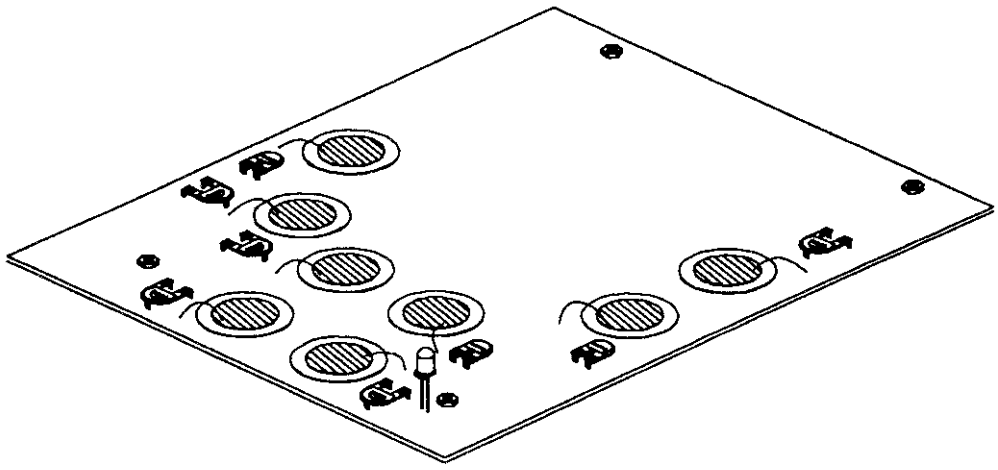
Thumbdrum Sensor Board

Model 9301
Assembly and Testing Manual



The ThumbDrum Sensor Board uses Piezo Electric Disks to convert finger taps into voltage pulses with peak amplitudes proportional to the force of the tap. Active circuitry buffers the outputs so they can be used to directly drive the inputs of Trigger-to-MIDI converters such as the PAiA 9201D Single Board Computer or Ringing Oscillator Tone Boards such as the PAiA 9302 Drum Tone Board.

ASSEMBLING THE SENSOR BOARD

Before beginning assembly, go through the manual. Look at the drawings. Feel the parts. You're naturally eager to plunge right in, but take a few deep breaths first.

Notice that each step in the manual is marked with a checkoff box like this:

DESIGNATION	VALUE	COLOR CODE
( ) R27	100 ohm	brown-black-brown

Checking off each step as you do it may seem silly and ritualistic, but it greatly decreases the chance of omitting a step and also provides some gratification and reward as each step is completed.

A full size drawing of parts placement on the circuit board as well as a phantom view of the board are in the center of this manual. This page may be removed for easy reference during assembly.

THE CIRCUIT BOARD

The Sensor Board is built on a single-sided circuit board. Before beginning assembly, clean oxidation from the copper side of the circuit board using scouring cleanser and water. The copper should be bright and shiny before beginning assembly.

Once you begin putting parts on the circuit board, it's a good idea to continue until all the parts are mounted. Stopping overnight may allow the copper to oxidize and make soldering more difficult.

TOOLS

You'll need a minimum of tools to assemble the kit - a small pair of diagonal wire cutters and pliers, screwdriver, sharp knife, ruler, soldering iron and solder.

Modern electronic components are small (in case you hadn't noticed) and values marked on the part are often difficult to see. Another handy tool for

your bench will be a good magnifying glass. Also use the magnifier to examine each solder joint as it is made to make sure that it doesn't have any of the problems described in the SOLDERING section which follows.

SOLDERING

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

Use only rosin core solder (acid core solder is for plumbing, not electronics work). A proper solder joint has just enough solder to cover the soldering pad and about 1/16-inch of 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 when actually there is a layer of flux insulating the component lead from the solder bead. This situation can be cured by reheating 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. Accidental bridges can be cleaned off by holding the board upside down and flowing the excess solder off onto a clean, hot soldering iron.

Use care when mounting all components. Never force a component into place.

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This product originated as a Do-It-Yourself article by John Simonton *and* Kent Clark *in the June and July 1993 issues of* Electronics Now *magazine. There may be differences between what appeared in the article and what is supplied with the kit. These differences, and any discussion of them, will be set aside with this italicized type. In some cases, notes packed with the parts will be used to call your attention to special situations.*

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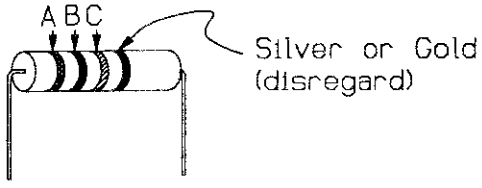
The ThumbDrum Sensor Board will have components mounted on both sides of the circuit board. Resistors, Capacitors, ICs and such will mount on the conventional "component" side (printed with parts placement legending) and the Piezo Disks, their SensitivityTrimmers and the Power LED will mount on the "solder" side which has the copper traces.

We begin with the components whose leads push through the circuit board from the component side and are soldered on the solder side.

RESISTORS

Solder each of the resistors in place following the parts placement designators printed on the circuit board and the assembly drawing Fig 1. Note that resistors are nonpolarized and may be mounted with either of their two leads in either of the holes provided. Before mounting each resistor, bend its leads so that they are at a right angle to the body of the part. Put the leads through the holes and then push the resistor firmly into place. Cinch the resistor in place prior to soldering by bending the leads on the solder side of the board out to an angle of about 45 degrees. Solder both ends of each resistor in place as you install it. Clip each lead flush with the solder joint as the joint is made.

Save the excess leads from all components, in later steps they will be used as circuit board jumpers.



DESIGNATION	VALUE	COLOR CODE A-B-C
( ) R1	1500 ohms	brown-green-red
listed below:	1000 ohms	brown-black-red

( ) R4	( ) R7	( ) R10	( ) R13
( ) R16	( ) R19	( ) R22	( ) R25

listed below:	1 megohm brown-black-green

( ) R 3	( ) R6	( ) R9	( ) R12
( ) R15	( ) R18	( ) R21	( ) R24

CAPACITORS

Ceramic Disk Capacitors

Most of the capacitors used in the FingerDrum are nonpolarized ceramic disks, either lead can go in either of the holes on the circuit board. Leads are already parallel to each other so they will not require any bending prior to installation. Like the resistors, push the leads of the capacitors through the holes in the board and push the part against the circuit board as far as it wants to go. Don't force it, it's OK if it sits a little off the board.

