# Versatile electronic stethoscope

**Design: Ray Marston**
**Development: Simon Campbell**

This unusual device can be a very handy tool for those who work with mechanical contrivances — anything from tractor engines to drill presses to watch mechanisms. Thrill to the clatter of clagged-out tappets, the grind of graunched bearings, the tick-tock of escapements . . .

"DOCTORS DO IT with stethoscopes ..." said the bumper sticker on the expensive imported car parked in the street near our offices. With this project, you can do it too! The purpose of a stethoscope is to enable you to hear what's happening inside an operating mechanism when it's difficult or impossible to see what's happening — in fact, listening may be better than seeing in some instances.

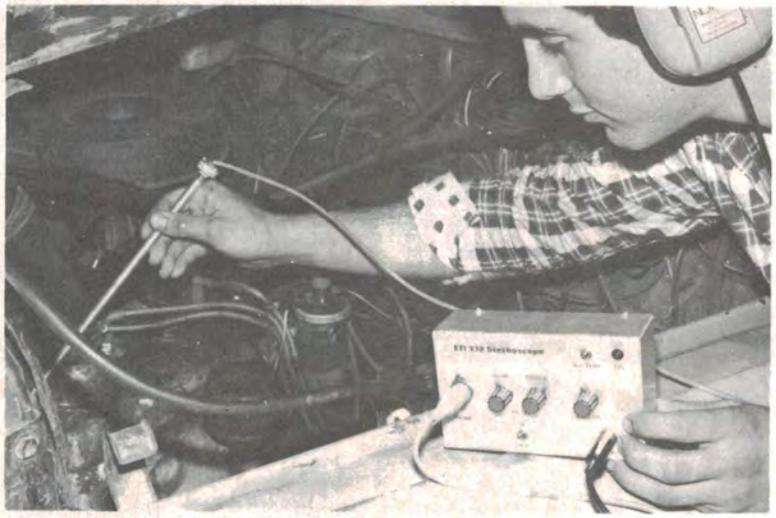
With this electronic stethoscope, you can effectively and effortlessly get right inside a car engine, for example, and listen to or locate all its internally generated sounds — the noise of bearings, pistons, tappets, etc. The various sounds produced by different parts of moving machinery have different characteristics, so this stethoscope incorporates a double filter network that can be used to pick out one set of sounds and attenuate others, thus facilitating fault-finding.

The stethoscope comprises an acoustic probe unit using some sort of microphone (several combinations are possible), the electronic 'clever bits' and a pair of standard stereo headphones. The probe unit is arranged to make mechanical contact with the machinery or object being examined and is coupled to the electronics, which are housed in a separate box, via flexible leads. The mechanical coupling provides an acoustic path to the microphone in the probe, and can be by direct contact or via a metal rod or tube.

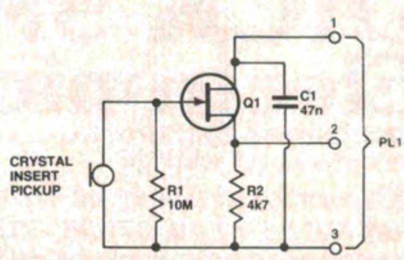
Sound is readily transmitted through the housing of any machinery, be it the engine block of a petrol motor, the case of a watch or clock, etc. This can be further transmitted through an object, such as a metal rod or a screwdriver, brought in contact with the machinery.

