'Front End' for your PC's soundcard

Here's a low cost preamp/buffer unit that will help you take full advantage of your soundcard's input capabilities for making measurements. It has a high input impedance and can handle a very wide range of signal levels, which makes it an ideal hardware accompaniment to much of the soundcard-based audio measurement software that's available via the Internet.

by Rob Evans

While it's a fairly safe bet that most PCs are fitted with a soundcard these days, those of us who aren't heavily into PC games probably use very little of its capabilities. If it's not producing blood-curdling screams during a Quake deathmatch, then it's most likely resigned to a mundane life of generating clangs, beeps and chimes in response to Windows' resource-gobbling activities...

There is however a surprisingly wide range of audio analysis and monitoring software available, that makes very good use of your soundcard and can be extremely useful itself in the process. Mostly using the card's input capabilities, these programs include oscilloscopes, spectrum analysers, FFT (Fast Fourier Transform) processors, circuit response plotters and loudspeaker analyser suites. Not surprisingly there's also quite elaborate audio signal generators on offer, which use the soundcard's signal *output* feature.

The good news about this abundance of interesting software is that a large proportion of it is available through the Internet, either as freeware (pay nothing), shareware (pay a little, depending on your moral stance) or in a restricted demonstration form of the real thing. Even this latter type can be quite useful in itself, as it often performs most of the functions of the fully paid-up version — and the latter in turn is probably well-priced anyway.

As intriguing as this software bonanza may sound though, the programs that make use of the soundcard's line-in socket (almost *all* of them) tend to be thwarted by the restricted nature of the card's input circuitry. More specifically, a soundcard's input has a quite limited dynamic range, a relatively low input impedance and a fairly crude overload protection setup.

In practice then, the program running on the PC can only monitor low-impedance, moderate-level signals, which really does limit the usefulness of the software. When running an oscilloscope program on your PC, for example, you can't check say the waveform around an op-amp because the soundcard's input will badly load the signal, and you dare not check the output of a hifi amp due to the large (and potentially destructive) size of the signal at that point.

This is of course where our new soundcard preamp box comes in. It offers switchable input level ranges of +20dB to -40dB in four 20dB steps, and importantly, presents a one megohm input impedance in much the same way as a conventional oscilloscope front end. It can also handle quite severe overload voltages, has a low output impedance, and is equipped with a limit indicator to alert the user when the soundcard's A/D converter has run out of range.

The preamp's circuitry is powered from the +5V outlet on the soundcard's DB15 joystick port connector, and feeds its output signal directly into the card's 3.5mm line-in socket, so it's very easy to hook up to the computer. In fact unlike most specialised PC add-on modules that use the parallel or series port as an interface, the preamp unit it won't interfere with the PC's more common operations, and can therefore be left permanently connected.

The software

While we really can't provide the details of all the soundcard-based programs here, we've plucked out a couple of interesting oscilloscope programs to give you a taste of what's available. As you can see from the screen shots, they present a pseudo-scope screen plus a range of user controls that attempt to emulate those on a conventional scope. Both offer dual-trace facilities by using the soundcard's left and right channels, display the incoming waveform in real-time, and operate under Windows V3.1 or Windows 95.

The screen shot shown in Fig.1 is of a quite elaborate scope program from an author in Moscow, which offers delayed trigger, FFT analysis, meter options, and a signal-triggered hold facility for capturing one-off events. Versions are available for both Win3.1 (V2.30) and Win95 (V2.51); however at this stage, both variations only use the soundcard in its *8-bit* mode — which rather restricts the scope's vertical resolution.

A quite different style of scope program is shown in Fig.2, this time from an author in Germany. As you can see, *Audiotester's* menu labels aren't in English, but this turned out to the only real negative point against this very comprehensive program. It uses the soundcard in its 16-bit mode (or higher, if available), offers a programmable sine/squarewave generator and a Spectrum Analyser along with the Oscilloscope, and has a fully scalable display screen — it can be 'dragged out' to cover all of the PC's screen, regardless of its resolution setting.

Audiotester is available to suit both Windows 3.1 and 95, and would be ideal for educational purposes thanks to its large-screen capabilities. And by the way, in response to our email query regarding an English version of the help file, the author replied that the latest update of the Win95 (32-bit) version can be configured to display menu items and controls buttons in English.

All in all, both of the example programs shown here are useful as audio-bandwidth digital oscilloscopes, or at the very least they offer an educational insight into the pros and cons of DSO's. It's quite easy to see how aliasing, plus restrictions in vertical resolution and bandwidth effect digital scopes, and you can also appreciate the advantages of a crisp display that can be 'frozen' at will. Education aside though, it's surprising how effective they can be when combined with our Soundcard Preamp...