Disk Capacitors

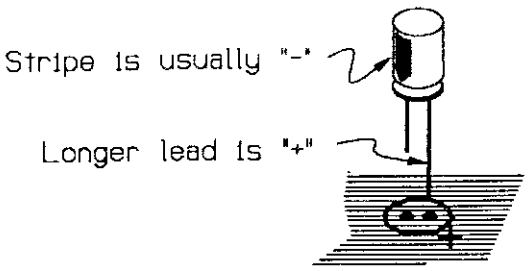
Capacitors are rarely marked with something so simple as their values these days. Instead, component manufacturers prefer obscure codes. You shouldn't have any problems with this since all of the ceramic disk capacitors are the same value

DESIGNATION	VALUE	MARKING
listed below:	.01 uF	103

( ) C3	( ) C4	( ) C5	( ) C6
( ) C7	( ) C8	( ) C9	( ) C10

Electrolytic Capacitors

Two of the capacitors are electrolytic types. Unlike the previous components, electrolytic capacitors are polarized and the leads are not interchangeable. Leads are marked "+" and/or "-" and the "+" lead must go through the "+" hole in the circuit board. Frequently the positive (+) lead of the capacitor is significantly longer than the negative (-) lead.



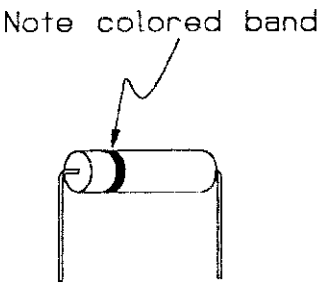
Usually the negative lead of the capacitor is marked rather than the positive. It naturally goes through the hole not marked "+".

Capacitors supplied with specific kits may have a higher Voltage (v) rating than that specified below.

DESIGNATION	VALUE
( ) C1	100 uF / 15V
( ) C2	100 uF / 15V

DIODES

Diodes are polarized and must be installed so that the lead on the banded end of the part corresponds to the banded end of the designator on the circuit board. Diodes are also somewhat heat sensitive so the soldering operation should be done as quickly as possible.



As with resistors, bend the leads so they are at a right angle to the body of the part.

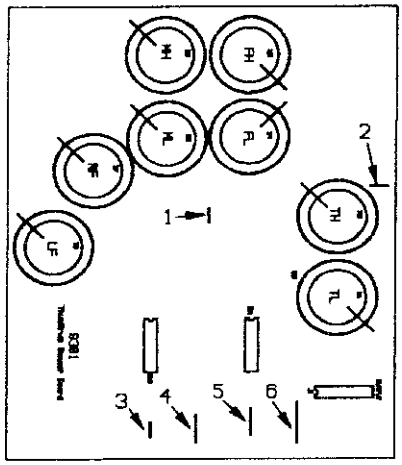
The LED D4 will be installed later.

DESIGNATION	TYPE
listed below:	1N4148 (may be 1N914)

( ) D1	( ) D2	( ) D3	( ) D5
( ) D6	( ) D7	( ) D8	( ) D9
( ) D10	( ) D11	( ) D12	( ) D13
( ) D14	( ) D15	( ) D16	( ) D17
( ) D18	( ) D19	( ) D20	

JUMPERS

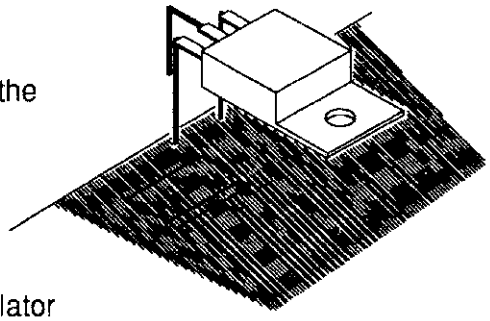
( ) Using the wire clippings saved while installing the previous parts, bend and install the six circuit board jumpers which are designated on the circuit board by bold lines.



There are 6 wire jumpers used on the circuit board

VOLTAGE REGULATOR

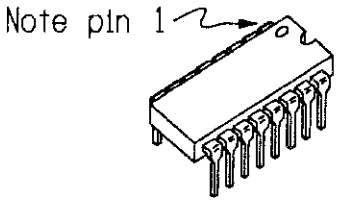
Locate the 7805 voltage regulator and form the leads as shown in the illustration so they match the holes in the circuit board. Press the Voltage Regulator against the board and solder the three leads. Clip excess lead off flush with the solder joint.



DESIGNATION	TYPE
( ) IC3	7805 +5V Voltage Regulator

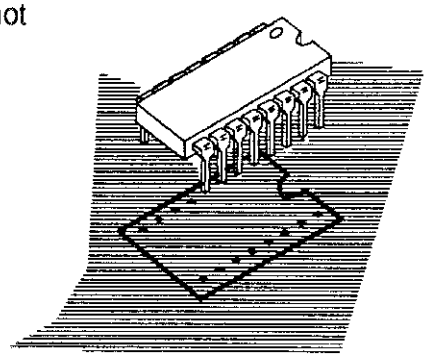
INTEGRATED CIRCUITS

Of all the parts, the ICs are the most easily damaged and should be treated with some respect. In particular, they may be destroyed by discharges of static electricity. Modern ICs are not nearly as sensitive to this kind of damage as were earlier versions, but it is still good practice to handle these parts as little as possible. Also good practice: don't wear nylon during assembly. Don't shuffle around on the carpet immediately before assembly (or if you do, touch a lamp or something to make sure you're discharged). Don't be intimidated. It's rare for parts to be damaged this way.



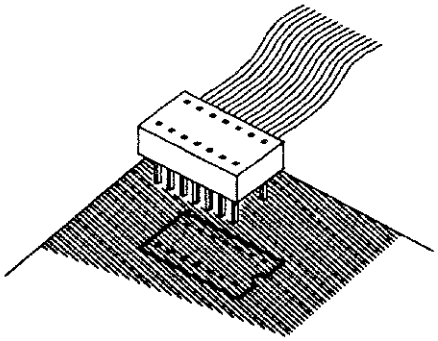
ICs are polarized in one or both of two ways; A dot formed into the case of the IC corresponding to pin 1 or a semicircular notch that indicates the end of the package with pin 1. Take care that this polarizing indicator corresponds to the similar indicator on the circuit board graphics.

