RS232 serial interface troubleshooter

Making a 'standard' RS232 interface work can be a nightmare. 'Standards' not withstanding, you can regain lost sleep with this troubleshooting unit.

Graham Wideman

IN LAST MONTH'S ETI we explained how computer serial interfaces of the RS232 type are supposed to work, and why they frequently won't. This month we present the design and construction details of a test unit which solves most of these problems. You may wish to build it as described here, or simply borrow the principles to troubleshoot interfaces using other instruments.

The troubleshooter provides the capability to patch together any wiring arrangement, and to monitor what is happening on each wire. In this much it parallels the better commercially-available RS232 'problem solvers'.

However, it also includes an apparatus for determining exactly which interface wires are outputs, inputs, not connected, or shorted, thereby making possible a complete picture of a totally unknown interface. This is extremely useful if the equipment in question has no manual, or as is more likely, has a manual which leaves the subject of the RS232 interface completely ambiguous.

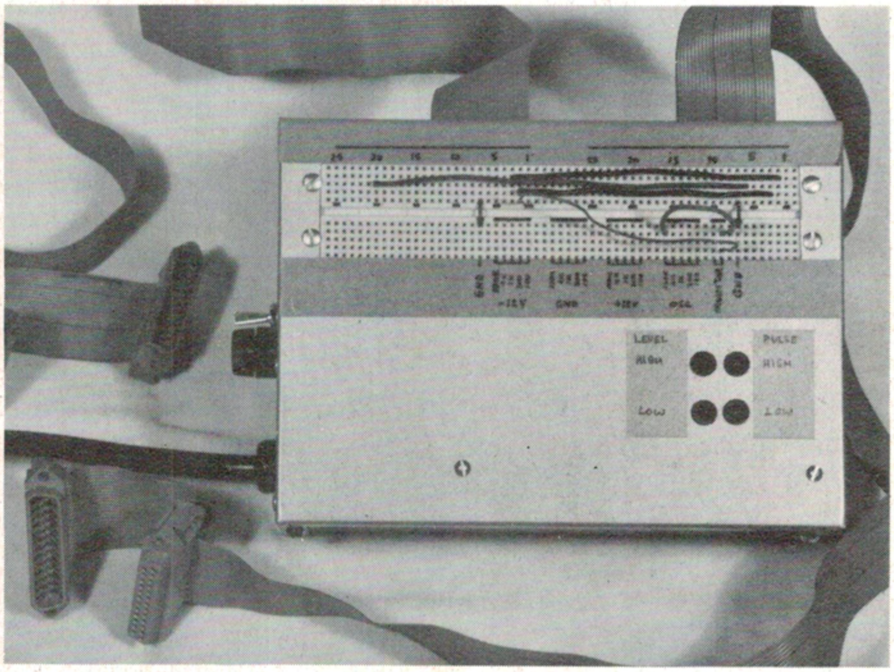


Figure 1. **The RS232 troubleshooter.**

Patching board

The heart of the troubleshooter is a breadboard patching block which is wired permanently to a pair of ribbon cables, each cable having attached to it both male and female DB25 connectors of the 'insulation displacement' squash-on variety. After peeling the adhesive plastic backing off the breadboard block (and cleaning it up a bit), the individual conductors of the ribbon cable are soldered to the *underside* of the rows of contacts in the breadboard, as shown in the photo of Figure 2, and detailed in the diagram of Figure 3.

This simple device already gives two capabilities, as shown in Figure 4. First, both cables can be attached, one to each of the pieces of equipment which are to be interfaced together. Having both a male and female connector on each cable ensures that plugging in will be no problem. Then the particular pin-to-pin wiring can quickly be tried out using jumper wires on the tester's breadboard patching area, before a permanent cable is made up.