To get hold of your own copy of these programs, there are several options. They can be downloaded from the *Electronics Australia* BBS and Internet Website, or sourced from their original (Internet) locations.

From our facilities, the files can be found in the 'EA Project Software' area as

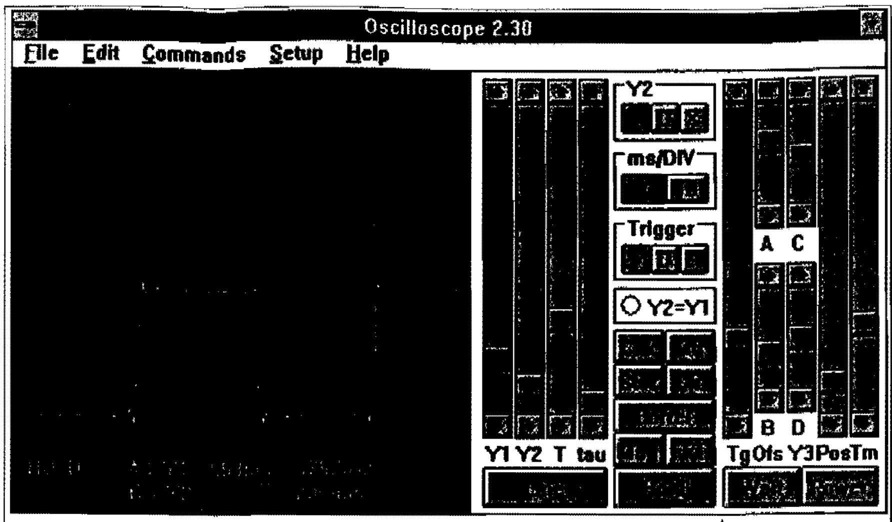


Fig.1 (above): A screen shot from the 16-bit version of Oscilloscope for Windows, shown here in its dual-trace mode. The 'front panel' slider controls can be used for a wide range of adjustments, once you figure out their somewhat cryptic labeling.

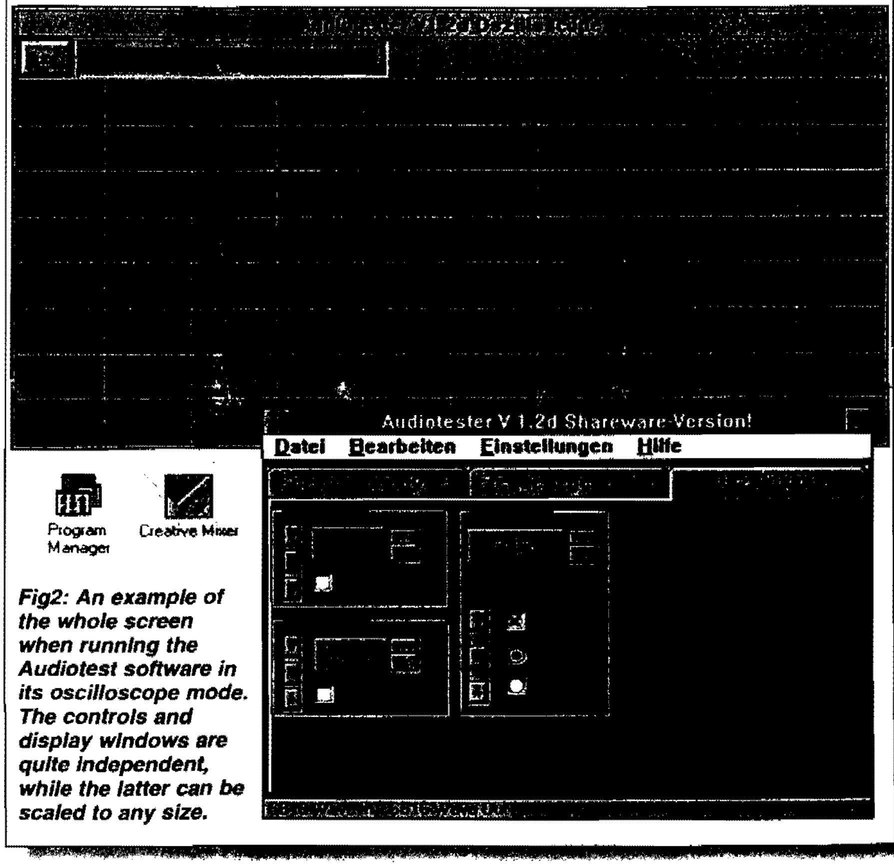


Fig2: An example of the whole screen when running the Audiotest software in its oscilloscope mode. The controls and display windows are quite independent, while the latter can be scaled to any size.

osc230.zip and **osc251.zip** for the 16 and 32-bit versions of the *Oscilloscope* program, while the *Audiotester* suite is available as **audiot16.zip** (16-bit) and **aud13d.zip** (32-bit). Note that you'll need the 32-bit version of both programs if you're running Win95.