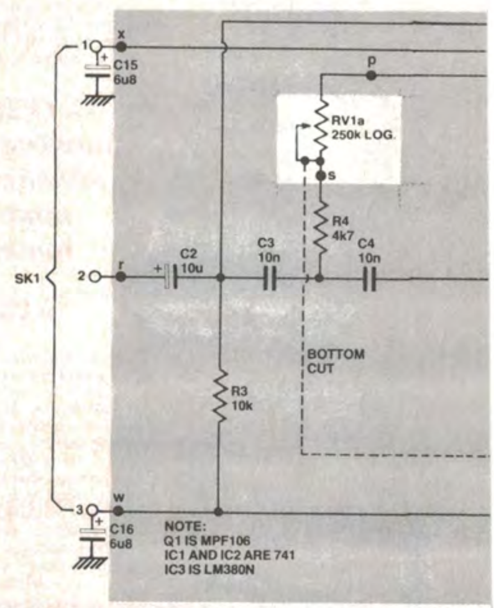
## The electronics

The circuitry used in this stethoscope comprises two filters, each of which has a variable cutoff, followed by a high gain IC power amplifier. The first filter is a *high-pass* type that attenuates frequencies *below* the cutoff frequency, which can be set anywhere between about 80 Hz and 3 kHz. The second filter is a *low-pass* type that attenuates frequencies *above* the cutoff frequency, which can be set anywhere between about 70 Hz and 15 kHz. The filters can thus be used to attenuate unwanted sounds, enabling you to pick out the desired sounds to a considerable extent in the right circumstances. The filter stages can be switched out if desired and the probe's microphone output coupled directly to the audio output stage. A common LM380 has been employed for the latter, principally for convenience, as it provides a considerable amount of gain and requires few components. A volume control potentiometer has been placed at the input to the LM380, since a level control is a very necessary item — as no doubt you will discover!



Using the stethoscope to listen to the tappets in a car engine.



The unit is powered from two internal 9 V batteries as portability is a necessary requirement. Headphones were employed rather than having a loudspeaker output, as they reduce ambient sounds which in some situations make listening to a speaker impossible as well as enabling you to concentrate on the sounds picked up by the stethoscope. Only low-cost headphones are necessary and any type having an impedance between 8 ohms and 500 ohms or so will do the job nicely.

The input impedance of the electronics is relatively low and a buffer is necessary when using high impedance microphones on the probe. The low input impedance also serves to reduce extraneous electrical noise pickup, to which high input impedance circuitry is prone. Crystal microphone inserts or earpieces are cheap, sensitive and effective for probe use, although we did try a rocking armature insert successfully, coupled directly to the high pass filter input. The buffer necessary with crystal microphones we mounted on the rear of the mics, as you can see from the photographs and drawings.

The stethoscope electronics are housed in a *metal* box — and for a very good reason. It provides shielding for the circuitry, preventing extraneous electrical noise pickup — which can be quite severe when using the project on a car engine. The ignition wiring radiates a considerable amount of noise energy and, while it's not possible to completely eliminate it, we have reduced the problem by using a metal box, low impedance input and bypassing at the input socket.

## Construction

It's probably best to commence with the mechanical work. We housed our unit in a K&W box, model C642, made by Ballarat Electronics Supplies and stocked by many retailers. It measures 150 mm wide by 95 mm deep by 55 mm high. Any metal box that will accommodate the pc board and major components may be used, however. Our Scotchcal front panel has been de-

### HOW IT WORKS — ETI 332

**Mechanical noises are coupled to a microphone or mic insert by a convenient means in a probe, the mic converting the mechanical noise to electrical signals. The resultant signal is passed to a filter/amplifier unit and converted to sound by headphones. Two active filters are employed. The first is a high-pass type employing a second-order RC network. This circuit has the advantage that the response rolls off below the cutoff frequency at a rate of 40 dB per decade. Thus, signals at one-tenth the cutoff frequency are attenuated by 40 dB. The R and C values may be designed to provide the cutoff at the desired frequency. The filter response is 3 dB down at the cutoff frequency. In our circuit, the resistors have been replaced by a combination of fixed and variable resistors to provide a variable cutoff frequency. The high-pass filter consists of IC1 and RV1, C3, C4, R4, R5. The filter has been designed to provide a cutoff that can be varied between a minimum frequency of 80 Hz up to a maximum of 3 kHz. Thus, with RV1 set to provide a cutoff of 1 kHz, signals at 100 Hz will be attenuated by about 40 dB.**

**The second filter, following the high-pass filter, is a low-pass type, again using a second-order RC network to provide a roll-off of 40 dB per decade, above the cutoff frequency. Again, the filter response is 3 dB down at the cutoff frequency. In our circuit, the resistors have been replaced with a combination of fixed and variable resistors to provide a cutoff frequency which can be varied at will. The low-pass filter consists of IC2 and RV2, C6, C7, R6, R7. The cutoff may be varied between about 700 Hz minimum and 15 kHz maximum. When RV2 is set to provide a cutoff at about 1 kHz, for example, signals at 10 kHz will be attenuated by about 40 dB.**

**The filter stages provide no gain. The op-amps employed require a split supply and the 'virtual zero volt rail' is provided by ZD1, which is biased via the buffer amplifier involving Q1. Capacitor C8 provides an ac bypass for the virtual zero volt rail.**

**The output from IC2 is coupled to the audio output stage via SW1, which permits the filter stages to be switched out of circuit.**

