Signal Injector/ Tracer

An easy to build, inexpensive invaluable item of test gear.

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Most electronic testing takes the form of initial checks to narrow down the area of the fault to one particular stage, followed by more detailed checks to determine exactly which component is faulty. A signal injector is a very useful device that is primarily used for the narrowing-down process, but which can sometimes be used for more precise checks. Basically all it does is to generate an audio frequency signal that can be coupled into various stages of audio frequency equipment.

Most signal injectors, including the present design, produce strong harmonics (multiples) of the fundamental audio frequency. These extend well into the radio frequency spectrum, and enable the unit to be used for checks on some kinds of radio receiver (including long and medium wave broadcast sets).

Fault-Finding Basics

A signal injector is used to test a piece of equipment that has a series of amplifiers or other signal processing stages (tone controls, etc.). The general idea is to inject the signal at the output first, and then gradually work forwards towards the input, injecting the signal at strategic points.

Each test should produce an output from the loudspeaker, headphones, or whatever is being used to monitor the output signal. However, if there is a fault in the unit, at some point the signal will be injected and no signal (or perhaps an inadequate signal) will be forthcoming from the loudspeaker. The fault then lies somewhere in the region of this last test and the previous one.

In fact you can work the other way around, starting at the input and working towards the output of the unit under test. It is then a matter of injecting the signal at various points until a proper signal is obtained from the loudspeaker. Again, the fault will lie somewhere in the region of the last and second-last test points.

There is a body of opinion in favour of making the initial test point somewhere in the middle of the signal chain, with subsequent checks being ahead of or after this point, depending on the result of this initial check. Whichever of these three methods you adopt, or if you adopt a random approach to selecting the test points, the basic idea is still to find successful and unsuccessful test points close together in the signal chain.

Example

A circuit of the type that can be checked using a signal injector is shown in Fig. 1. This is a common emitter amplifier based on TR1 and a two stage highpass filter having IC1 as the buffer amplifier. Feeding even a weak signal to the input should produce a strong output due to the high gain of the amplifier. Assuming that this test fails to give a suitable output and that the circuit is faulty, the next injection point would be at the base of TR1, and has presumably gone open circuit (or perhaps it is connected via a "dry" joint).

If this check is successful, the next test point is at the collector of TR1. When using a signal injector you need to bear in mind that connecting the output of the injector to the output of a stage in the test circuit is not necessarily a good idea. t could conceivably result in damage to the injector or the circuit being tested. This is unlikely, but it is quite probable that the output will heavily load the output of the injector so that only a low output level is obtained.

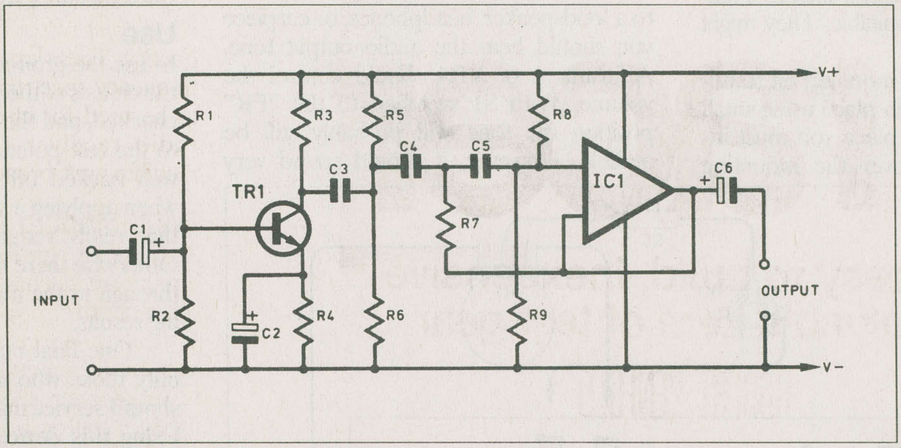


Fig. 1. A typical circuit of the sort that would be used with the Signal Injector.

In this case the output impedance of TR1 is relatively high, and the injector should have no difficulty in inserting a fairly high signal level here. It should also have no difficulty in injecting a signal into the subsequent test points at the junctions of C3/C4, C4/C5, and C5/R8.

The output of IC1 is a different proposition, and operational amplifiers (and most other integrated circuit amplifiers for that matter) have a very low output impedance. It would not be advisable to inject a signal into the output of IC1. A much better approach would be to disconnect the positive terminal of C6 from the circuit board, and to inject the signal into this lead.