The pins of the ICs may be splayed somewhat and not match up exactly with the holes in the circuit board. Carefully re-form the leads if necessary so that they are at right angles to the part. Solder each IC in place as it is installed by initially soldering two pins in diagonal corners of the pattern. Make sure that the part is seated firmly against the pc board by pressing it down while remelting the solder joint at first one corner, then the other. Finally, solder the remaining connections.



DESIGNATION	TYPE
( ) IC1	LM324 Quad Operational Amplifier
( ) IC2	LM324 Quad Operational Amplifier

DIP CABLE

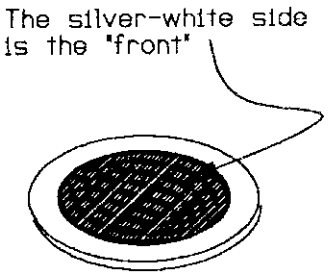


A section of ribbon cable terminated on both ends with 14 Pin DIP Headers will be used to make the connections between the Sensor Board and the MIDI or Tone Boards. On the Sensor Board end this cable is soldered directly to the circuit board.

( ) Locate the Ribbon Cable with 14-pin headers on both ends. Solder one of the headers to the circuit board at the location indicated as J1 by the legending. Notice that the ribbon should exit the header toward the closest edge of the circuit board. Push all 14 of the Header pins though the holes until the Header is sitting flush with the board. As with the integrated circuits, first solder diagonal pins and then press the header firmly against the board while remelting these connections. Finish by soldering the remaining pins.

SOLDER SIDE PARTS

It is now time to mount the Piezo Disks, Sensitivity Trimmers and Power/Level LED. We've saved these parts for near the end so you would have some practice soldering. Remember that unlike previous components, these parts mount on the "solder" or copper trace side of the circuit board.

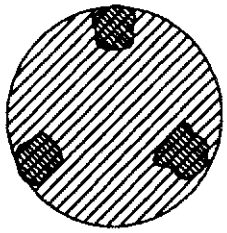


Begin by locating the ten Piezo Disks and identifying their silver-white front and brass back faces.

It is important that the disks be installed so that they are elevated above the board slightly. If they are flush with the board, transmission of mechanical shock may result in cross-talk between sensors. In the steps on the following page a cardboard sensor locating shim provided will

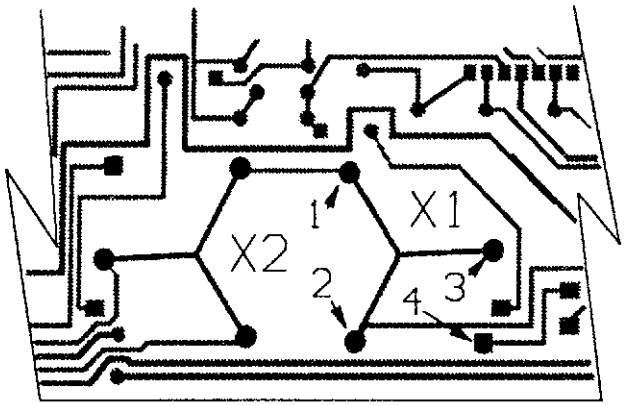
be used to mount the sensors with the appropriate spacing from the board.

"Tin" 3 spots on back face circumference



( ) "Tin" three equally spaced spots around the circumference of the back face of one of the Piezo Disks as shown in the illustration.

Here's a pointer: make sure the tip of your iron is clean by wiping it with a damp sponge or rag and then melt enough solder onto the tip to form a small drop hanging from the end. This solder drop will help conduct heat into the disk. Hold the heat to the disk until fresh solder fed into the blob melts readily. Don't feed in too much new solder.

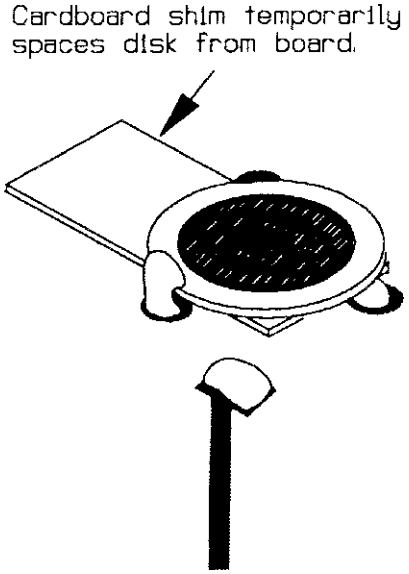


There are 4 pads for each Piezo Disk

( ) With the circuit board positioned so that the conductors are facing up, locate the trace patterns for the Piezo Disk X1 (the sensor in the Thumb Low position). Notice that the single square pad and three round pads associated with each Piezo Disk do not have holes drilled in them. Tin these pads by melting enough solder onto them to form a small bump.

( ) Locate the cardboard shim supplied and place it over the sensor traces as shown on the facing page. Place the Piezo Disk, with the front face up, on top of the cardboard so that the solder bumps on the sensor align with the sensor mounting pads. Carefully remelt the solder on the disk and the pad so that they join. If the disk moves sightly or you're not happy with the alignment for any reason, redo the operation. Make sure that the sensor is parallel to the board with its silver face up before proceeding to the other sensor disks.

( ) When you're satisfied with the alignment of the disk, permanently fasten it in place by remelting the other two support points. Withdraw the shim.



Similarly, mount the remaining seven Piezo Disks. Notice that in some cases the disks are close together. It's important that they not touch each other to prevent cross-talk. Following the sequence listed below will provide the maximum work space as each sensor is installed.

DESIGNATION TYPE

listed below: Piezo Disks

( ) X2 ( ) X3 ( ) X4 ( ) X5
( ) X6 ( ) X7 ( ) X8

The connections between the front faces of The Piezo Disks and the circuit board will be made using the very small diameter wire-wrap wire supplied. All of these wires will be the same: cut a 1" length and remove 1/8" of insulation from each end. Heat the exposed wire strand on each end and melt a small amount of solder onto it.