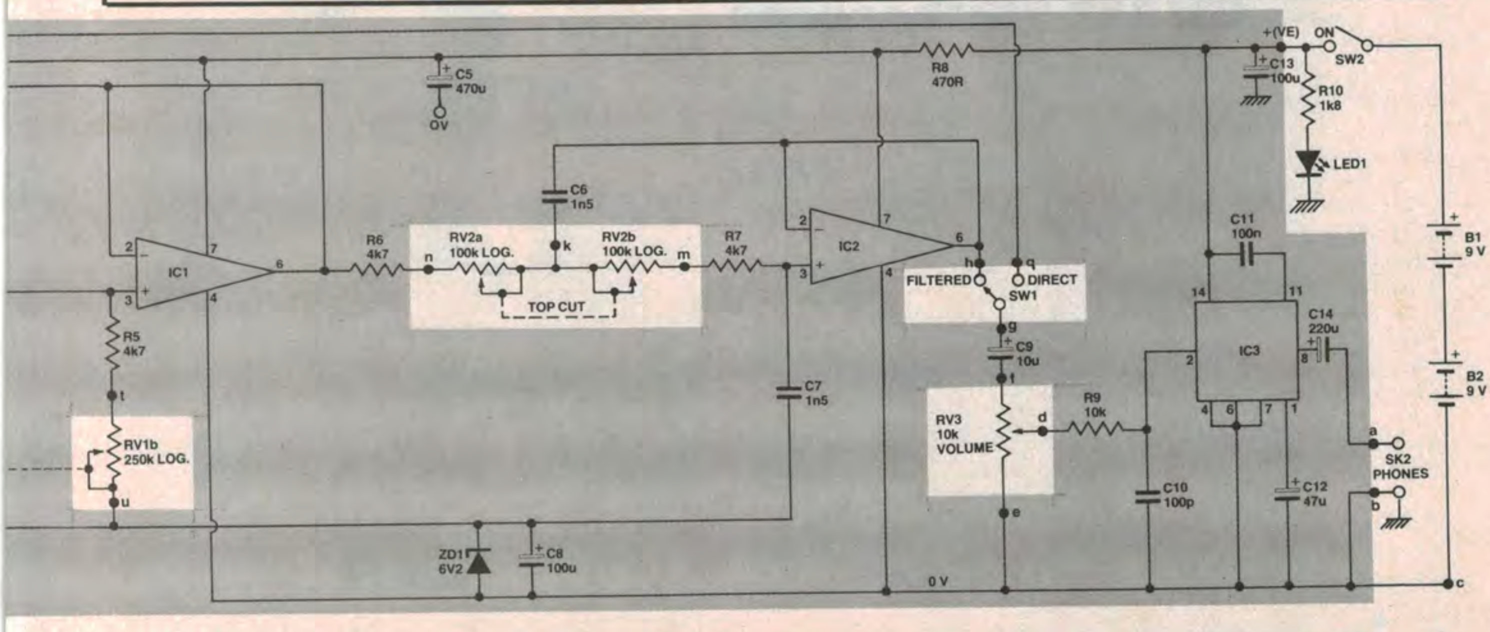
**As stated earlier, high impedance crystal type mics require a high-to-low impedance buffer. This is the function of Q1 and associated components, R1, R2, C1. This is a simple source follower circuit, Q1 being a JFET device. Capacitor C1 provides a supply rail bypass.**

**Signals are passed either direct to the output stage or through the filters via SW1. Capacitor C9 provides dc blocking and couples signals to the volume control, RV3. The audio output stage employs an LM380 high gain preamp/power amp IC. Signals from the volume control are coupled to the input via R9/C10, which is a low-pass network with a cutoff around 150 kHz. This provides a measure of high frequency stability for the IC as well as reducing RF pickup that can upset the operation of the unit. Audio output is coupled via C14 to the headphones. Capacitors C11 and C12 are bypasses.**

**Power supply for the electronics is provided by two 9 V batteries connected in series. Supply rail bypassing is provided by C13 and R8/C5. LED1 and its associated current limiting resistor, R10, provide an 'on' indicator.**

**Capacitors C15 and C16 bypass any extraneous electrical noise induced onto the input cable. These are mounted directly at the input socket.**

**If a rocking armature insert is used for the probe, a 4k7 resistor should be connected between pins 1 and 3 of the input DIN plug to provide bias for the virtual zero volt line provided by ZD1.**




Completed stethoscope, ready for action! The probe here was made from a crystal earpiece, a length of 10 mm tubing being pushed over the ear plug.

signed to suit the K&W box. The artwork for this has been reproduced below, full size, and can be used as a template to mark out hole centres for drilling. The pots, switches, etc, all mount on the box lid. Use a centre-punch to locate hole centres before drilling as this stops the drill wandering. Once you've completed this, clean off any burrs with a small rat-tail file and see that the pots, switches, etc, fit properly. If all's well, carefully cut the Scotchcal panel to size (if you're using it) and apply it to the box lid. Then cut the holes on the Scotchcal panel where you drilled the lid.