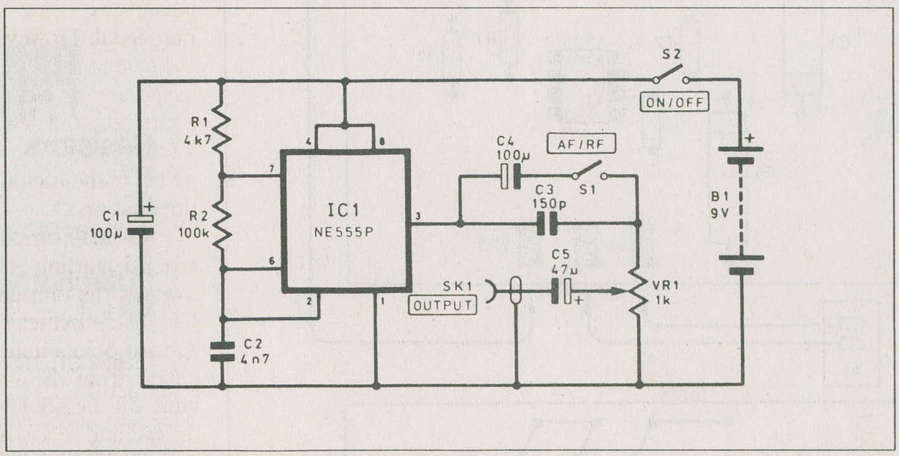


Fig. 2. The circuit schematic for the Signal Injector.

If a circuit has a lot of stages with low output impedances it might be better to adopt an alternative method of fault finding, such as using a signal tracer (as described elsewhere in this issue).

Conclusions

With any electronic testing you should try not to jump to conclusions. There is a very big difference between jumping to conclusions and reaching reasoned conclusions. For example, if applying a signal to the right hand end of C5 produces an output signal, but injecting the signal at the left hand end does not, a fault in C5 is the obvious conclusion. There is another possibility though, which is that R7 has gone short circuit, and is therefore short circuiting this test point to the output of IC7.

Signal injecting will often only indicate the general area of the fault, and some further testing may be needed in order to locate it precisely. In this example one end of R7 could be disconnected. If this restores the output signal, then it is R7 that is faulty. If not, then the defective component is indeed C5. Alternatively, a multimeter could be used to check the resistance of R7.

The Circuit

The circuit diagram of the Signal Injector is shown in Fig. 2. This is little more than a 555 timer integrated circuit used in the standard astable configuration. There is some advantage in using the TLC555CP low power version of the 555 as this gives somewhat lower current consumption and stronger radio frequency harmonics on the output. The circuit will work quite well with the standard 555, though. Timing components R1, R2, and C2 give a roughly squarewave output at a middle audio frequency of approximately 1kHz.

With S1 in the "RF" position the output signal is coupled via C3 to the output level potentiometer (VR1). The small value of C3 results in the audio frequency content on the output signal being severely attenuated. In theory the audio frequency content of the output signal should be irrelevant when the signal is injected into the RF or IF stages of a radio receiver. In practice a strong audio frequency signal can break through to the output and give misleading results.

When S1 is closed, C4 is switched in parallel with C3, and it then provides full coupling of the output signal through to VR1. C5 provides DC blocking at the output so that connecting the unit to a test circuit will not upset the biasing of that circuit. The unit can provide quite a strong output signal, and it is suitable for testing loudspeakers and headphones.

Construction

Details of the circuit board and wiring are provided in Fig. 3. Construction of the board is fairly straightforward, using perfboard or Veroboard, but be careful to get the orientations of C1, C4 and IC1 correct. There is a crossover connection on the underside of the board between IC's two rows of pins. Put in one of these wires and then cover it over with insulating tape at the appropriate place so that it is insulated from the wire that is taken over the top of it.

In places there are several wires running close together. It is important to keep these wires quite taut so that there is no risk of them accidentally short circuiting to one another.

The components should fit into virtually any small plastic case. The controls and SK1 are mounted on the front panel, with the circuit board mounted on the base panel. I used a 3.5 millimetre jack socket for SK1, but virtually any two-way socket can be used here. Two single-way sockets such as 2 millimetre types are also suitable. They might be less fiddly to wire up.