The second way to use the device as so far described, is for 'tapping into' an existing interface arrangement which is now perhaps malfunctioning. Suppose

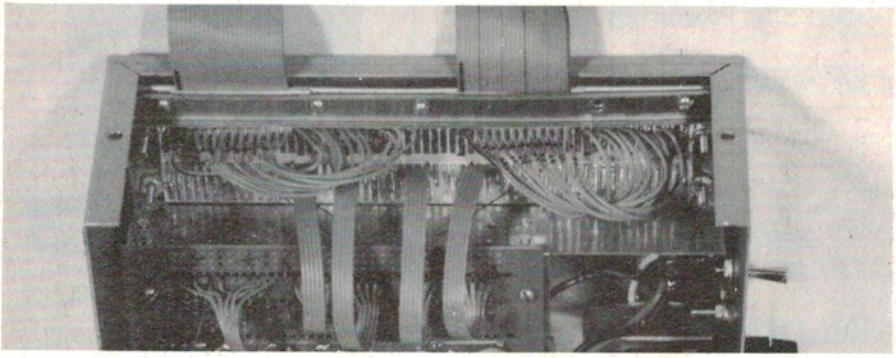


Figure 2. **Closer view of breadboard area used for patching the troubleshooter's two DB25-equipped ribbon cables, and for connection to the unit's signal monitor and test signals.**

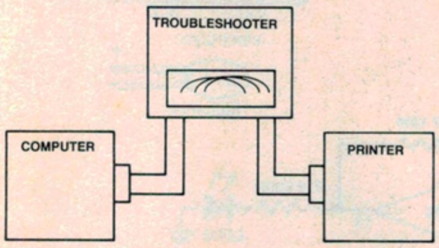


Figure 4a. **Using the troubleshooter's patching area to rig new trial cable before making permanent version.**

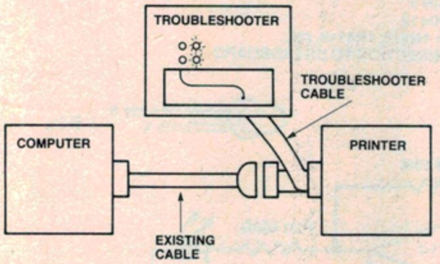


Figure 4b. **Using just one ribbon cable, the troubleshooter provides a convenient way to tap into and monitor the signals on a 'supposed to be working' RS232 hookup.**

the 'existing system' is a computer talking to a printer. Simply unplug one end of the computer-to-printer cable (let's say the printer end), and plug it into one of the two connectors (male or female as appropriate) on one of the troubleshooter's ribbons. Plug the remaining connector on the *same* ribbon into the receptacle on the printer. Now the short length of ribbon between male and female DB25s carries the connection from computer to printer, and in addition this ribbon brings out all 25 lines to the breadboard where they may be conveniently monitored.

Signal monitor

In order to monitor the signals on an RS232 line it is possible to get away with simply a LED with a resistor in series. However this loads the line, possibly changing the conditions you were trying to monitor. Additionally, you would not see any quick pulses of activity which may be important.

Consequently the monitor incorporated in this tester has been designed to address these two problems. Four LEDs are used, two to indicate a steady high or low level, while the other two flash on for about a half second in response to a positive or negative pulse. The level LEDs respond only to valid high or low signals; a voltage in the middle (around zero), or an open line will cause neither LED to illuminate. The LEDs are powered from a built-in mains power supply, and the RS232 line is monitored via high impedance buffers, so as not to disturb it.

(It should be remembered here that the RS232 line levels are −3 V to −12 V for a 'low' representing a data '1', and +3 V to +12 V for a 'high' representing a 'zero'. With no data the line sits at low.)

