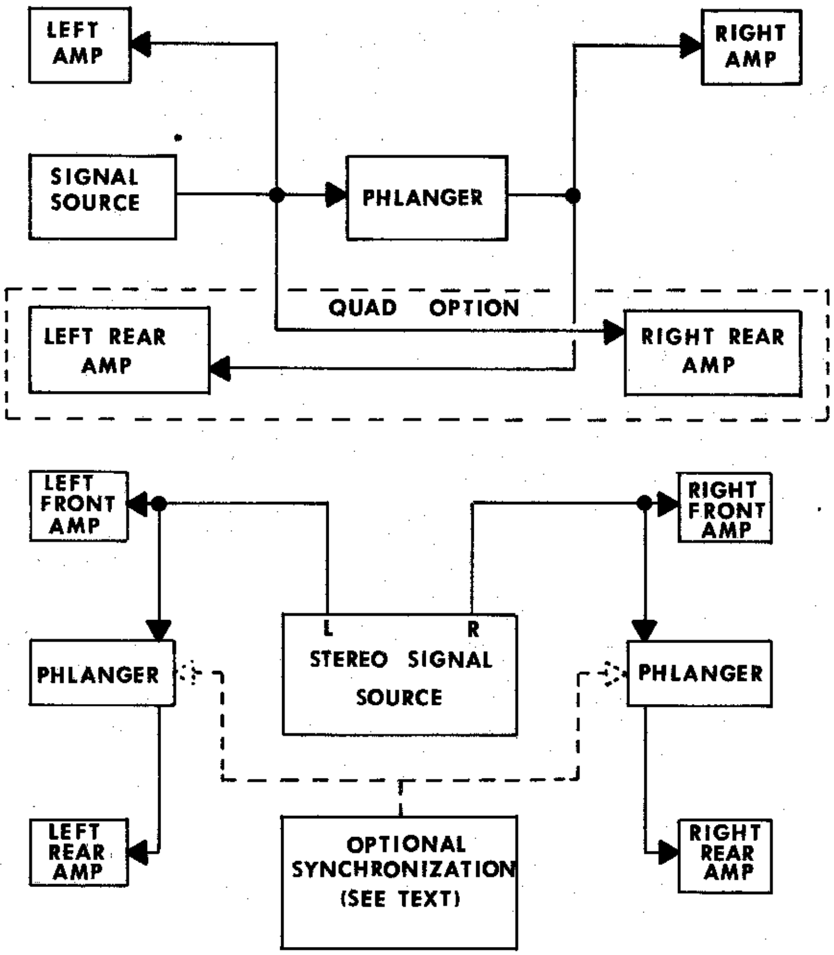


Figure 9

When the Phlanger is interfaced with a voltage controlled music synthesizer, astounding effects can be obtained through use of sequencers, envelope generators, and envelope followers as control sources for the speed and center inputs. Using the Phlanger near maximum delay time will give the effect of having more than one signal source (voice doubling). Many synthesists use multiple oscillators tracking together and tuned in unison to provide more body to the sound -- as if more than one instrument is playing. Voice doubling is an electronic simulation of this effect, so you can save the other oscillators for generation of additional sounds. Today's string synthesizers take on new depth and realism when processed through voice doubling.

Using the Phlanger to process an organ can result in an excellent simulation of the rotating speaker effect so often associated with organs. To achieve this sound, the span and center controls should be set below midrange. Accent control should be at midrange or less. A simple external footswitch circuit can be built which accurately duplicates the effect of motor speed build-up and braking in a large rotating speaker. See figure 10. The complete circuit can be housed in the foot switch box and operated with four penlight batteries or a 9 volt transistor battery.

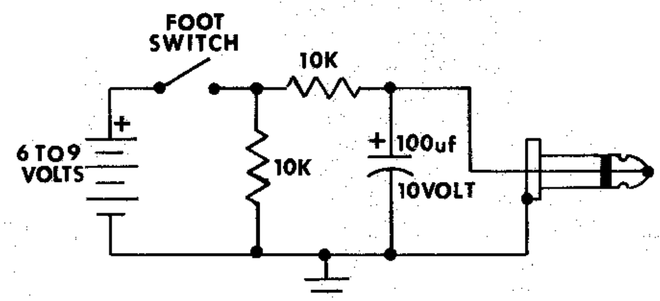


Figure 10

Similarly, the PAIA/DeArmond foot pedal (model #1600) can be used to supply a variable foot controlled source of bias voltage for the Phlanger. Instructions are included with the foot pedals describing the installation of batteries in the pedal for this purpose.