The board can be mounted on standoffs, or it can be fixed in place using small bolts. If it is bolted in place you must include short spacers over the mounting bolts. Without these, the components will be forced from the circuit board as the mounting nuts are tightened.

The point to point wiring is not too difficult. The connections to the board are made via flying leads soldered to the underside. The other ends of the leads are bound to the component tags using the **Easiwire** "pen". Note that C5 is mounted off-board, and is wired direct to SK1 and VR1. Take care to connect it the right way around, as it's a polarized type.

Testing

With the unit switched on and connected to a loudspeaker, headphones, or earpiece you should hear the audio output tone. Adjustment of VR1 should control the volume. With S1 switched to the "FR" position the tone will probably still be audible. However, it should sound very thin, with most of the fundamental and lower harmonics being filtered out. It may be barely audible if the output is fed to a low impedance loudspeaker.

A more useful check is to connect a set of test leads to the output of the unit, and to place the non-grounded lead very close to a radio receiver tuned to the long or medium wavebands. The radio should pick up the harmonics and produce the audio tone regardless of the setting of the tuning control (except that strong transmissions might operate the receiver's automatic gain control circuit and leave the tone barely audible).

Use

In use the grounded test lead connects to the chassis of the piece of equipment being checked, and the other test lead is applied to the test points. It is best to keep VR1 well backed off and to only advance it when applying a signal to a part of a circuit that really requires a high signal level. Otherwise there is a risk of signal breaking through to the output and giving misleading results.

One final but important point is that **only those who are suitably experienced should service mains powered equipment. Using this device to test mains powered equipment that does not incorporate an isolation transformer could prove lethal.**

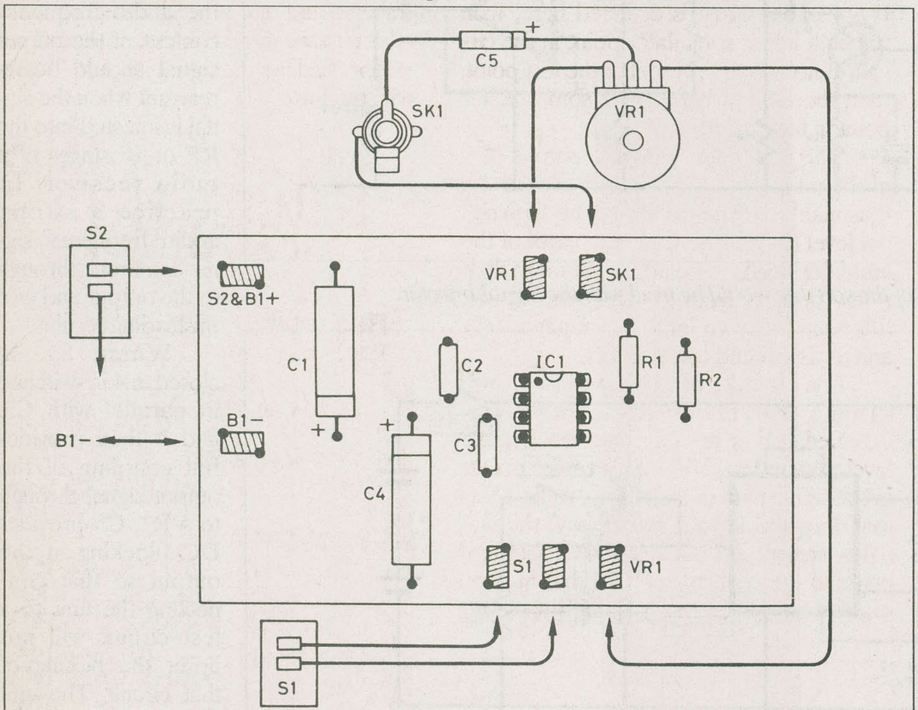


Fig. 3. Construction of the Signal Injector.

PARTS LIST

Resistors

R1 .... 4k7
R2 .... 100k
0.25 watt 5% carbon

Potentiometer

VR1 .... 1k lin.

Capacitors

C1,C4 .... 100u elect. 10-16V
C2 .... 4n7
C3 .... 150p ceramic
C5 .... 47u elect. 10-16V

Semiconductor

IC1 NE555P or TL555P timer (see text)

S1,S2 .... SPST sub-min toggle
B1 .... 9 volt battery
SK1 . 3.5mm jack socket (see text)

Battery connector; 8 pin DIP socket; case; perf or Veroboard; control knob; wire; etc.