The monitor input is soldered to the underside of a contact strip on the breadboard (actually two strips, in case of wear), and thus may be patched to any other contact as desired for observation of the signals there. ▶

```
Test Signals                                        From DB25s
                                         Ribbon
                        ooooo   ooooo       DB25
                        ooooo   ooooo    24  25   DB25 Cable A
                        ooooo   ooooo    22  24        |
                        ooooo   ooooo    20  23        |
                        ooooo   ooooo    18  22        |
                        ooooo   ooooo    16  21        |
                        ooooo   ooooo    14  20        |
                        ooooo   ooooo    12  19        |
                        ooooo   ooooo    10  18        |
                        ooooo   ooooo     8  17        |
                        ooooo   ooooo     6  16        |
                        ooooo   ooooo     4  15        |
                        ooooo   ooooo     2  14        |
                        ooooo   ooooo    25  13        |
                        ooooo   ooooo    23  12        |
                        ooooo   ooooo    21  11        |
                        ooooo   ooooo    19  10        |
                        ooooo   ooooo    17   9        |
                        ooooo   ooooo    15   8        |
         Ground         ooooo--ooooo     13   7        |
                        ooooo   ooooo    11   6        |
 -12V     100k          ooooo   ooooo     9   5        |
  "         4k          ooooo   ooooo     7   4        |
  "         1k          ooooo   ooooo     5   3        |
  "       300           ooooo   ooooo     3   2        |
  "       100           ooooo   ooooo     1   1   DB25 Cable A
                        ooooo   ooooo
                        ooooo   ooooo
Ground    100k          ooooo   ooooo
  "         4k          ooooo   ooooo
  "         1k          ooooo   ooooo
  "       300           ooooo   ooooo
  "       100           ooooo   ooooo
                        ooooo   ooooo    24  25   DB25 Cable B
                        ooooo   ooooo    22  24        |
 +12V     100k          ooooo   ooooo    20  23        |
  "         4k          ooooo   ooooo    18  22        |
  "         1k          ooooo   ooooo    16  21        |
  "       300           ooooo   ooooo    14  20        |
  "       100           ooooo   ooooo    12  19        |
                        ooooo   ooooo    10  18        |
                        ooooo   ooooo     8  17        |
Osc.      100k          ooooo   ooooo     6  16        |
  "         4k          ooooo   ooooo     4  15        |
  "         1k          ooooo   ooooo     2  14        |
  "       300           ooooo   ooooo    25  13        |
  "       100           ooooo   ooooo    23  12        |
                        ooooo   ooooo    21  11        |
Monitor                 ooooo   ooooo    19  10        |
  "                     ooooo   ooooo    17   9        |
                        ooooo   ooooo    15   8        |
         Ground         ooooo--ooooo     13   7        |
                        ooooo   ooooo    11   6        |
                        ooooo   ooooo     9   5        |
                        ooooo   ooooo     7   4        |
                        ooooo   ooooo     5   3        |
                        ooooo   ooooo     3   2        |
                        ooooo   ooooo     1   1   DB25 Cable B
                        ooooo   ooooo
```

Figure 3. **Diagram showing one possible arrangement for the breadboard connection area. Note that the DB25 ribbon cables occupy one 'side' of the board, and the test monitor and signals occupy the other. Opposite each ribbon's pin number 7 is a ground connection, across which would normally be installed a small jumper.**