To check out a wide range of other programs that use soundcards we'd recommend taking a look at **http://web.arca.net/top/** on the Internet. This 'soundcard program collection' site mostly offers links to other sites containing individual programs, and gives a handy synopsis of each. Note that not all links work though, and to be quite honest, a few of the programs are downright weird and not particularly useful...

Also note that while the *Oscilloscope* program shown here was located via this path, the impressive *Audiotester* package was not listed. We found that at **http://www.lautsprecher.de/**, perhaps proving that a wide and thorough Internet search is often worthwhile.

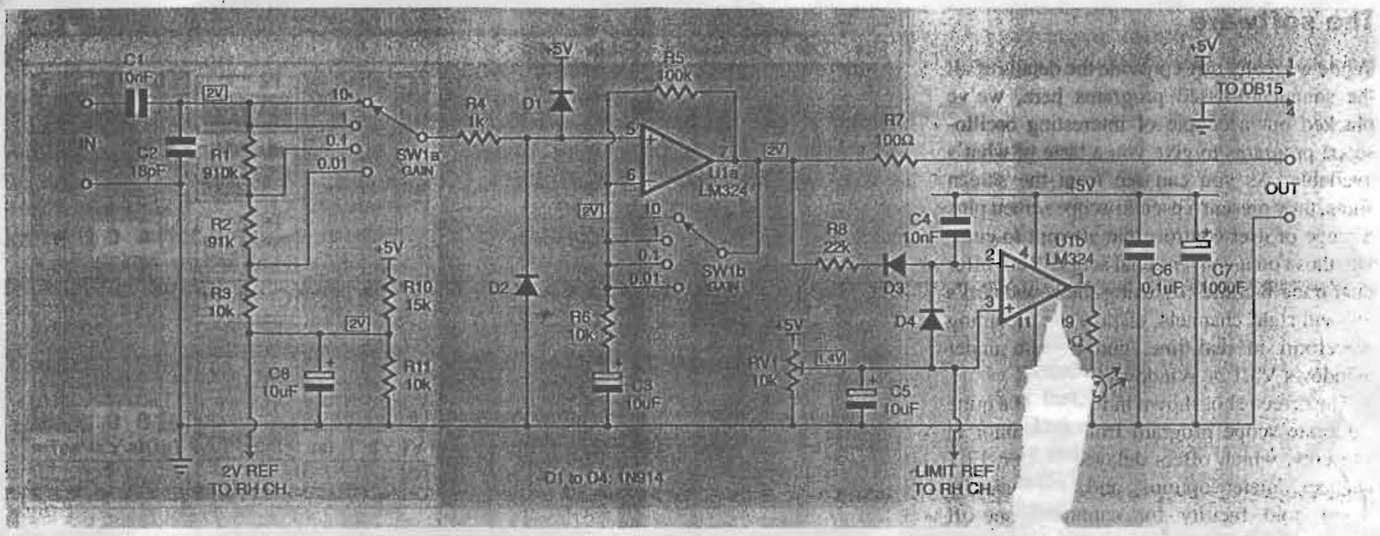


Fig.3: The preamp's circuit is based around attenuator R1 to R3 and gain stage U1a, which combir ... offer an overall gain range of +20dB to -40dB in SW1's four steps. U1b activates LED1 when the preamp's output level exceeds ... undcard's input range.

About the circuit

The soundcard preamp's schematic is shown in Fig.3, which includes the circuitry for the unit's left channel plus the voltage reference and bypass capacitors common to both channels — as you'd expect, the basic circuit for the right channel is identical to the left. The circuit is based on a simple three-level attenuator (R1 to R3) which feeds a non-inverting amplifier stage formed by U1a, where the attenuation and gain for these two stages is determined by the position of SW1 (GAIN).

Taking a closer look at the circuit, input signals are coupled to the attenuator stage at R1 via AC coupling capacitor C1, while the input is bypassed at high frequencies by C2. The three-step attenuator divides the input signal by one, 10 and 100 (0dB, -20dB and -40dB), and the level selected by SW1a is passed to the following preamp stage U1a (pin 5) via isolating resistor R4. This resistor also acts with protection diodes D1 and D2 to hold the incoming signal within the circuit's power supply range.