You may have to practice stripping this wire, there's a knack to cutting through only the insulation without nicking the conductor There's more of this wire supplied than you need so if you mess up, you won't run short.

( ) Solder one end of a piece of wire-wrap wire to the square pad that is part of the foil pattern for sensor X1 by remelting the solder on the pad and pressing the end of the wire into it. Check the parts placement graphics on the component side of the board if you are unsure which pad goes with the sensor. Dress the wire around the edge of the Piezo Disk and not across its top. We will be mounting a foam pad over these sensors later and we won't want the wire to get in the way.

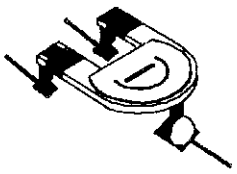
( ) Solder the other end of this wire to the silver colored front face of Piezo Disk X1. Unlike soldering to the back face of the sensor, this operation will require very little heat. BE QUICK. If you blow it the first time and wind up with a small hole in the silver and the wire not attached, it probably is not the end of the world, just solder to another place. A small hole won't affect the operation of the sensor a lot.

Similarly, make the connections between the front faces and the circuit board on the remaining Piezo Disks.

( ) X2 ( ) X3 ( ) X4 ( ) X5
( ) X6 ( ) X7 ( ) X8

TRIMMER POTENTIOMETERS

The sensor sensitivity trimmers are mounted on the solder side of the board so they will be accessible through holes in the case top. Mount the 10 trimmer potentiometers by inserting their three pins into the holes provided. Press them down until the "shoulders" of the solder pins are resting on the surface of the circuit board conductor. When soldering these parts, use a lot of heat. It is easy to make poor joints on these connections because the copper trace will accept solder more quickly than the resistor pins.



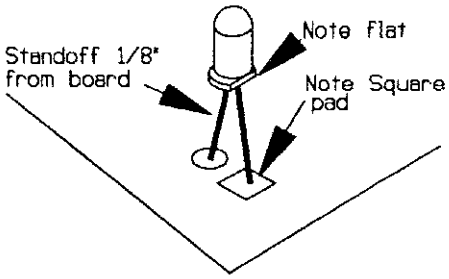
DESIGNATION TYPE

listed below: 100k ohm trimmer resistors

( ) R2 ( ) R5 ( ) R8 ( ) R11
( ) R14 ( ) R17 ( ) R20 ( ) R23

LED

Locate the Light Emitting Diode and install it on the conductor side of the board. Push the LED's leads through the holes but do not push the part against the circuit board, instead, solder it in place so that it stands off from board by about 1/8". Also, Notice that the LED is polarized and the lead marked by the flat on the case must go through the hole in the SQUARE Pad.

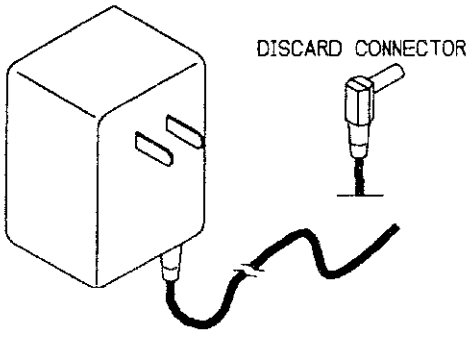


DESIGNATION TYPE

( ) D4 Light Emitting Diode

WALL-MOUNT POWER SUPPLY

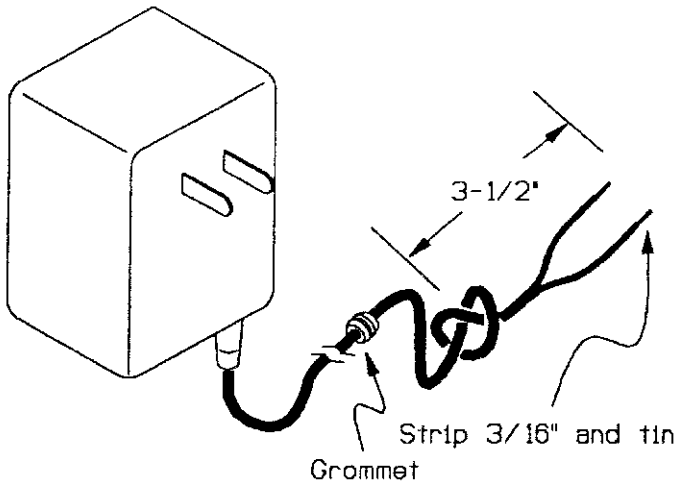
Locate the Wall-Mount Power Supply PWR1. If this part has a connector on the end of its cable, remove and discard it as shown. Notice that one of the two wires coming from PWR1 is polarized with a contrasting stripe. A note packed with the Power Supply will identify the striped lead as being (+) or (-).



Power Supplies provided with individual kits may have a current rating greater than the 100mA minimum.

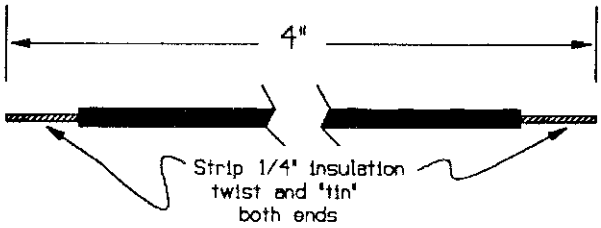
( ) Push the free end of the Power Supply's cord through the 1/4" Rubber Grommet supplied. Place a knot in the cord 3-1/2" from the end.

( ) Separate the cord into two wires back to the knot. Remove 3/16" of insulation from the end of each wire, twist the exposed wire strands together and "tin" them by melting a small amount of solder into the strands. Pre-tinning will make soldering easier.



( ) Locate the Slide Switch S1 and solder the "+" lead of the Power Supply to Lug #1. (see illustration below).

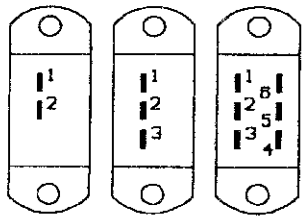
( ) Prepare the 4" length of #22 stranded wire supplied by stripping 1/4" of insulation from each end and twisting and tinning the exposed wire strands.



( ) Solder one end of this wire to Lug #2 of the slide switch S1.