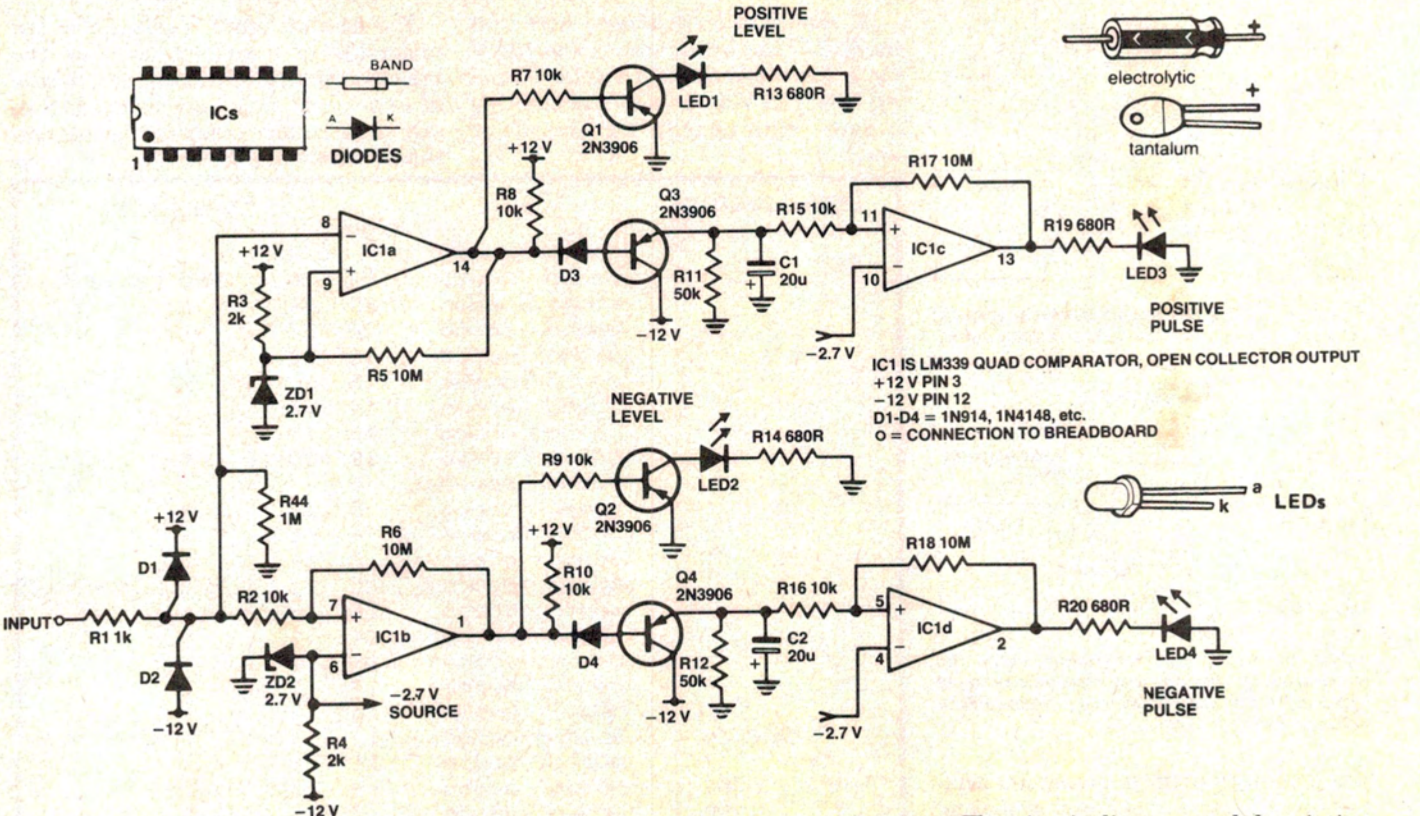


Figure 5. **Circuit diagram of monitor section.**

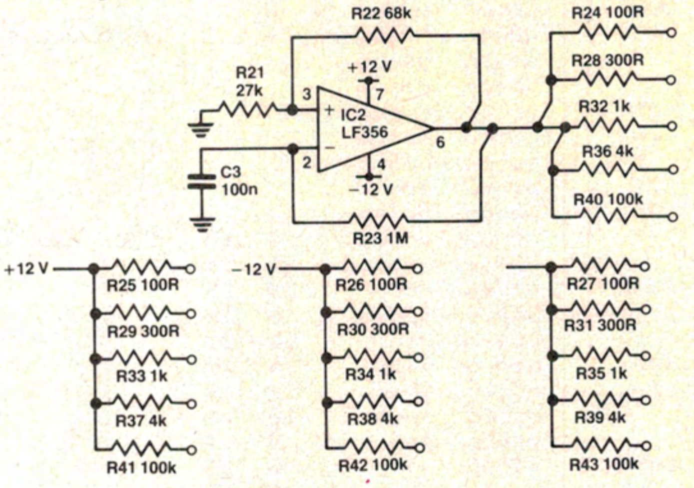
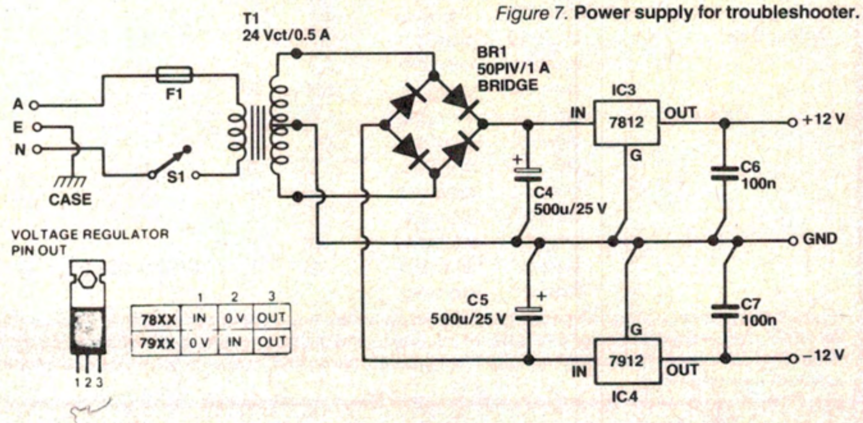