Since the circuit operates from a single-ended 5V supply — courtesy of the soundcard joystick port — the op-amp stages are biased at around half of the supply rail by the voltage divider formed by R10 and R11. Here, the 2V reference level is bypassed by C8 then applied to U1a's non-inverting input via the attenuator network (R1 to R3) and R4.

Note that a 2V standing level has been used rather than exactly half of the supply voltage (2.5V), since the LM324 op-amp outputs can swing from about 0 to 4V with a 5V supply. In short, the 2V bias level guarantees symmetrical output clipping.

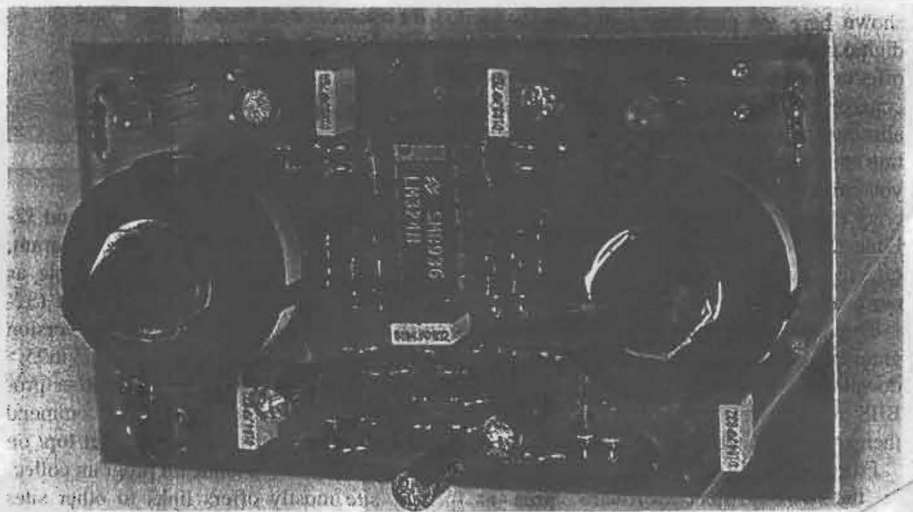
By the way, we've elected to use a low-cost LM324 quad op-amp here rather than a more sophisticated chip, since despite its fairly mundane noise and bandwidth performance it's quite adequate for the job. Plus of course, very few (readily available) op-amps can perform reliably with a supply rail of just 5V...

If you want to capitalise on the full resolution offered by programs that use the soundcard's A/D in its 16-bit mode though, you'll need to fit a higher-performance quad op-amp such at the TL074. This in turn means that the +5V supply from the joystick port will need to be replaced by a higher voltage DC level from a separate source, since the TL074 needs a supply of at least +/-4V (8V total). However, the performance of the LM324 is sufficient for most applications, plus of course, the proposed +5V connection scheme is very convenient.

Returning to the circuit, signals applied at U1a's non-inverting input are amplified by a factor of 10 or one depending upon the position of gain/level switch SW1b. In the position shown in the schematic, U1a is set to gain c... y feedback network resistors R5 ... R... AC coupling capacitor C3. The ...nai... itch positions (1, 0.1 and 0.01) s... the ... gain to one by shorting out feedback ...sistor R5.

With SW1a/b in the '10' position as shown then, there is 0dB attentuation at the input plus 20dB of gain contributed by U1a, therefore setting the overall preamp gain at that figure. This combination of input attenuation and U1a's gain gives the required 20dB, 0dB, -20dB and -40dB levels of preamp gain, while maintaining a constant input impedance of around one megohm (R1 + R2 + R3). All in all, this is a flexible enough arrangement for most applications, including a simple oscilloscope front end.

The now buffered and amplified (or attenuated) input signal is passed to the preamp's output via isolating resistor R7, and also feeds the limit indicator circuit (U1b) via R8. Here, the op-amp's non-inverting input (pin 3) is fixed at a reference level (say, 1V) by RV1, while the inverting input (pin 2) is nor-



The assembled preamp circuit board, ready to be installed in the case.

nally held at about 2.6V by U1a's nominal 2V output, plus the voltage drop across D3. (Note that the op-amp's PNP transistor input stage will *source* a small amount of current, holding D3 forward biased.)

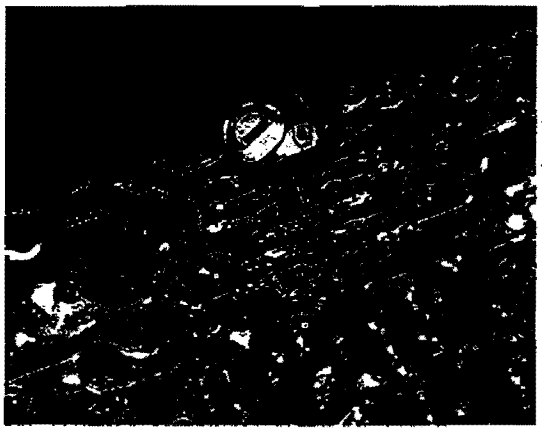
In its static (no input signal) state then, the levels at U1b's inputs will force the output (pin 1) low, which in turn holds LED1 off via its limiting resistor R9. U1b's output will then stay at a low level until U1a's output signal is greater than 3.2V peak-to-peak — that is, 1.6V peak.