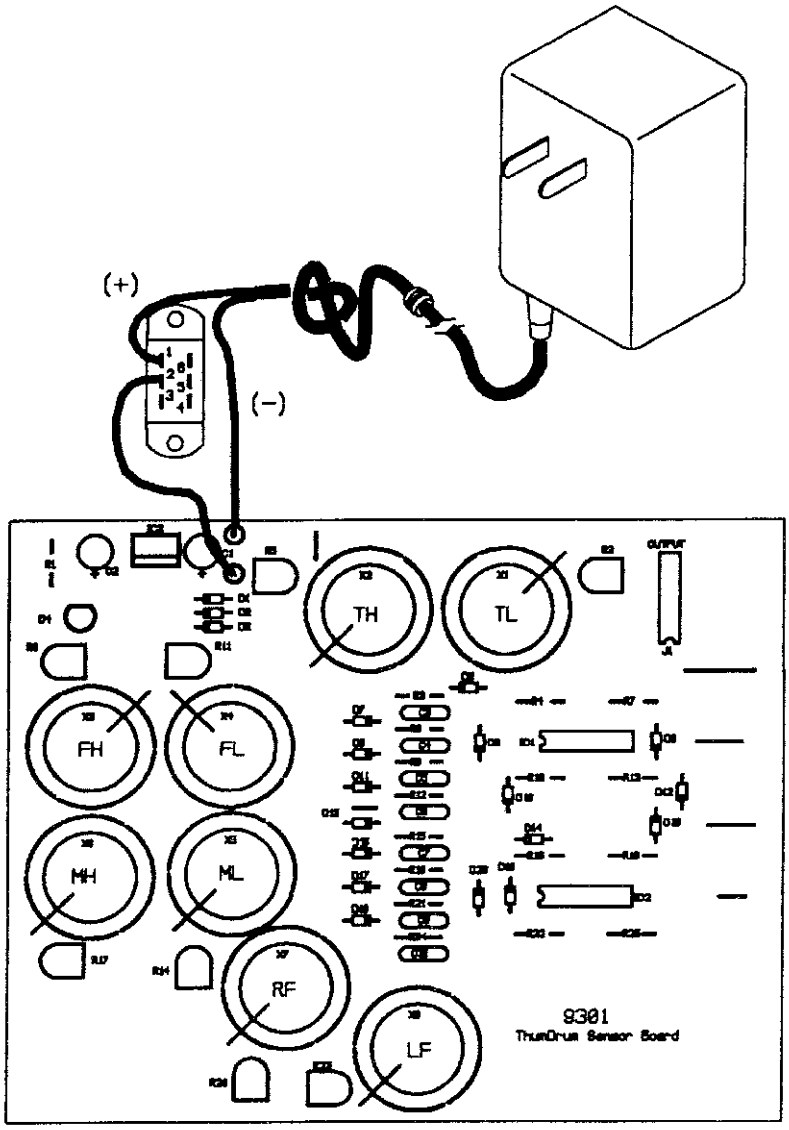
( ) Solder the free end of the wire from above to the circuit board pad marked "A". Insert the end of the wire from the component side, solder and clip any excess lead from the joint.

( ) Solder the "-" lead of the Power Supply to the circuit board pad marked "G".



Switches will look like one of these. Only 2 lugs are needed.

This completes electrical assembly of the ThumbDrum Sensor Board. Shortly we'll plug it in and do some preliminary tests, but first take a break. Do something else for a while and when you come back, admire your work critically. Are all the polarized components like ICs, diodes and capacitors properly installed? Are the solder joints shiny and smooth? If not, reheating them may help. Are there any joints that have so much solder on them that they may be short circuiting to other conductors? See pg 3 for hints on removing excess solder.


(+)
(-)
TH
TL
FH
FL
MH
ML
RF
LF
9301
ThumbDrum Sensor Board

PRELIMINARY TESTING

We won't be able to do a full functional test of the Sensor Board until we add either the MIDI or Tone Boards, but even without these pieces we can make sure that there aren't any major problems.

Since there is no protective case around the circuit board at this point, make sure that it is resting on a surface that is free of pieces of wire or metal that might cause short circuits. There are no high voltages on the circuit board or at the switch, so you needn't be very concerned about shock hazards.

BUT BE WARY:
If there were some defect in the Wall Mount Power Supply that allowed leakage from the AC line to the cord connected to this apparatus there could be a shock hazard if you are touching a ground or making contact with a wet floor.

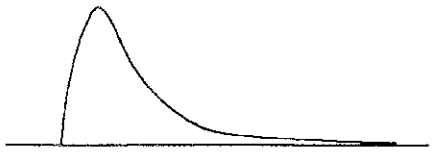
Plug the wall-mount power supply into an electrical outlet. Slide the power switch bat toward Lug #1 to turn the unit on. The LED should light and if it doesn't, stop immediately and find out why. It may be something as simple as a dead electrical outlet, or it may be a bad connection or solder bridge on the circuit board.

When the LED lights, let the unit idle for a few minutes while you check for overheating components (in particular the ICs). There should be no hot spots on the board, so if you feel a lot of heat coming from a component, unplug and find out why - a solder bridge is a likely candidate.

In addition to indicating power, the LED is also a quick and convenient means of "calibrating" the FingerDrum sensor sensitivity without test equipment. We'll get to the calibrating part of things shortly, but for now we'll simply use the LED as an indicator that individual pads are producing an output.

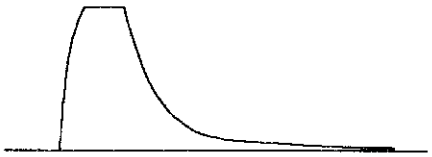
Set all trimmers to their maximum sensitivity (adjusting disk fully clockwise) and tap firmly on any of the pads while you observe the Power LED. You should see it brighten briefly when a pad is struck with a forceful tap. Tap each percussion pad in turn to see that each produces a response.

An Oscilloscope or Volt-Ohm Meter (VOM) can be used to check the outputs by connecting the "-" or ground lead of the instrument to any convenient circuit board ground point (pad "G", for example) and connecting the "+" or hot lead to each of the outputs at the pins of the DIP header which terminates the ribbon cable. On a 'scope you should see a trace something like that shown to the right. A VOM, when set to a scale which can measure 5 volts, will indicate a signal is present with a momentary up-scale meter deflection.