Figure 6. **Circuit of test oscillator, and other test levels.**

Figure 7. **Power supply for troubleshooter.**



The circuit diagram and description for the monitor, the test oscillator to be described, along with the power supply, are to be found in Figures 5 to 7.

Generated signals

Of immediately obvious use are the 'high' and 'low' signals provided. These may be used to apply 'halt' or 'go' signals to handshaking lines. Additionally there is built-in a square-wave generator which continuously oscillates between high and low conditions at a rate of approximately five times per second.

Each of these signals, along with ground, is supplied to contacts on the breadboard via a selection of resistors, from 100 ohms to 100k ohms. The usefulness of this arrangement may not be immediately apparent, and for explanation I must describe the electronic circuits which transmit or receive on an RS232 line.

How it works

The monitor

The schematics for the troubleshooter's main monitor, test oscillator and power supply are to be seen in Figures 5 to 7.

Components R1-D1-D2 prevent the input signal from causing damage should it happen to exceed the troubleshooter's power rail limits. From there the input signal is routed to two very similar 'channels', one concerned with 'high' levels and pulses, the other with 'low' levels and pulses.

Looking then at the positive channel, the input signal arrives at the negative input of comparator IC1a, where it is compared to a reference of about 2V7 (which is set by ZD1 at the positive input of IC1a). Supposing that the input signal exceeds 2V7, then IC1a's output is low, turning on Q1 via R7, and illuminating LED1 to indicate a 'high level'.

At the same time, the low level (about −10 V) at the output of IC1a turns on Q3, quickly charging C1 'down' to about −9 V. IC1c sees this voltage and compares it to −2V7, sees that it is lower and lowers its own output illuminating LED3 to indicate a 'high pulse'.

If the monitor input now drops below 2V7, IC1a's output will go high, turning off Q1 and the 'high-level' LED1, and also Q3. However the 'high pulse' LED3 will remain on for a short while (about a half second) as C1 is charged up past the 2V7 point by R11. Notice that this delayed LED3 action would have occured even if LED1 had been on for only an invisibly short length of time. Hence LED3 makes visible short pulses which cannot be seen by simply watching the level, whether on the troubleshooter's level LEDs, or even with an oscilloscope.

The negative channel works similarly, the only change being to swap the positive and negative inputs of the input comparator.

Test oscillator

As we shall see, IC2's output must sit in either high (about +10 V) or low (about −10 V) states. Let us assume it is initially low, and that C3 starts out uncharged, so that there is 0 V at the op-amp's negative input.

Since the op-amp output is at say −10 V, the positive input will be at approximately −3 V, established by the R21-R22 voltage divider. Remembering that we assumed the negative input to be at 0 V, the 'low' output will remain temporarily unchanged.