At this point, the negative half-wave rectifier action of D3 will drive U1b's inverting input from 2.6V down to less than 1V, which in turn forces the op-amp's output high and thereby activates the limit indicator LED1. Note that C4 smoothes the rectified signal, while the current sourcing effect of the op-amp's inverting input (as mentioned above) acts as a pull-up resistor of a few megohms — effectively, the discharge resistor for C4.

Diode D4 has been included to limit the rectified signal at U1b's inverting input to around 0.6V below the reference voltage at RV1 — C5 ensures a low impedance AC path. Without D4 an increasing input signal strength (in this example, more than 3.2V p-p) will cause a greater charge on C4 and therefore a longer discharge time when the signal falls away. The practical effect of this is that LED1 would stay on for much longer in response to a larger overload signal, making the limit indicator difficult to read.

With the arrangement as shown however, the excess signal is dropped across R8 thanks to the limiting action of D4, so the circuit is only ever 'overdriven' by a small and consistent amount. As a result, the LED's activity will accurately track signals that exceed the preset limit level, as determined by the setting of RV1. This is set so that the LED reflects the limit of the soundcard's input voltage range, which will be less than that of the preamp itself — but more on this adjustment later.

The remaining parts of the schematic diagram show supply bypass capacitors C7 and C6, plus a couple of links to the matching locations in the right channel's circuit. These are from the 2V reference circuit (R10/R11, etc.) and the limit reference voltage at the wiper of RV1, so only one limit adjustment is need for both channels.



Note that both RV1 and the external wiring PCB pins are fitted to the copper side of the board.

Construction

The soundcard preamp is very easy to put together, with all of the components held on one small PCB (code 98sci7) measuring 52 x 92mm. The complete assembly is mounted into the box panel via the two rotary switch shafts, while flying leads are used to connect to the PC's joystick port (+5V power) and the soundcard line-in socket.

Begin the construction in the usual way by installing all of the lower profile components first (resistors and diodes), then moving on to the larger parts. As always, take particular care with the orientation of the semiconductors and electrolytic capacitors, and refer to the component overlay diagram at all times. We used PCB pins for the external connection points by the way, but since the PCB assembly is mounted directly onto the box panel the pins were fitted to the copper side of the board.

This may be the best mounting method for the trimpot as well, since it will need to be adjusted to suit the PC's soundcard when the preamp is up and running. On the other hand, if you drill an access hole through the board, the trimpot could be installed on the component side in the normal way.

Other than that, note that the LEDs and BNC sockets must be left until last, and the rotary switches should be fitted hard down on the board with the locating spigot positioned as shown on the overlay diagram — this will make the shaft flats line up with the knob grub screws. Also, make sure that the range positioning ring on each rotary switch is set for four positions, rather than the default six.

At this point it's probably a good idea to test the assembly before it's installed in the case, since this final process is a little messy to reverse should the unit need fault-finding.

To perform an initial check, first install and solder the LEDs at their full leg length, as their height above the board will need to be adjusted later. Then connect a +5V power source (from a bench supply or the soundcard) and check that the circuit's 2V bias point, and pins 7 and 8 of U1 settle at this level. Next select the 0.01 gain position on each channel and confirm that the state of the limit LEDs can be controlled by adjusting RV1 — this indicates that the limit detector circuit (U1b) is functional.

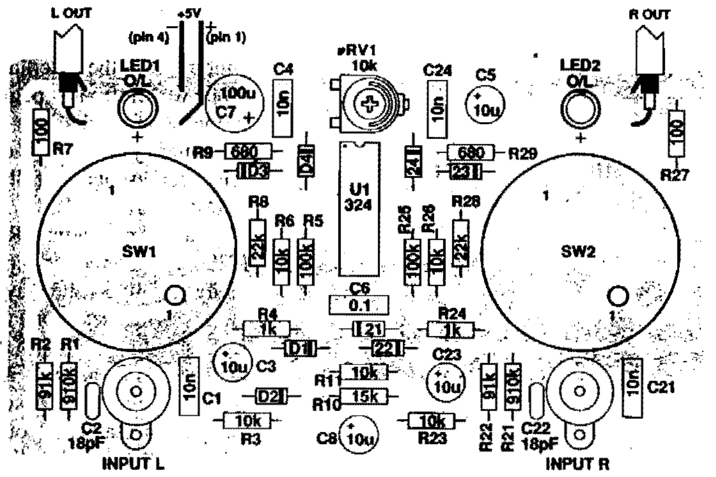
With RV1's adjustment temporarily set so that the limit LEDs are just off, now place your finger on the PCB input socket pad of each channel, while winding up the matching GAIN rotary switch. This is the proverbial 'blurt' test, and should cause the channel's limit LED to activate when the GAIN control is in the 1 or 0.1 position.

