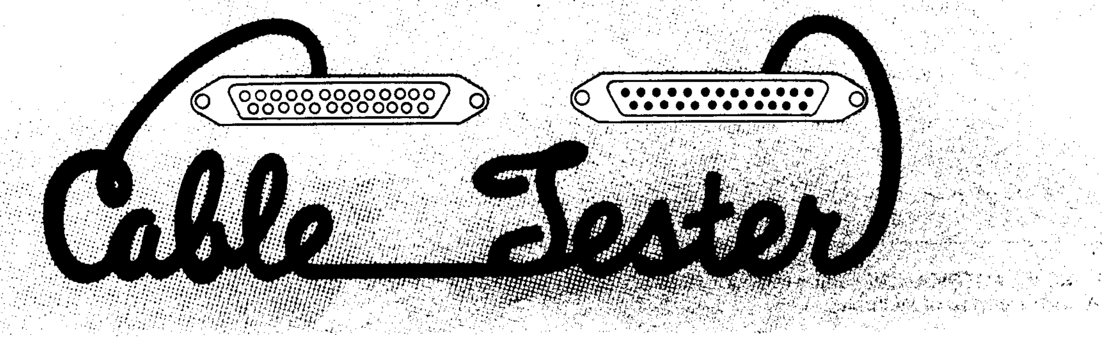

*Build **PcSuperCon,** a low-cost multipath continuity tester.*

JAMES J. BARBARELLO

TESTING MULTICONDUCTOR CABLES for continuity is a time-consuming task. Unless you can afford expensive, specialized equipment fopr doing it, it is also difficult to do it without making errors.

A number of years back, I was at a contractors plant where two technicians were testing cables. Each held a probe connected to an ohmmeter. One technician would touch a pin on a connector attached to one end f a long cable assembly and yell something like "C-24." The other would move his probe to his connector's pin C-24 to check for continuity, and then he'd check every other pin to make sure that there weren't any short circuits. This continued for what seemed like forever, and I remember thinking "That's got to be the most boring task in the world!". Unfortunately, that wasn't an isolated event--I saw this scenario played out again and again in different plants.

When there are many connections in a cable, PC board, or other device, you must check to make sure all the intended connections are correct, and that no unintended connections (short circuits) are present. This kind of repetitive task doesn't have to tie up two technicians-it's just right for a personal computer.

Continuity testing

The theory behind continuity testing is pretty simple if you understand these terms:

- Line-A connection between two points.
- Test Signal-An electrical signal (AC or DC) that's used to determine if continuity exists on the line.
- Input-That end of the connection path where the test signal is inserted.
- Output-The other end of the connection path where the test signal is sensed (by a meter or other measuring device).
- Short Circuit-An unwanted connection between two conductors.
- Open Circuit-The absence of an intended connection in a conductor.

Figure 1 shows how continuity is tested manually A test signal is provided at the input of one conductor. Each of the outputs is then checked for the presence or absence of the test signal, and the results are recorded; the signal should appear at the output of the input line, and it should not be present at any other output. The test signal is then applied to the next input and the process is repeated until all wires have been checked.

The number of tests that must be performed to ensure that all wires are checked against all others is the permutation of the number of wires present. The permutation of a number (N) is N+ (N- l)+ (N-2)+...+1. Soforfivewires, you must to perform 5+4+3+2+1, or 15 tests. The number of tests needed increases very quickly as the number of wires increases. For instance, for 25 wires you must perform 325 tests.

In Figure 1, the input and output probes are moved manually from one wire to the other. The procedure can be partially automated with the setup shown in Fig. 2 in which the probes are "moved" with a series of switch-

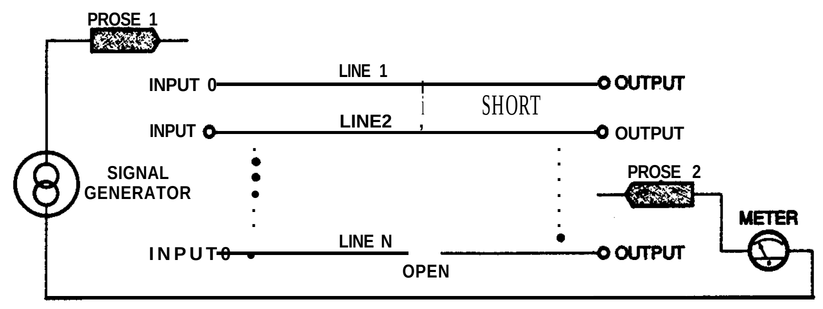

FIG. I-CONTINUITY IS TESTED MANUALLY by providing a test signal at the Input of one wire and then checking each of the outputs for the signal.

es. To test line 1, close switch S1-a. Then close S1-b and measure. Open S1-b, close S2-b and measure. Repeat this until you get to the "Nth" switch (SN-b). Then repeat the procedure again after opening S1-a and closing S2-a.