At midrange settings of the sensitivity trimmers, sensor outputs will be shaped like this.

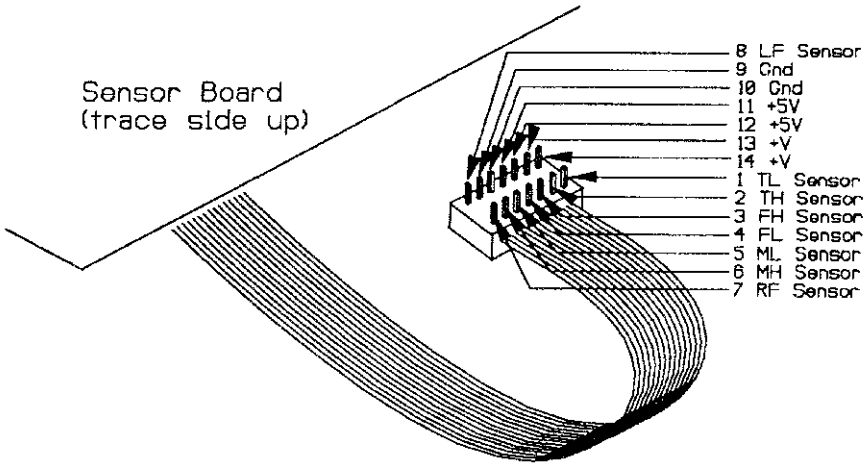
If you run into problems, isolate the defect by focusing on the section of the circuitry with the problem. For example, if you don't get an output from one of the sensors, concentrate on the circuitry for that particular sensor as shown in the Schematic Diagram. Remember the connections to the trimmer potentiometers? Recheck them. If nothing works, use a VOM to check that the V+ power (approx. 14VDC) and the +5v. reference supplies are present.



At the most sensitive trimmer settings (CW rotation) the waveform will be clipped at about 7V.

When you're confident that the Sensor Board is working properly, put it aside while you assemble either the MIDI or Tone Boards.

At this point there will be some items supplied with this kit which you have not yet used; 8 Foam Percussion Pads and a 6" length of double stick foam tape. Adhering the foam percussion pads to the face of the piezo sensors (using the double stick tape) should wait until the Sensor Board is placed in its case to assure alignment with access holes.



DESIGN ANALYSIS

The sensor board converts the force of a finger striking a pad into a voltage pulse with peak amplitude proportional to how hard the pad was hit. Underneath each pad is a Piezo Electric Disk like the kinds that are commonly used as speakers in computers and such. It's probably not news to you that when you tap these disks a voltage appears between the front and rear faces.

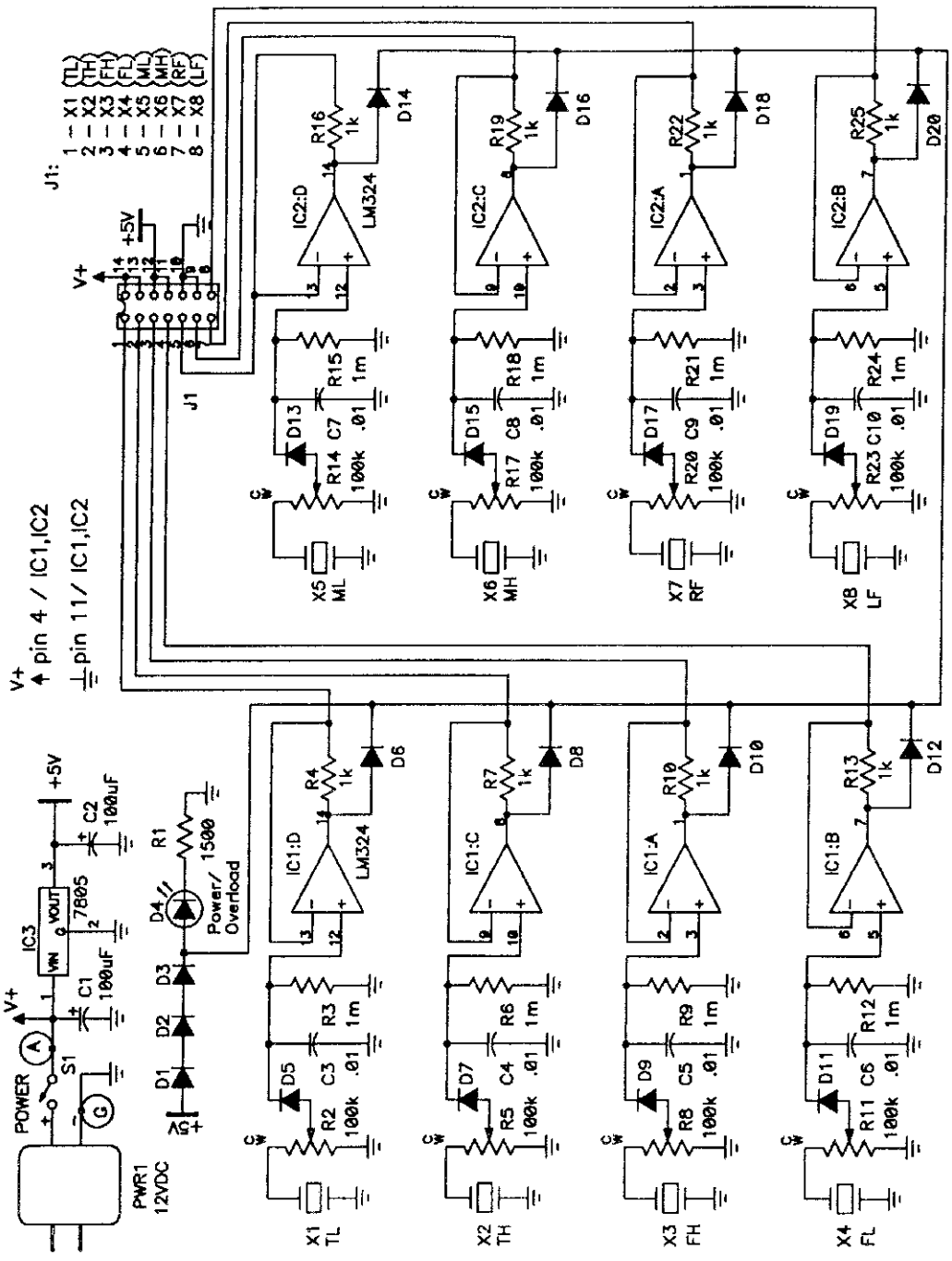
The schematic is shown on the facing page. Even a brief glance at this drawing will show that it is the same basic circuit repeated eight times. We'll look at the circuitry around IC1:D in detail.