Once these tests have been completed you can be confident that the preamp circuit is functioning and ready to be installed in the box. Start this job by desoldering the LEDs so they are free to move in the pad holes, then fit the BNC sockets into the box panel with generous lengths of tinned copper wire soldered to their lugs — that's a total of four lengths.

By the way, if the BNC socket locking nuts are fairly large, check if they will foul the bodies of the rotary switches when the board assembly is installed. If this looks to be the case, installing a spacer washer on each rotary switch shaft should sort out the problem.

The completed board assembly can now be eased into the box front panel, with the copper wires from the BNC connector slid-

Follow this overlay diagram carefully when assembling the unit. Note that the +5V supply cable is terminated in a DB15 line plug with the pin connections shown, so that power can be extracted from the soundcard's joystick port.



ing through their matching pad holes — don't let the wires kink during this process. When the assembly is fully home, the rotary switch locknuts can be fitted and the LEDs pushed up into their matching front panel holes, then soldered in place.

Next, solder the BNC socket extension wires to the board. Then connect the power and output signal cables to their correct PCB pins, as shown in the overlay diagram. Take particular care with the polarity of the +5V power cable, since a mistake here will probably destroy U1 and C7, and could even damage the soundcard's 5V outlet circuitry. Note that we used pins one and four on the DB15 joystick port connector, where pin 1 is positive and pin 4 is the 0V/ground connection.

The signal-out lead to the soundcard is terminated in a stereo 3.5mm plug, and depending on the size of its cover will suit either figure-eight or twin-core shielded cable. At the preamp board end, the figure-eight type can be split into individual leads then connected to the PCB as shown in the overlay diagram. The twin cored cable type will need to be connected at the PCB pins for one channel, then the remaining wire core run across to the output pin on other side of the board.

Limit LED setup

As mentioned above, the limit indicator circuit's threshold will need to be adjusted to suit the soundcard you'll be using, via trimpot RV1. This is set so the limit LED will come on *just* as the soundcard's A/D converter has run out of range, so you'll really need a test signal source to complete the job.

If you don't have access to an audio oscillator though, you can just adjust RV1 so that the voltage on its wiper reads close to 1.4V, as this setting seems to suit the A/D input range in the industry-standard Soundblaster cards. This in turn equates to a (roughly) 0.8V RMS signal at the sound card input socket, with the software-controlled A/D gain set at full — that is, its 'line-in' level setting fully up.

This is in fact the best way to arrange the soundcard when using our preamp unit, since with the line-in level set to maximum, the card's A/D will run out of range before any of the preceding analog stages clip — including the input circuitry in the soundcard itself. It also means that you have a gain structure that's easy to go back to each time you use the preamp unit, plus you'll always be sure that the limit LEDs are telling the true story.

Another point worth mentioning about the soundcard setup is that if the card's mixer/controller software has tone control adjustment capabilities, these should be either bypassed or set for a flat frequency response. The mixer's main (output) volume control can be used to some advantage though, since this will control the signal level sent to the soundcard speakers, allowing you to also *hear* the signal you're monitoring with an oscilloscope program...

Getting back to the preamp's setup, the limit LED circuit can be calibrated from a (preferably 1kHz sinewave) test oscillator by using a scope program on the PC to monitor the preamp's output waveform, then slowly winding up the oscillator level until the scope waveform just begins to flatten on top. If the soundcard's line-in control is set at full, then you can be quite sure that this effect represents the full range of the card's A/D converter.