Next, mount all the pots, switches and sockets, etc. Solder the input bypassing capacitors, C15 and C16, to the DIN socket as shown in the wiring diagram. Note that the value of these two capacitors is not critical and may be anything between 1u and 10u. Solder R10 in place.

You can tackle the pc board next. This is fairly straightforward. We recommend you use our pc board, as the LM380 is prone to instability unless its surrounding circuitry is mounted in a particular fashion. Our pc board will avoid any instability problems with this stage. The ICs may be mounted first, noting they are all oriented the one way, followed by the resistors, greencaps, the ceramic capacitor (C11) and the zener diode (watch its polarity), leaving the electrolytics until last. All the electrolytics are single-ended, pc mounting types, you'll notice. Take care you mount these the right way round.

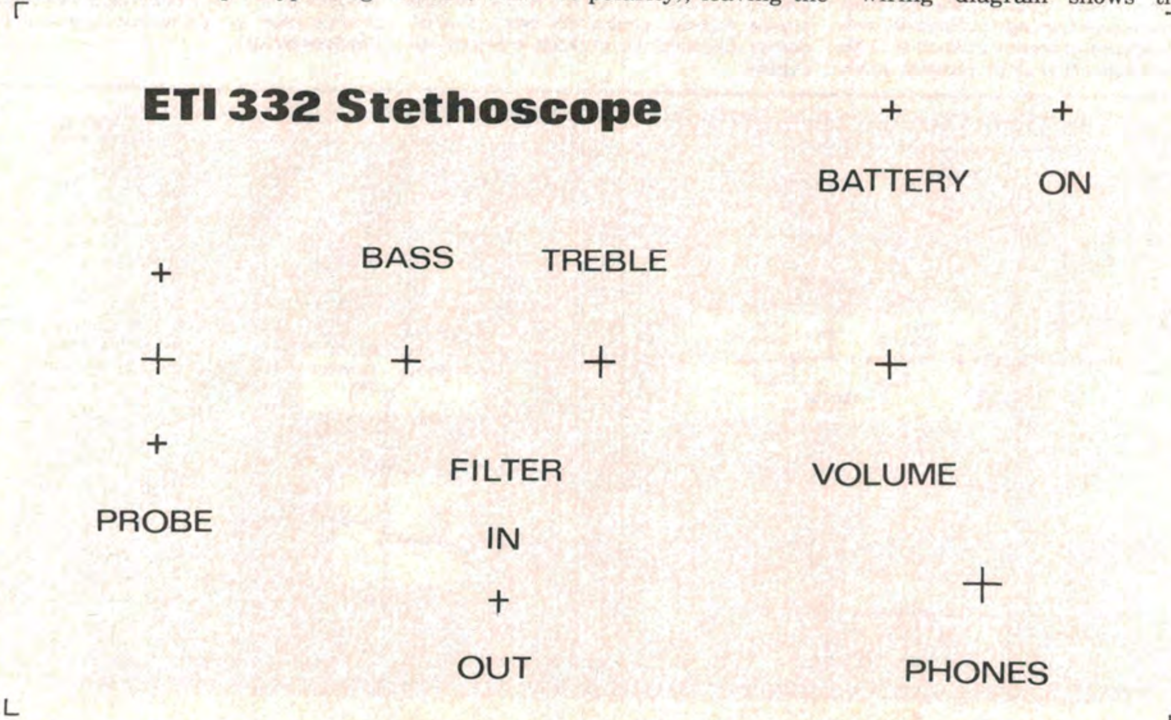
Having completed the loading of the board, check everything *carefully*.

The wiring between the pc board and external components may be tackled next. Follow the wiring diagrams for this stage of the construction, checking each set of wires as you proceed.