SIGNAL TRACER

Tracing Technique

A signal tracer is used in much the same way as a signal injector (as described in the previous section), but I suppose could be regarded as the inverse of an injector. Rather than generating a signal, it takes a signal from the test circuit, amplifies it, and feeds it to a loudspeaker. In other words, it is just a reasonably sensitive audio power amplifier and loudspeaker. It could be regarded as the electronic equivalent of a stethoscope.

Apart from use as a signal tracer, this unit is one of those general purpose items of equipment that no electronics hobbyist should be without. A device of this type proves to be indispensable on numerous occasions when testing projects or just dabbling with circuits. It can save hours of time being held up by what turns out to be a simple problem with a broken socket, short circuited plug, etc., as well as sorting out more difficult problems.

As when using a signal injector, the basic idea of signal tracing is to find a break in the signal chain. It is used for testing the same types of equipment, which means linear circuits having a series of amplifiers of other signal processing stages.

If a signal tracer was used to check the test circuit in the *signal Injector* article (Fig. 1 of that article), the first requirement would be that a suitable signal should be applied to the input of the circuit. This signal could be provided by a signal injector or generator, but where possible I prefer to use the normal signal source for equipment. One advantage is that this automatically provides the equipment with an input of the correct amplitude. Also, you will not always be searching for a complete break in the signal path. The problem might be one of distortion, and any distortion will probably be more noticeable on a speech or music signal than on a simple test signal.

In common with signal injection, you can start at the input, the output, or in the middle. For this example we will assume that the starting in the middle technique is to be adopted. An acceptable first test point would therefore be at the junction of C3 and C4 (Fig. 1, *Signal Injector* article). If a suitable signal is detected here, then the fault lies at some later point in the circuit. If no signal is present at the test point, then the fault is here, or at some earlier point in the circuit.

This test point is at the output of a high gain amplifier, and it would be reasonable to expect a reasonably high signal level here. If the volume control of the amplifier needs to be advanced more than a few degrees from its minimum setting, this would tend to indicate a fault in TR1 and its associated components.

For the sake of this example we will assume that the signal is either not detected, or is at a grossly inadequate level. We must therefore try earlier points in the signal path in an attempt to find one that does provide a signal. If (say) the signal is present at both sides of C1, but appears at the collector of TR1 and in subsequent stages at only about the same level, this would suggest that TR1 is failing to amplify the signal properly and is faulty.

The problem could be due to a fault in one of the other components in this part of the circuit though. C2 going open circuit or not being connected properly would result in low gain through TR1. It is easy to test for this using the signal tracer, and it is just a matter of checking for a signal at the emitter of TR1. The decoupling effect of C2 should result in no significant signal here.

If the signal level at TR1's emitter is much the same as the signal level at its base, this would suggest that C2 is not having any effect on the circuit. A signal tracer is just as useful for detecting signals where there should be none present, as it is for finding signals that are "absent without leave".

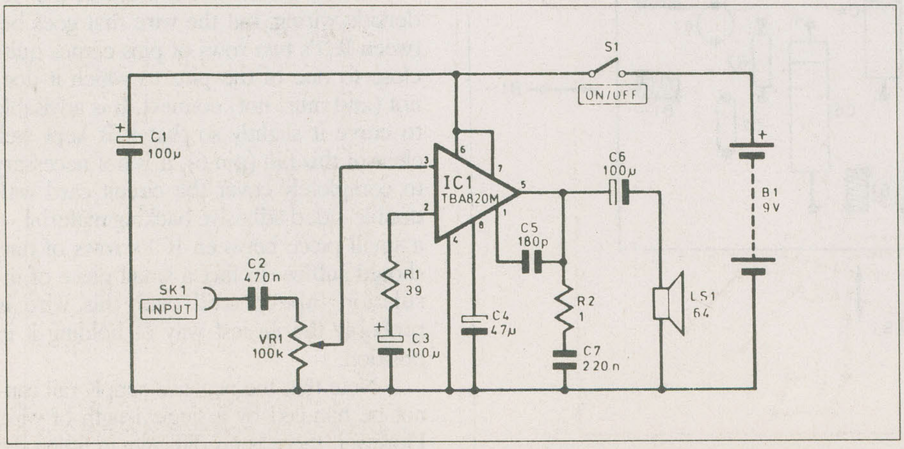


Fig. 1. Circuit diagram of the Signal Tracer.