Processing miked drums through the Phlanger gives an effect of tuning the drum sound. With the controls set for automatic sweep of the flanging effect, the drums will sound as if they are constantly being retuned while they are being played. The increased tonality of the drums greatly increases their presence and solo potentials.

It soon becomes evident that with a flanger that has controls for so many sections of the circuitry, a near infinite number of applications can be found. And they need not be music processing jobs. How about adding delayed triggering to your oscilloscope. Or a voice operated switch for your transmitter that won't chop off the first syllable of your message. And there's lots more. As always, get a good feel for the operation of the controls -- then experiment.

DESIGN ANALYSIS

The primary component in the Phlanger is the Analog Delay Line IC. This device is new and special enough to warrant a description of how it works and how to use it.

The Reticon SAD-1024 is a dual 512 stage analog shift register which represents the third generation of analog delay IC's. Reticon's use of N-channel technology eliminates the need for multiple supply lines, increases linearity and distortion specs, improves dynamic range (S/N > 70db), and decreases loss. The SAD-1024 utilizes MOS transistors and capacitors in an array as shown in figure 11. The schematic shows one of the two identical circuits contained in the IC. The circuit requires a bi-phase clocking signal of Ø1 and Ø2 (Ø2 is the complement of Ø1) which has a minimum frequency of twice the highest frequency to be successfully passed through the delay line. The clock signals should swing between Vdd and ground. When Ø1 is high, the input signal is applied to input capacitor Cs. At the moment of clock transition, the input transistor is disabled and the voltage on Cs is frozen. With Ø2 now high, the charge on Cs is passed through a buffer and onto the capacitor in stage 1. The next time Ø1 is high, another sample of the input is taken and likewise passed down the chain of 509 storage capacitors. At the 510th stage the signal is applied to two parallel shift registers, one having three stages and the other having four stages. The signal will appear at output A 512 clock half-periods after it was applied to the input. The same output will appear at output A during the following, or 513th, clock half-period. This allows the output to be a more continuous representation of the input signal, and aids in suppressing residual clocking glitches. Thus the time delay of the circuit can be figured by:
Td = 512/2Fc where Fc is the frequency of the clock lines Ø1 and Ø2.