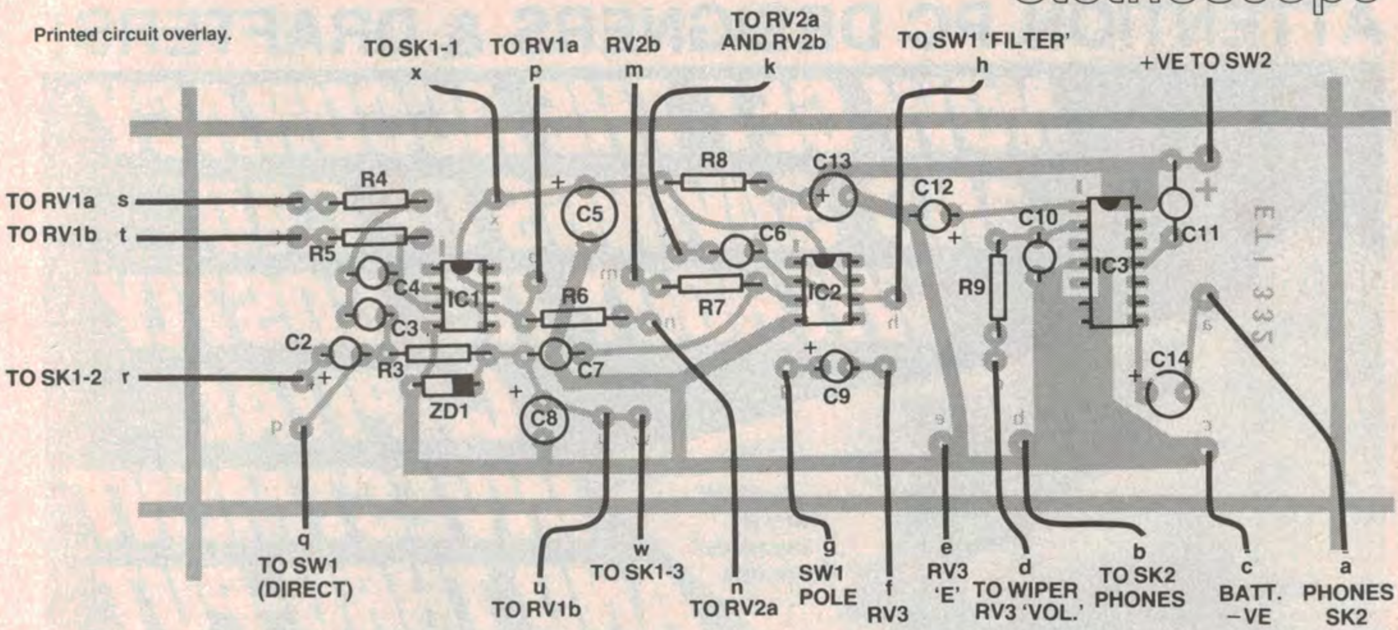
You can make a preliminary check of the electronics once you've completed this stage. Check your wiring first, then connect the two batteries, turn the volume control to minimum, plug in your headphones and switch on. Some hiss should be evident; this is normal. With the filter switched in, turning the volume control fully up (do it slowly) should result in a slight increase in the noise level. Turn the volume control to minimum gain and switch the filter out. Touch your finger to pin 2 of the DIN socket and slowly advance the volume control. This should produce some audible noise and hum. The hum level will depend on the local hum field. If it is low, you may have to advance the volume control a fair way.

If all checks out well you can mount the pc board in the bottom part of the case, along with the batteries. We used double-sided sticky pads, as they're effective, convenient and save drilling!

Making the probe(s) comes next. Exactly how you go about this will depend on what you want to do. With crystal insert mics, the buffer is mounted on the rear of the mic terminals. The accompanying probe wiring diagram shows the general



Printed circuit overlay.




technique. The buffer electronics is protected by encapsulating it in quick-setting epoxy. The mechanical coupling arrangement will depend very much on the particular mic insert employed and the application you have in mind. We made up several probes to suit different applications. If the mic has a metal case connect it to the probe cable's shield.

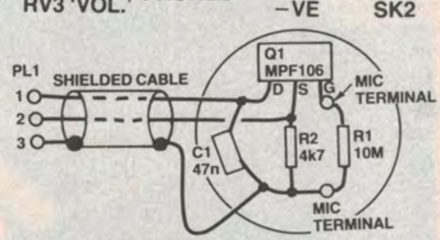
When you've finished your probe you can test it by simply coupling it to the speaker of a small portable transistor radio. Check that the filter controls function by varying them across the full range.

## Using it

The best way to get to know how to use the instrument is to practise on a few things. Clocks are wonderful for this! The old-style mechanical wristwatch also provides an excellent signal source. You can hear your heartbeat by using a microphone insert without a mechanical probe, and we even discovered that the main bearing in our workshop drill press was 'cactus' when trying out the stethoscope!