PARTS LIST

Resistors

R1 39
R2 1
0.25 watt 5% carbon

Potentiometer

VR1 .... 100k log. carbon

Capacitors

C1,C3 .... 100u elect. 10-16V
C2 .... 470n
C4 .... 47u elect. 10-16V
C5 .... 180p ceramic
C6 .... 100u elect. 10-16V
C7 .... 220n

Semiconductor

IC1 TBA820M (or LM386 – see box)

Miscellaneous

SK1 Standard jack socket (see text)
LS1 64 ohm loudspeaker (see text)
B1 9 volt battery
S1 SPST sub-min toggle

Battery connector; 8 pin DIP socket; case; board; control knob; wire; etc..

Circuit

There are a number of small audio power amplifier integrated circuits which could be used as the basis for a unit of this type. I chose the TBA820M as it is readily available, has quite a good specification, and is well suited to battery operation. It will work on supply voltages as low as three volts, and it has a low quiescent current consumption of only about four milliamps. The full circuit diagram for the Signal Tracer appears in Fig. 1.

The input signal is coupled via DC blocking capacitor C2 to volume control VR1. From here the signal is coupled straight into the non-inverting input of IC1. No DC blocking capacitor is needed here. In fact VR1 acts as the input bias resistor for IC1, and so it is essential that no input coupling capacitor should be used.

Capacitor C5 provides a small amount of high frequency attenuation which aids the stability of the circuit. This does not significantly affect the unit's audio frequency response. C4 is a decoupling capacitor that helps avoid problems with instability due to feedback through the supply rails (as does the main supply decoupling capacitor, C1).

Gain

The voltage gain of the circuit is controlled by an internal feedback resistor, and discrete feedback components R1 and C3. The specified value for R1 gives a voltage gain approaching 200 times, and an input of only about 10mV RMS will drive the amplifier to full output power.

In this application there is an advantage in high sensitivity and high impedance as this enables very weak signals to be detected. The gain and input impedance could be made higher by raising the value of VR1 and reducing the value of R1. The specified values probably represent the best compromise for these components, since boosting the gain and input impedance would risk instability due to stray feedback, and would reduce the output quality. The sensitivity is quite good anyway. Remember that 10 mV is needed for full output power, but inputs of well under a millivolt will produce a clearly audible output.

Capacitor C6 couples the output signal to a high impedance loudspeaker (LS1). The maximum output power into a high impedance speaker is not very high, and is less than 100 milliwatts RMS This should be sufficient for the present application, but an eight ohm impedance loudspeaker can be used if a higher output power is required (at the expense of current consumption and therefore battery life). R2 and C7 are needed in order to prevent high frequency instability.

Although the quiescent current consumption of the circuit is typically only 4mA, the current drain rises significantly at high volume levels. Using a high impedance loudspeaker the average current consumption is still only likely to be about 10 milliamps or so, and a PP3 size battery should be adequate. I would recommend a higher capacity type (such as six HP7 size cells in a holder) if an eight ohm impedance loudspeaker is used.