You can now adjust RV1 so that the limit LEDs have only just come on, and you're ready to roll. By the way, with the preamp's GAIN switch set to one (1), the scope waveform should start to clip as the oscillator output reaches about 0.8V RMS (when using a typical soundcard). Also note that the preamp has a maximum output of about 1.4V RMS, so the soundcard's input signal is still 'clean' as the A/D runs out of range. ❖

PARTS LIST

Resistors

R1,21	910k
R2,22	91k
R3,6,11, 23,26	10k
R4,24	1k
R5,25	100k
R7,27	100 ohms
R8,28	22k
R9,29	680 ohms
R10	15k
RV1	10k horiz. trimpot

Capacitors

C1,4,21,24	10nF MKT
C2,22	18pF ceramic
C3,5,8,23	10uF 16V electrolytic
C6	0.1uF MKT
C7	100uF 16V electrolytic

Semiconductors

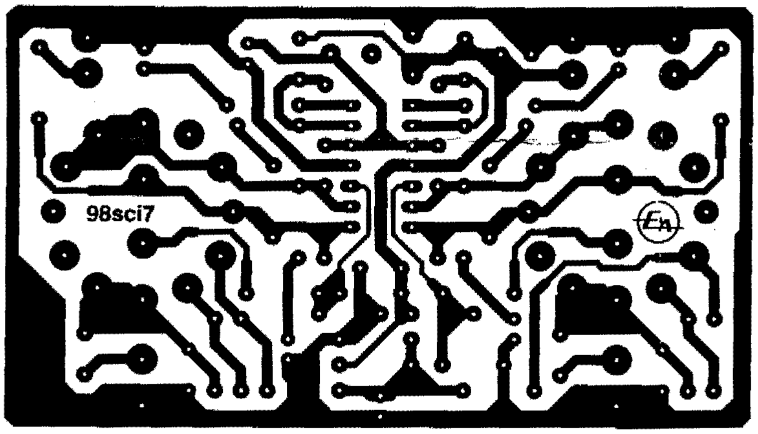
U1	LM324 quad op-amp
LED1,2	3mm LEDs
D1-4,21-24	1N914 signal diodes

Switches

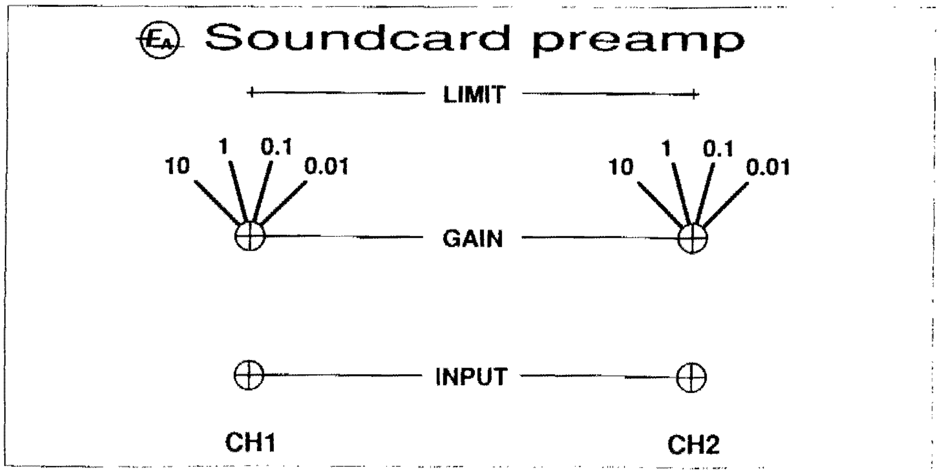
SW1,2	2-pole PC-mount rotary switches

Miscellaneous

2 x panel-mount BNC sockets, 3.5mm stereo line plug, DB15 line plug with backshell, knobs for rotary switches, 41 x 68 x 130mm zippy/jiffy box, 52 x 92mm PCB (code 98sci7), twin-core or figure-eight shielded cable, light-duty twin cable.



The full-sized circuit board pattern shown on the left can be used to make your own PCB, while the front panel artwork below will suit a standard zippy/jiffy box.