When working on a vehicle engine, watch out for fan blades. We found we could effectively sort out various engine sounds by judicious adjustment of the filter controls and careful placement of the probe.

Happy listening!




General construction for the buffer, mounted on the rear of a mic insert.

## PARTS LIST — ETI 332

**Resistors** all ½W, 5%

| | |
|---|---|
| R1 | 10M |
| R2, 4, 5, 6, 7 | 4k7 |
| R3, R9 | 10k |
| R8 | 470R |
| R10 | 1k8 |
| RV1 | 250k/C dual log. |
| RV2 | 100k/C dual log. |
| RV3 | 10k/C log. |

**Capacitors** (all electros single-ended)

| | |
|---|---|
| C1 | 47n polycarbonate |
| C2, C9 | 10u/25 V electro. |
| C3, C4 | 10n greencap |
| C5 | 470u/25 V electro. |
| C6, C7 | 1n5 greencap |
| C8, C13 | 100u/25 V electro. |
| C10 | 100p ceramic |
| C11 | 100n greencap |
| C12 | 47u/25 V electro |
| C14 | 220u/25 V electro. |
| C15, C16 | 6u8/25 V tantalum. |

**Semiconductors**

| | |
|---|---|
| IC1, IC2 | 741 |
| IC3 | LM380 |
| Q1 | MPF106 or similar |
| LED1 | TIL220R red LED, or sim. |

**Miscellaneous**

| | |
|---|---|
| SW1 | SPDT toggle switch |
| SW2 | SPST toggle switch |
| PL1 | 3-pin DIN plug |
| SK1 | 3-pin DIN socket |
| SK2 | 6.5 mm stereo headphone socket (or to suit plug-on headphones) |
| B1, B2 | No. 216 9 V batteries and clips to suit |

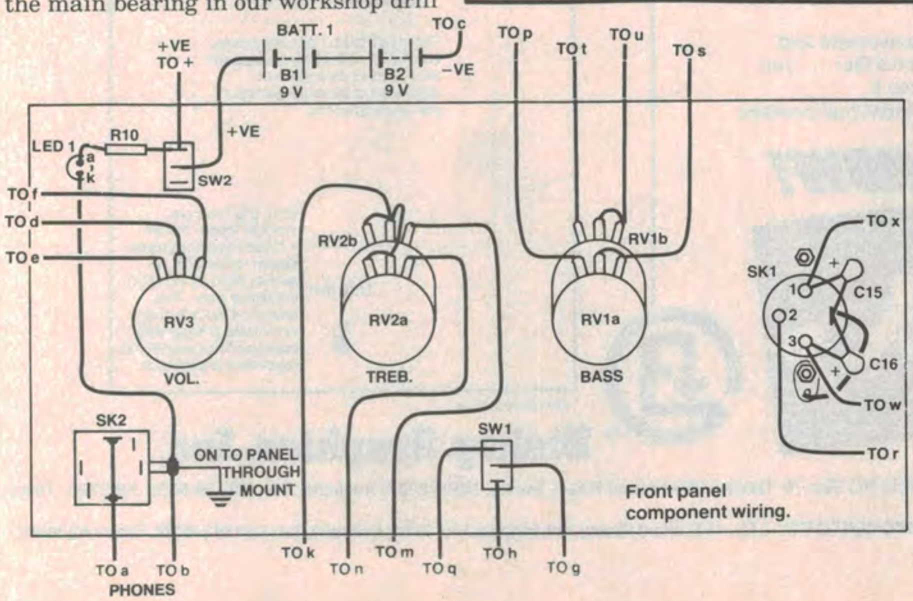
ETI-332 pc board; case — 150 x 95 x 55 mm or similar (we used a K&W model C642); three small collet knobs or similar; Scotchcal front panel; one crystal earpiece or crystal mic insert; rod or tube for probes; two-core shielded cable; one pair of 8 ohm headphones (higher impedance types will also be OK); wire, nuts, bolts, etc.

### Price estimate

We estimate the cost of purchasing all the components for this project will be in the range:

**$35 - $40**

Note that this is an **estimate** only and **not** a recommended price. A variety of factors may affect the price of a project, such as — quality of components purchased, type of pc board (fibreglass or phenolic base), type of front panel supplied (if used), etc — whether bought as separate components or made up as a kit.




Front panel component wiring.