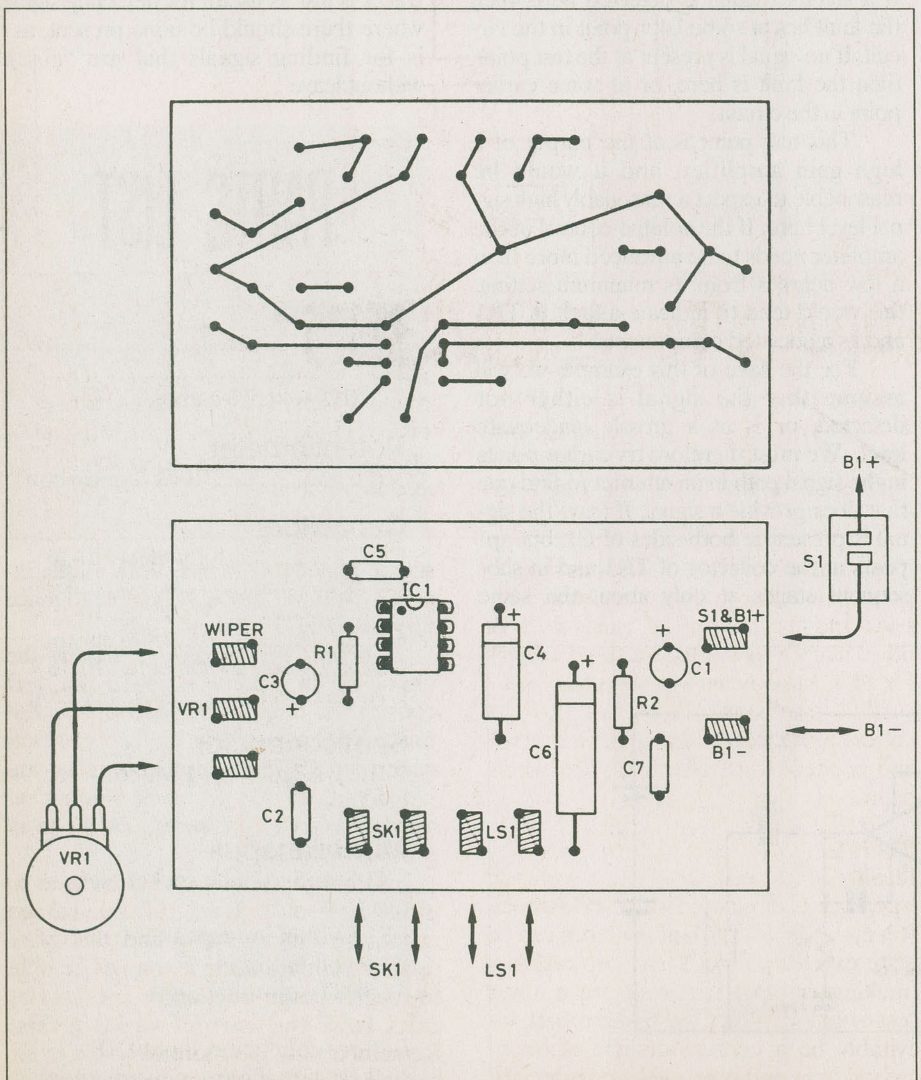


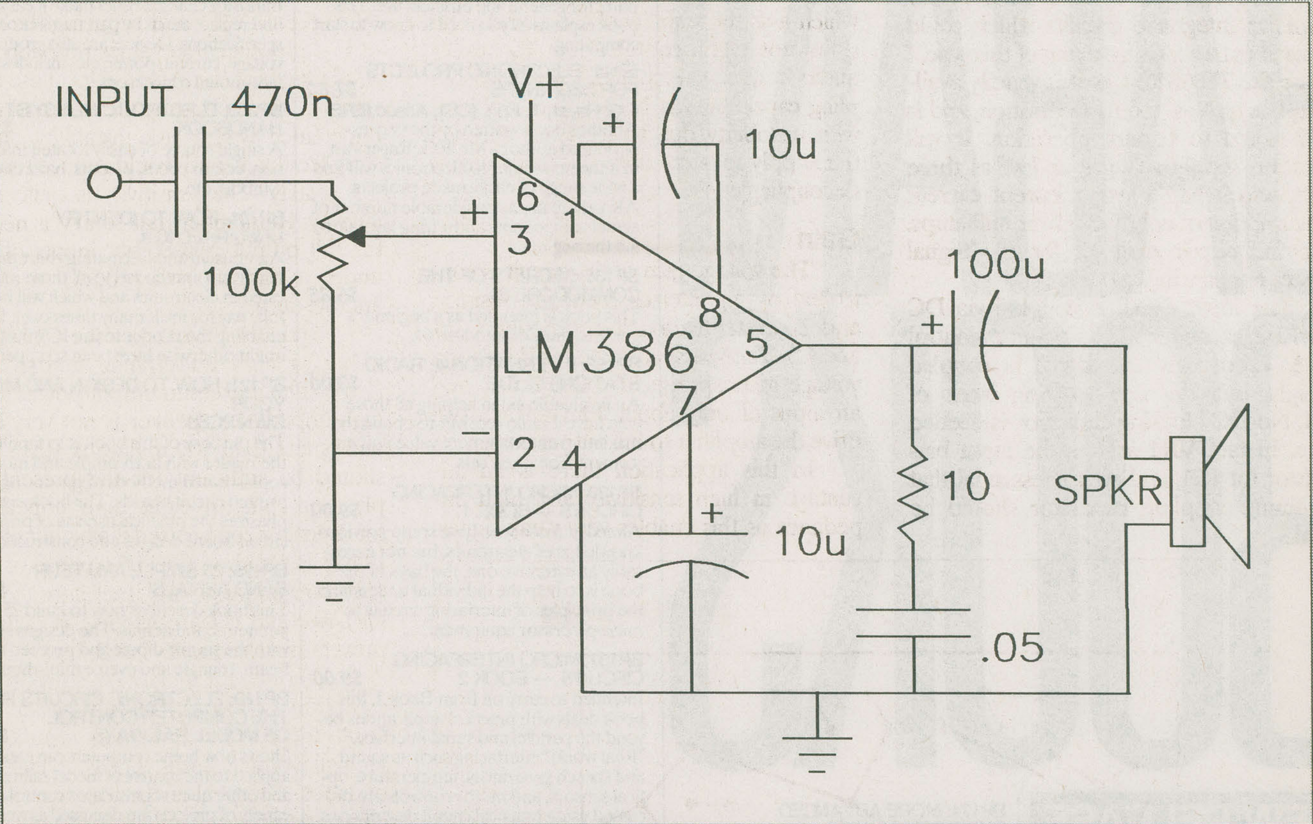
Fig. 2. Construction of the signal tracer.