The output of the piezo sensor X1 is wired to trimpot R2, which controls the sensor's output level and allows compensation for differences in output from specific sensors, individual differences in finger strength, and so on. After attenuation, the oscillatory transient output of the Piezo Disk is processed by the simple peak-detector consisting of D5, R3 and C3 to produce a predictable pulse output. Rise time of the pulse is a fraction of a millisecond and the decay time constant is about 20 ms. The peak level of the pulse is proportional to the force of the tap so the pads are touch-sensitive.

The processed signal is buffered by IC1:D to become the trigger output for the channel. The arrangement of R4 may be slightly different than you would expect (the output of the circuit is the input of the OpAmp) but putting the output "inside" the feed-back loop like this allows individual pads to be wired-or'd together to drive a single control line. It's easier to do drum rolls on two pads than one.

LED D4 serves two functions; it's the POWER light and also provides a simple way to calibrate the sensitivity of the sensors without test equipment. The voltage dropped across the diodes D1-D3 causes the junction of D3 and D4 to be at about 3v with respect to ground. When the output of IC1:D reaches a voltage slightly less than 4v, D6 forward biases and begins to add current to the current already flowing into D4 through D1-D3 and as a result the LED glows more brightly. This increase in brightness becomes noticeable when the output of IC1:D begins to approach its maximum allowable output of slightly less than 5v.

Since the Sensor Board is the common circuitry whether you're adding the Drum Tone Board or the MIDI Computer Board, the power supply goes here. Power from a 12VDC wall wart is switched by power switch S1, filtered by electrolytic C1 and becomes the unregulated V+ supply for OpAmps. The 7805 +5V voltage regulator chip IC3 provides power for the MIDI Computer, if you're going to use one, or becomes the internal audio ground in the Tone board. The individual sensor outputs and power appear at a 14-pin DIP header which will serve as the connector to the MIDI or Tone boards.


J1:
1 – X1 (TL)
2 – X2 (TH)
3 – X3 (FH)
4 – X4 (FL)
5 – X5 (ML)
6 – X6 (MH)
7 – X7 (RF)
8 – X8 (LF)
V+
pin 4 / IC1,IC2
pin 11/ IC1,IC2
+5V
POWER
S1
PWR1
12VDC
IC3
7805
C1 100uF
C2 100uF
D1
D2
D3
D4
Power/ Overload
R1 150Ω
IC1:D
IC1:C
IC1:B
IC1:A
IC2:D
IC2:C
IC2:B
IC2:A
LM324
R2 100k
R3 1m
R4 1k
R5 100k
R6 1m
R7 1k
R8 100k
R9 1m
R10 1k
R11 100k
R12 1m
R13 1k
R14 100k
R15 1m
R16 1k
R17 100k
R18 1m
R19 1k
R20 100k
R21 1m
R22 1k
R23 100k
R24 1m
R25 1k
C3 .01
C4 .01
C5 .01
C6 .01
C7 .01
C8 .01
C9 .01
C10 .01
D5
D6
D7
D8
D9
D10
D11
D12
D13
D14
D15
D16
D17
D18
D19
D20
X1 TL
X2 TH
X3 FH
X4 FL
X5 ML
X6 MH
X7 RF
X8 LF

ThumDrum Sensor Board
Packing List

2	LM324 Quad op-amps
1	7805 +5V Voltage Regulator
2	100uF/15V Electrolytic Capacitors
8	.01 uF Ceramic Disk Capacitors
19	1N914 or 1N4148 Silicon Diodes
1	Red LED
8	100k Horizontal Mount Trimmer Potentiometers
1	1500 ohms all resistors 1/4W. 5%
8	1k
8	1 megohm
1	SPST Slide Switch (may be SPDT or DPDT)
1	12VDC 100 mA. Wall Mount Power Supply
8	Piezo-Electric Disk Transducers
8	Foam Percussion Pads
4	in. #22 Stranded Wire
18	in. Wire Wrap Wire
6	in. Double Sided Foam Tape
1	1/4" Rubber Grommet
1	6" Long 14 Conductor Ribbon Cable w/14 Pin DIP Headers
1	Cardboard Shim
1	9301 Printed Circuit Board