This semi-automated approach has two advantages. It eliminates the possibility of not making effective contact with thee wires. If you must test many of the same kinds of circuits,

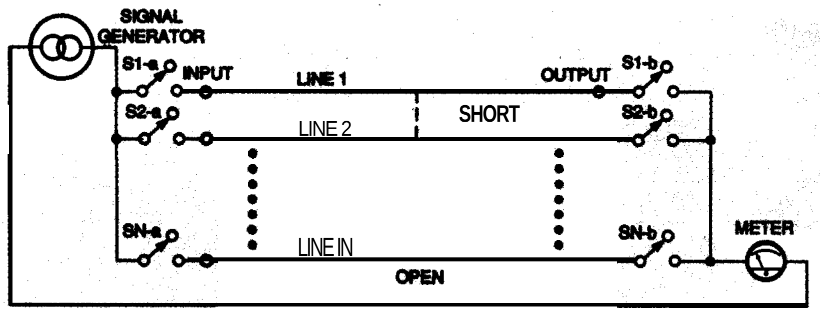

FIG. 2-SOME AUTOMATION can be introduced to continuity testing by "moving" the probes with a series of switches.

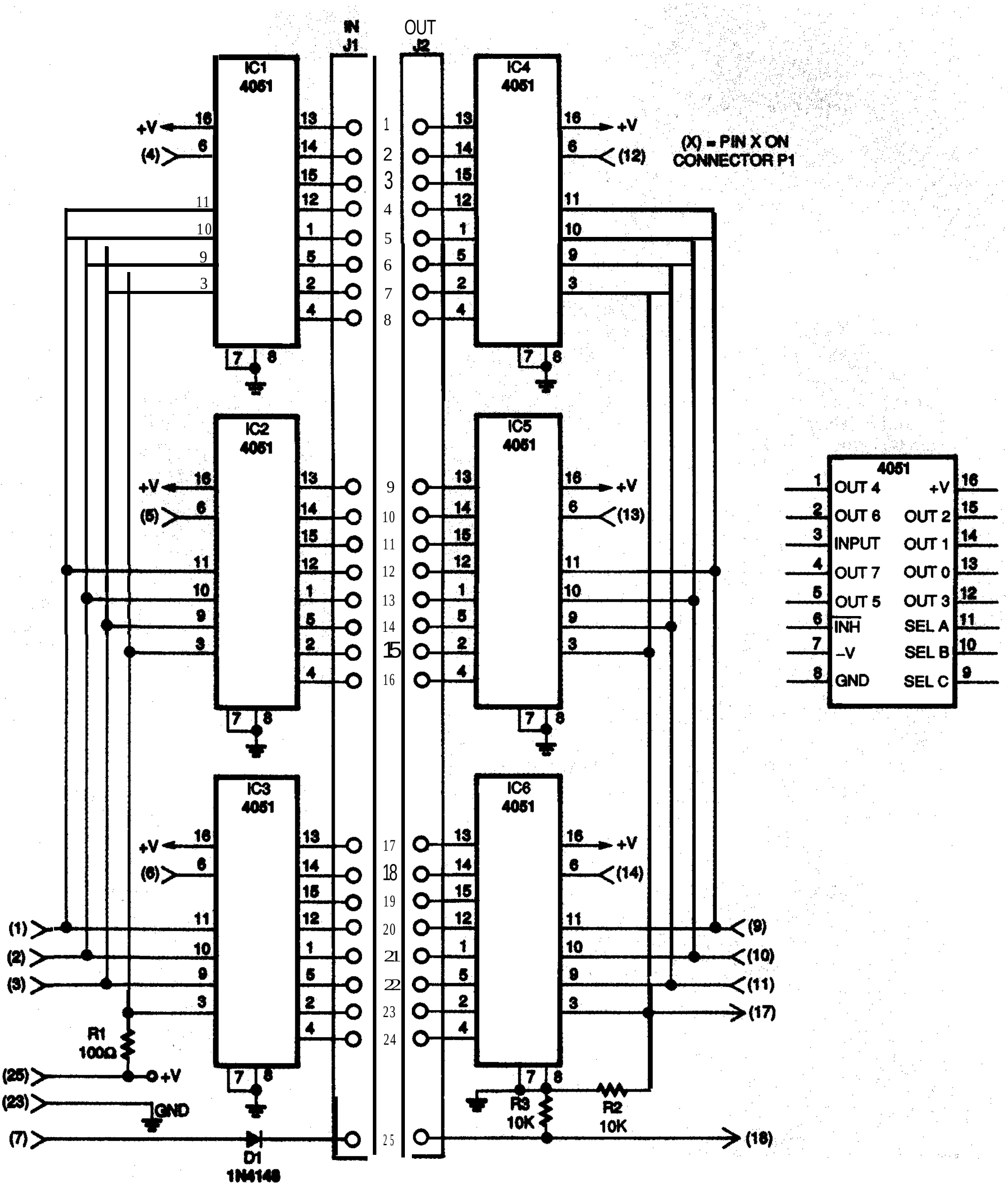

FIG. 3—TO MAKE A PC do continuity testing, the mechanical switches in Fig. 2 must be enplaced with electronic ones. The 4051 contains eight electronic switches.

TABLE 1

Inhibit Input	Select Inputs C	B	A	Decimal	Closed Switch (all others open)
0	0	0	0	0	S1
0	1	0	0	1	S2
0	0	1	0	2	S3
0	0	1	1	3	S4
0	1	0	0	4	s5
0	1	0	1	5	S6
0	1	1	0	6	S7
0	1	1	1	7	S8
1	X	X	X	o-7	All Open

you can wire the switches to a connector that mates with the circuit you're going to test. Then, it's a simple job to connect and disconnect the circuit. This will help to prevent mistakes and it will save some-but not enough-time.

PC continuity testing

To make a PC do all the work, the mechanical switches in Fig. 2 must be replaced with electronic ones. Then the PC must control those switches, provide the test signal, and sense the outputs. In the circuit shown in Fig. 3, the mechanical switches have been replaced by a CD4051B CMOS 8-channel analog multiplexer/demultiplexer. The 4051 contains eight electronic switches, controlled by three select input pins 9.10, and 11. Table 1 shows how the inputs select the switches that will be activated. When any one switch is closed, the other switches are open (high impedance). When the inhibit line is high, all of the switches are open, regardless of the select inputs.

The circuit in Fig. 3 is controlled by the PC I/O interface shown in Fig. 4. The PC I/O interface is described in detail in *Radio* Electronics,July 1991, page 53. The connections marked Pl go to a female DB-25 jack that mates with the PC I/O board. Jacks Jl and J2 are the input and output connectors for the device (most likely a multiconductor cable) to be tested.

The continuity tester contains six 4051s, three on the input side and three on the output side. The common inputs of the 4051s (pin 3) are connected

PARTS LIST

R1—100 ohms, ½-watt
R2, R3—10,000 ohms, ¼-watt
D1—1N4148 or 1N914 diode