Construction

The circuit and wiring are shown in Fig 2. Assembly of the board presents few problems, but be careful to get IC1 and the electrolytic capacitors fitted to the board the right way round.

There are no cross-overs in the underside wiring, but the wire that goes between IC1's two rows of pins comes quite close to one of the pins to which it does not (and must not) connect. It is advisable to curve it slightly so that it is kept well clear of this pin (pin 6). It is not necessary to completely cover the circuit card with double-sided adhesive backing material — a small piece between IC1's rows of pins should suffice. In fact a small piece of insulation tape placed over this wire is probably the easiest way of holding it in position.

Note that the negative supply rail cannot be handled by a single length of wire. However, there is no difficulty in fitting the main wire and then adding the branch wire which carries the ground connection to LS1.



SUBBING THE LM386

If the TBA820 is unavailable, the LM386 power amp (Radio Shack 276-1731) will provide the same specifications with a few different parts and a slightly different pinout. The schematic is shown above.

The differing parts are the 10u from pins 1 to 8, which sets the gain at the required 200, the 10u from pin 7 to ground, which improves the rejection of noise from the V+, and the .05/10 ohm network on the output, used for high frequency stability.

The unit should fit into most small plastic cases, but be careful to choose one that will provide sufficient space for the loudspeaker. A grille for the loudspeaker must be made in the case. The easiest way of doing this is to drill a matrix of small holes (about five millimeters in diameter will do). Take care to position the holes accurately, as it is easy to make a slightly sloppy job of this.

Miniature loudspeakers rarely have provision for screw mounting. Consequently, it will almost certainly have to be glued in place using a good quality general purpose adhesive. Avoid smearing any adhesive onto the diaphragm as this could seriously impair the audio output.

Try to arrange the layout so that the wiring to VR1 and SK1 is not intermingled with that of the loudspeaker. This would encourage stray feedback and instability. The input wiring should b kept as short as possible in order to discourage stray feedback and the pick up of mains hum or other interference. I used a standard jack for SK1, but any audio connector should suffice. You could even just drill an entrance hole for the test leads in the case and connect them directly to the circuit board.

In Use

Ideally the test lead should be a screened type, such as those used with oscilloscopes. Ready-made test leads of this types can be quite expensive though, and two ordinary (multimeter type) test leads are a lower cost solution. With these there will inevitably be a certain amount of background hum and other pick up, especially when the leads are not connected to a signal source, or are connected to a weak high source impedance signal. With a little ingenuity you will probably be able to make up your own shielded test leads.

Connect the ground test lead to the chassis of the equipment under test, and connect the other lead to the various test points. Unless you have the necessary experience and are sure you know what you are doing, **do not try fault finding on mains powered equipment. To do so is potentially fatal.**

Although the unit cannot be used to measure signal levels and calculate voltage gains, you will probably find that after some experience using it you will be able to roughly gauge whether or not test circuits have the correct signal levels. Remember that the more VR1 has to be backed off in order to prevent overloading, the stronger the signal at the test point. ■