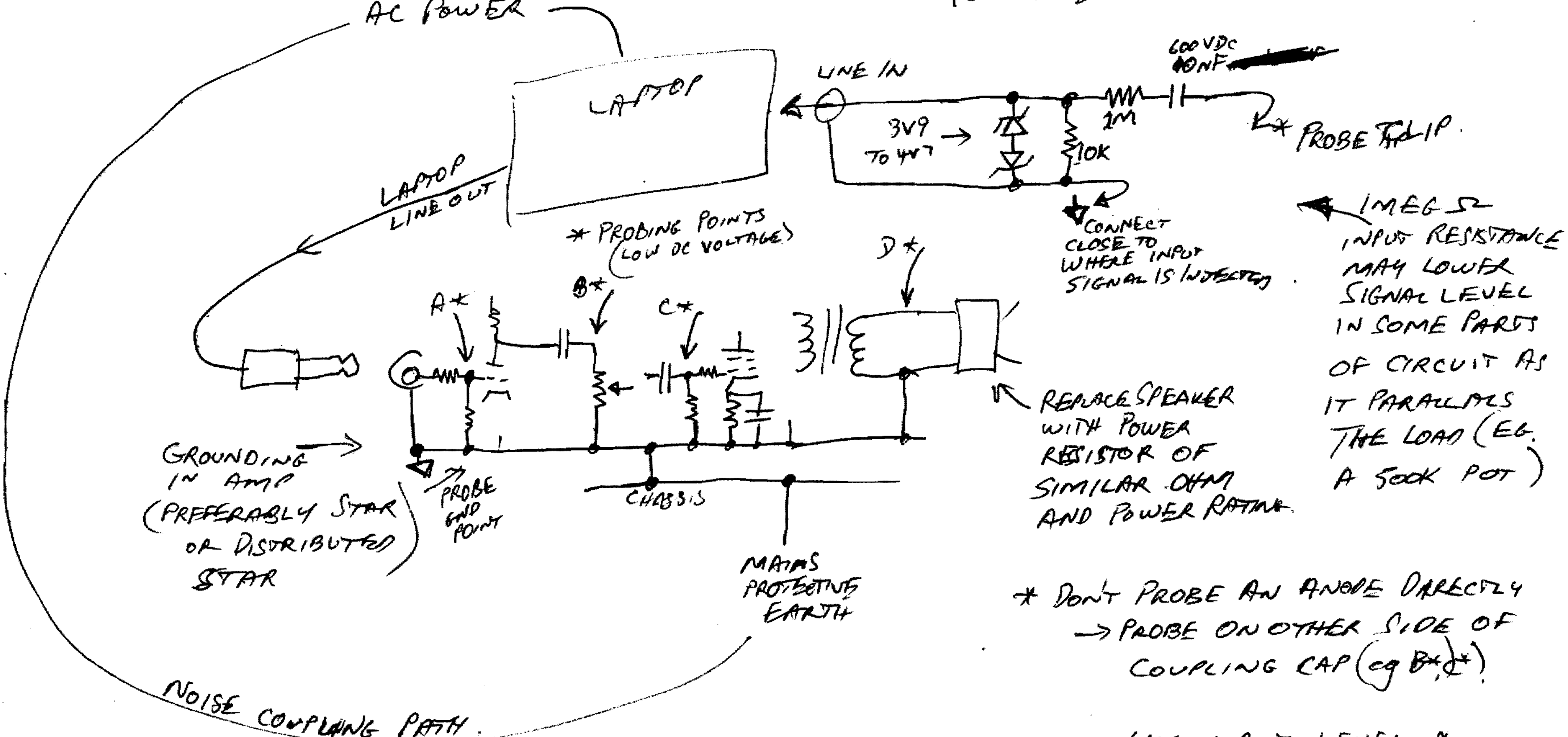
Soundcard preamp – Altronics K2875

Electronics Australia, August 1998, “Front End for your PC’s soundcard”, construction project.

1Meg input impedance. 10nF 1kV capacitor coupled input. 3.2Vp-p linear limit for 1x and 10x input. 32Vp-p linear limit for 0.1x input. 320Vp-p linear limit for 0.01x input. 1k series limit to protection diodes clamping to rails for 6Vp-p hard clipping. Always move attenuator to 0.01 setting when connecting to a circuit, or changing circuit conditions – to limit charging currents through the opamp. Although input level could withstand above 500VDC, that would be unwise due to cable insulation, and preference is to keep under 300V, which should be ok for many plate signals, although 1Meg loading will influence signal level. Always use additional earthing strap to chassis.

Output to soundcard is driven by LM324, with no limiting apart from series 100R, and 0V rail to nearly 5V rail swing.

100:1 DIVIDER PROBE.



* DON'T PROBE AN ANODE DIRECTLY
  → PROBE ON OTHER SIDE OF COUPLING CAP (eg B*, C*).

* LAPTOP MAY BE NOISY
* CHECK IF RUNNING ON BATTERIES CHANGES NOISE FLOOR
* ~~CHECK~~ USE DIRECT CONNECTION OF 1/4" JACK TO PROBE TO SET UP LAPTOP AUDIO ~~[illegible]~~ LEVELS & SCALES. AND CHECK FOR APPROXIMATE FLAT RESPONSE. AND ALSO TO SEE ~~AT~~ WHEN CLIPPING STARTS AN ~~[illegible]~~LAPTOP LINE OUT AMP.

* INCREASE INPUT LEVEL & CHECK WHEN DISTORTION THROUGH EACH STAGE INCREASES.
  → MAY NEED TO TURN POTS DOWN SO OVERLOAD INPUT DOES NOT OVERLOAD OUTPUT.

* ALWAYS HAVE A RESISTOR LOAD ON SPEAKER OUTPUT