However, the low output will charge C3 via R23 downwards. After a while the op-amp negative input will be less than its positive input (at −3 V), and thus the output will change states to +10 V. When this happens the voltage at the positive input changes, of course, to +3 V, maintaining this state of affairs.

Again we must wait for C3 to be charged via R23, this time up to +3 V. You should be able to see that this oscillating action will continue, and that the period is the time taken for C3 to charge from −3 V to +3 V, then back down to −3 V, when R23 is pulled up to +10 V and then down to −10 V respectively.

The values given provide a frequency of about 5 Hz, quite suitable for this testing purpose.

The oscillator output is delivered to the breadboard area via various values of resistor, as described in the text.

Of drivers and receivers

For various reasons, special purpose buffers are used to send signals and receive signals on an RS232 line. These are called 'drivers' and 'receivers', and are exemplified by the National LM1488 and 1489 respectively. Figures 8 and 9 show a simplified view of how the driver output and receiver input look electrically.

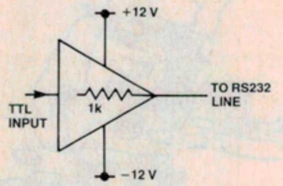


Figure 8. **Simplified view of an RS232 'driver' output.**

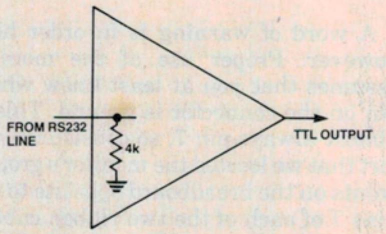


Figure 9. **An RS232 'receiver' looks like this electrically.**

The points to notice are that a receiver input looks like a (approximately) 4k resistor to ground. An operating driver output looks like a (approximately) 500 ohm resistor pulling up to 12 V (nominally), or pulling down to −12 V, according to its state.

Knowing these facts it is apparent that if a high or low signal is applied through a resistor to a receiver input or driver output, the resulting signal on the line (which can be monitored) will be high, low or in-between depending upon the value of resistor used.

Therefore, when looking at an unknown line, by applying the test oscillator's output via each resistor in turn, it is quickly possible to tell what that line does. The chart in Figure 10 details this. ▶

Parts List

Resistors .... ¼ W unless specified

R1	1k
R2	10k
R3, 4	2k
R5, 6, 17, 18	10M
R7, 8, 9, 10, 15, 16	10k
R11, 12	50k
R13, 14, 19, 20	680
R21	27k
R22	68k
R23	1M
R24, 25, 26, 27	100
R28, 29, 30, 31	300
R32, 33, 34, 35	1k
R36, 37, 38, 39	4k
R40, 41, 42, 43	100k
R44	1M

Capacitors

C1, 2	20u/20 V electrolytic
C3, 6, 7	0u1 tantalums
C4, 5	500u/25 V electrolytic

Diodes

D1, 2, 3, 4	1N914 or 1N4148 etc
ZD1, 2	2V7 small zener diode
BR1	Bridge rectifier, 50 PIV/1 A
LED1, 2, 3, 4	LEDs of your choice of colour

Transistors

Q1, 2, 3, 4	2N3906

Integrated circuits

IC1	LM339
IC2	LF356A
IC3	7812
IC4	7912

Transformer

T1	240 V primary, 12-0-12/500 mA secondary

Miscellaneous

Breadboard, case, fuse and holder, switch for power, power lead and plug etc.

Line Condition	Oscillator Signal via Resistor (ohms) 100k	4k	1k	300	100
Open	HL	HL	HL	HL	HL
Receiver Input	None	HL	HL	HL	HL
Driver Out-Low	L	L	L	FL/HL	HL
Driver Out-High	H	H	H	FH/HL	HL
Short to Ground	None	None	None	None	None
Short to +12 V	H	H	H	H	H
Short to −12 V	L	L	L	L	L

Charts shows the Level LEDs (not 'pulse' LEDs) activated in various cases.