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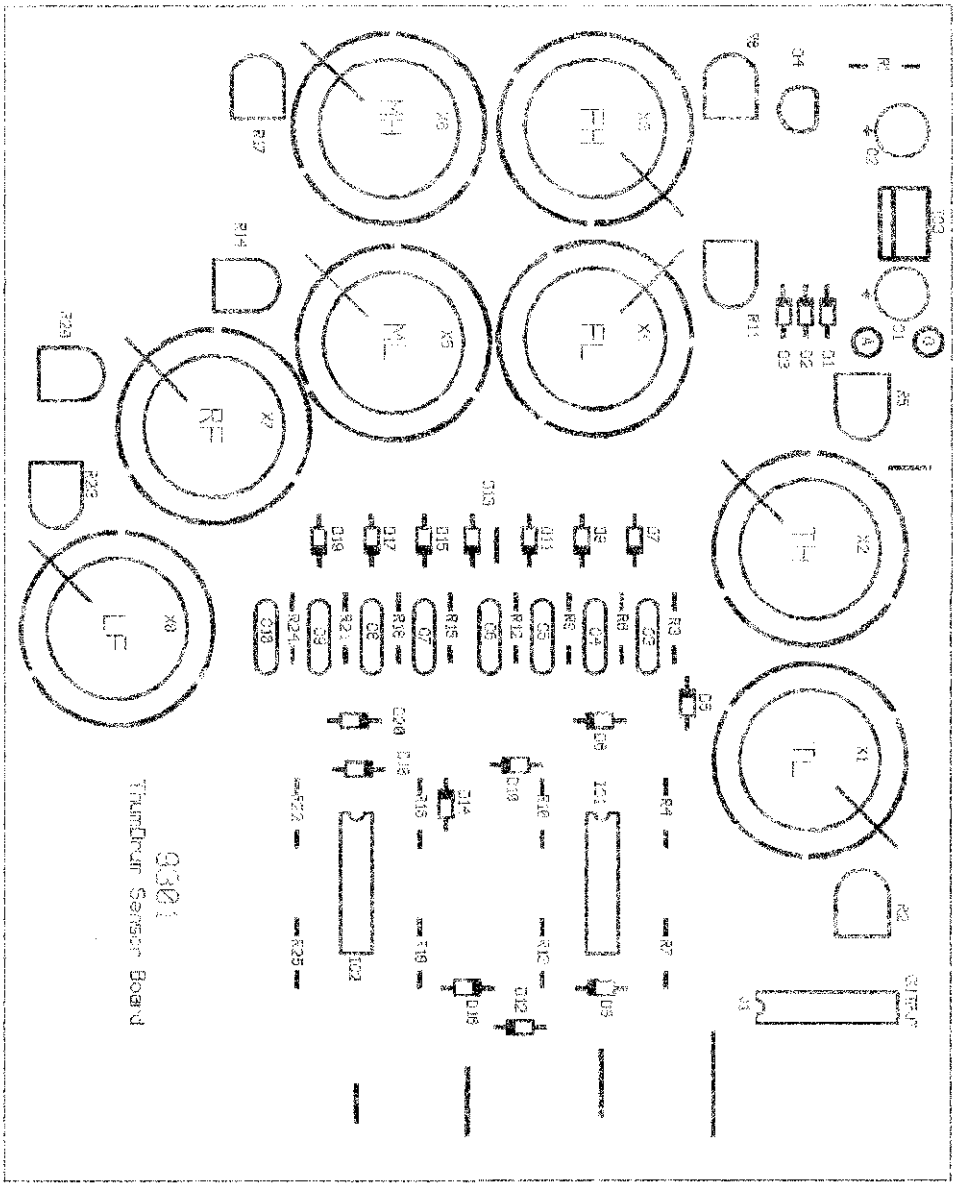

Fig 1a. Most of the components mount on the legended side of the circuit board in the locations shown in this Parts Placement drawing. Piezo Disks, Trim Pots and the LED mount on the conductor side.

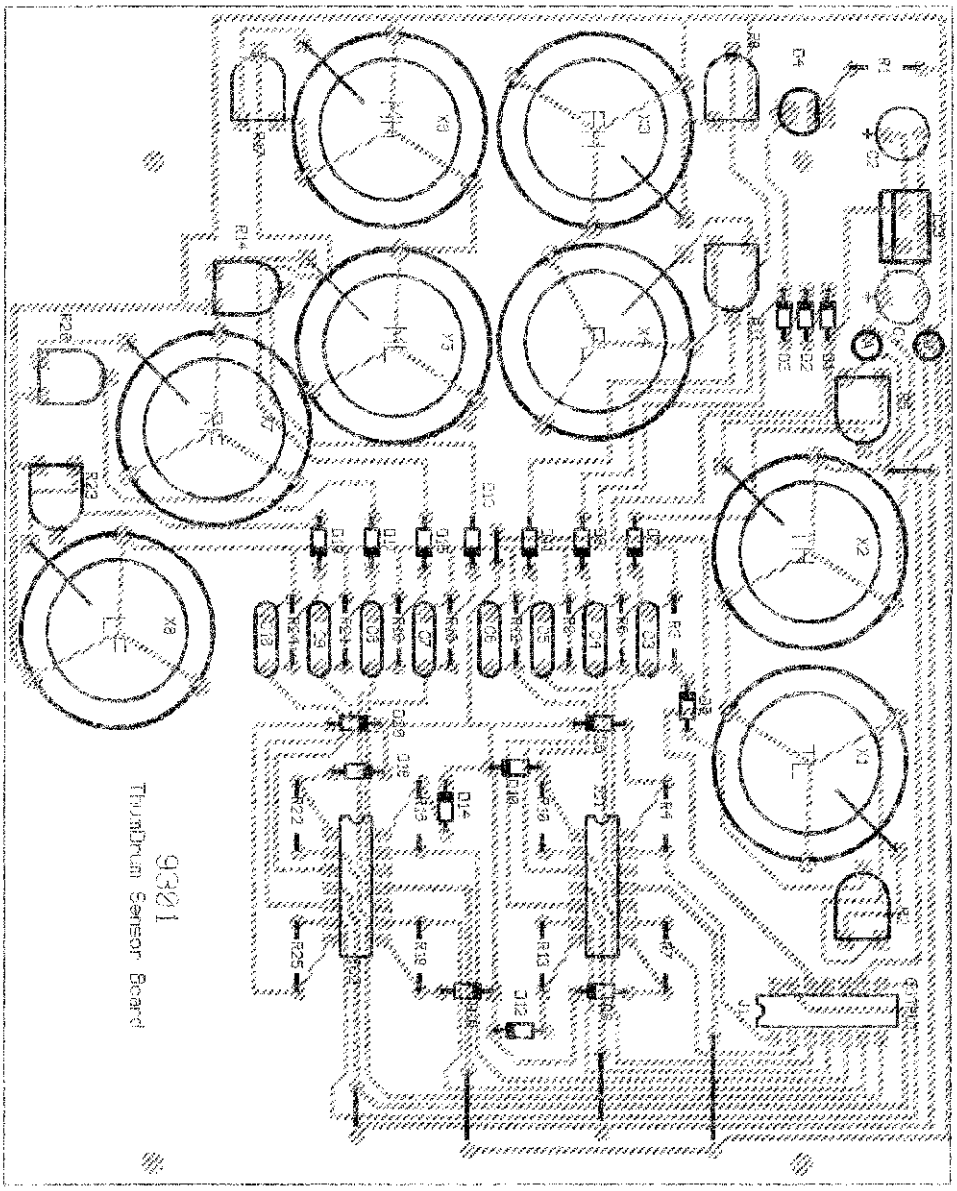

Fig 1b. This phantom view of the circuit board conductors will be useful if you have to trace out the circuit.