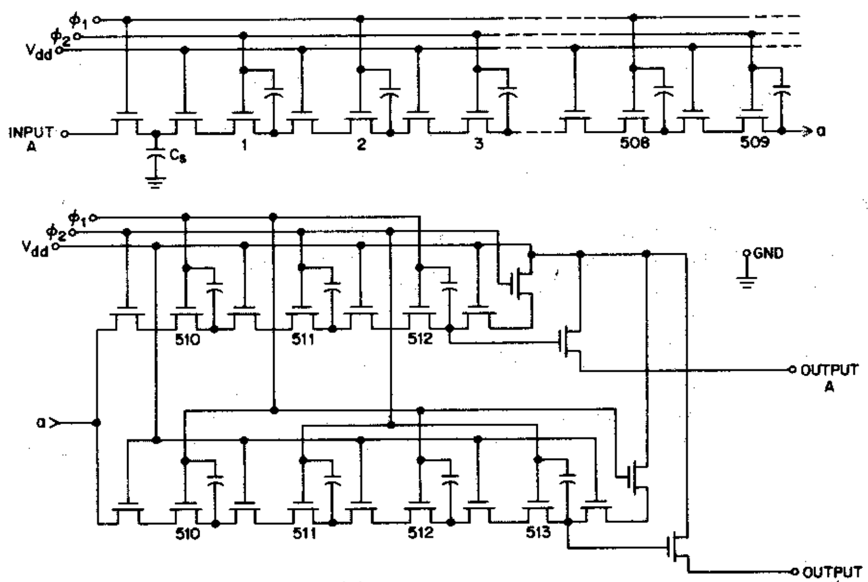


Figure 11

Being a strict sampled data device warrants some discussion of **sampling theorems** and special precautions which need to be taken. When sampling an analog signal, consideration must be given to the number of samples required to accurately reproduce the original waveform. When the sample rate is 10 or more times the frequency of the input, the condition is known as oversampling. This is a favorable condition, as the more samples taken per period yield increasingly accurate reproduction of the input signal. As the input frequency is increased or the sample rate is decreased, fewer of the harmonics of the input signal will be reproduced due to the inability of the sampling system to capture such rapid fluctuations. When the input frequency approaches half of the sample rate critical sampling occurs. Only the fundamental sine wave will be reproduced from even the most complex input waveforms. As the sample rate falls below twice the input frequency, drastic distortion of both waveform and frequency will occur. This is called undersampling and, except for special applications, should be avoided. For most audio applications, oversampling with a possible approach to critical sampling will be the operating region most used.

To avoid modulation of the input signal against the clock frequency, the input of a delay system should have a low pass filter whose corner frequency is one-half to one-third the minimum clock frequency. For audio use, the input signal will already be limited, so as long as the clock remains above 30KHz no input filter will be required. The output, however, will definitely need some type of filtering. Due to the sampled nature of the delay chip output, the signal will at best be a stairstep approximation of the input signal. Also, there will be narrow glitches or spikes riding on the waveform which correspond to the clock transitions encountered within the delay chip. An output which, like the input filter, is a low pass set at one-half or more of the minimum clock frequency will 1) remove the residual clock signal, and 2) smooth the stairstep approximation to a nearly identical duplicate of the original input signal - except, of course, delayed by X amount of time. For audio use, an output filter at 15KHz with a minimum clock rate of 30KHz is about as far as you want to push it. Some audio fanatics may be concerned about this setup having a maximum waveform recovery of a sine wave at 15KHz. But consider - primary fundamental frequency content of most music is only up to about 4KHz. Energy distribution above this point consists primarily of harmonics of the lower frequency waveforms. At 15KHz, these harmonics are running tens of db below the signal level of the fundamentals, and any loss is negligible.

The complete Phlanger schematic is shown in figure 8. The input signal is buffered by IC1C and superimposed on a bias voltage determined by the setting of R5. For proper operation of IC2, the bias must be set to 40% of the supply voltage. The output of IC1C is fed to the inputs of the dual delay line, IC2. Note that the clock signals to each delay line are reversed, so Ø1 for one line is Ø2 for the other. This is known as parallel multiplex operation and causes the input to be alternately sampled by the two delay lines. The result is that the input is sampled twice as many times per period as with the normal mode of operation, and the output signal is a more accurate representation of the original input. One output from each delay line is applied to the summing/balance network R6/R7. Accent control R8 selects the amount of delayed signal to be fed back to the input for regeneration. R9/C4, R10/C5, R11/C6 are low pass filters used to remove the high frequency clock signal from the audio signal, and to smooth the "staircase" sampled waveform into a duplicate of the original. Mixing control R12 selects normal input, or delayed signal, or any blend of the two. The mixed signal is amplified by IC1D to provide unity gain through the complete audio circuit.

The remaining two sections of IC1 comprise the low frequency triangle oscillator used to sweep the flanging effect. IC1A forms an integrator whose slope is voltage controlled. Control voltage is derived from Speed control R17 or from remote input J4 which is buffered by Q1. IC1B is used as a Schmitt trigger which determined whether the integrator will slope positive or negative. Peak trimmer R27 fine tunes the triangle output amplitude of IC1A for optimum use with the following circuitry. Span control R25 determines the amount of triangle signal used to modulate the high frequency clock. As the span control is decreased, an increasing amount of fixed DC voltage is provided by Center control R26. Alternately, external control voltage can be applied to Center jack J3 to set the initial high frequency clock rate. The resultant mixed signal from this control network is available at the wiper of Span control R25, and is applied to current source Q4. This current source replaces the standard timing resistor for the VCO IC4. With the current range provided, the frequency range of IC4 is applied to the clock input of one of the D-type flip-flops in IC3. This stage serves two purposes: dividing the clock signal by two, and generating complementary square wave outputs from the Q and $\bar{Q}$ outputs. These complementary signals drive the delay line clock inputs with a frequency range of 30KHz to 500KHz.

The power supply for the Phlanger is a standard full wave bridge rectifier with center tap which provides a bipolar 9 volt supply for the circuitry.