H = High; L = Low; None = neither LED on; HL = alternating H and L; FL = Flashing Low; FH = Flashing High

Figure 10. **Chart showing how to test an unknown RS232 line, and the monitor's indications under various conditions.**

A word of warning is in order here however. Proper use of the monitor assumes that you at least know which pin on the connector is ground. This is almost always pin 7, so consistently in fact that we located the monitor's ground points on the breadboard opposite to the pins 7 of each of the two ribbon cables, and permanently left a small jumper installed at these two locations (see Figure 3). However, there are lurking about some units which don't abide by this standard. The only thing you can do about this (if you are documentationless and suspect this problem) is to open the case and actually trace the unit's circuit-board ground and see what DB25 pin it goes to.

Construction notes

The construction is not too critical. As can be seen the prototype version was built using Veroboard. One plan which is extremely useful to follow is to make a simple frame assembly like the one shown in Figure 11, which serves two purposes.

First it includes a flat clamp to grip the two ribbon cables (liberal use of double-sided wall-tile sponge adhesive tape also helps). Secondly, it keeps together the circuit board and the breadboard. In both these respects it makes wiring to the breadboard easier, and virtually eliminates any problems of wire breakage when the various parts are moved about during construction or testing of the project. As the photos show, the entire guts of the prototype can be removed in one piece, connected to the case only by the leads to the PSU.

Another hint: DON'T FORGET when soldering the ribbons to the breadboard that the numbering of the DB25 pins is *not* the same sequence as the ribbon cable conductors. This is shown in Figure 3.

Improvements

Although our troubleshooter has proved tremendously useful, I cannot claim that our prototype is the last word. In fact, I feel that if done again we would add several extra LEDs as simple on-off high-low indicators along with the existing level plus pulse monitor, so as to keep an eye on several lines at once. You may wish to adopt this idea in your unit. ●

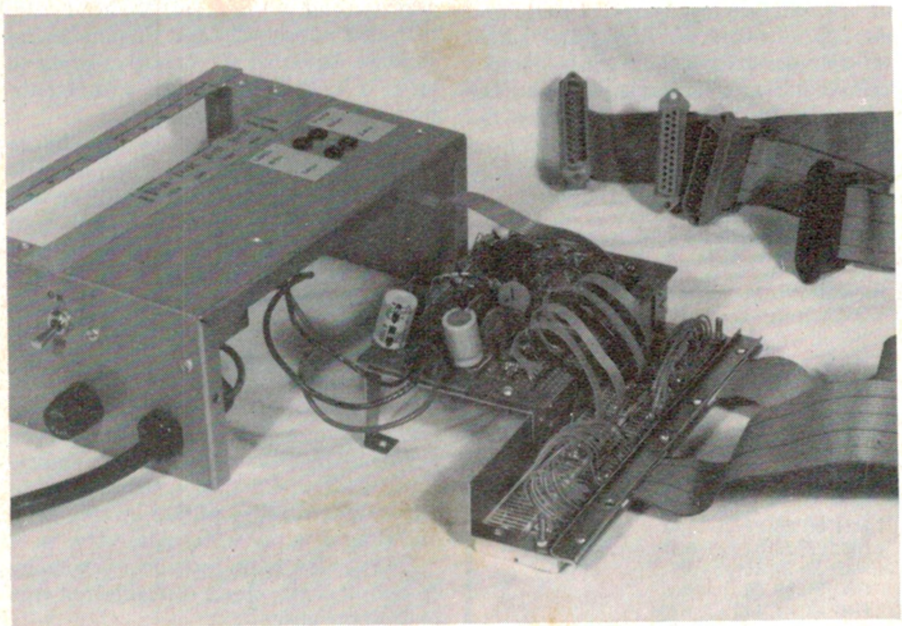


Figure 11. **When constructing a unit such as this, where there are a lot of wires hanging around, it's helpful to use brackets and cable clamps like the ones in this photo. They prevent undue strain on soldered connections, improving reliability, and enable the circuitry to come out of the box in one piece, more or less, for testing purposes during construction, or later if the unit needs repair.**