J1, J2, P1—female DB-25
IC1–IC6—CD4051B CMOS 8-channel analog multiplexer/demultiplexer, Harris or equiv.
Breadboard (Radio Shack solderless P/N 276-174, solderable P/N 276-170, or equivalent), 30 feet of 24 gauge solid wire, enclosure

Note: The following items are available from J.J. Barbarello, 817 Tennent Road, Manalapan, NJ 07726:

- **A complete PC I/O board kit (part No. PCIO, contains PC board and all components)—$39.95**
- **Software, including compiled and source code versions containing the enhancements mentioned in the article (part No. PCC-S, specify disk size)—$8.00**
- **Continutiy tester parts (part No. PCC-H, contains six 4051 ICs, R1–R3, and D1—$8.00**

Send check or money order (foreign orders please send payment in notes redeemable at a U.S. bank. Please specify part numbers. The author will answer all questions, but they must be accompanied by a self-addressed stamped return envelope.

through current-limiting resistor Rl to +5 volts DC, obtained from pin 25 of the PC I/0 card. When any of the switches in IC1, IC2, or IC3 is turned on, 5 volts is passed through that switch to Jl and the associated test line. Switch selection is controlled by pins 1, 2, and 3 of Pl, which are connected to the select inputs of the 4051s. This allows the PC to select any one of the eight internal switches in ICl, IC 2, or IC3.

The select inputs of all three 4051s are connected together. However, only one 4051 should be active at a time if the circuit is to work properly Therefore, the inhibit pins (pin 6) of the 4051s are also controlled by the PC. That permits the computer to activate any one of the 4051s and inhibit the other two.

The output side of the tester is essentially the same circuit, but with one difference. The 4051 common output/input pins (pin 31 are connected together and output at Pl pin 17. That pin, an input to the PC I/O board, must see either a low (ground) or high logic level. Since the 4051s will output either a high (+ 5 volts) or a high-impedance open, R2 is positioned between the output and ground as a pull-down resistor to ensure that a logic low can be sensed.

The goal of the circuit design was to test cables with up to 25 conductors. However, the three 4051s can test only 24 lines. Therefore, another way to check that last line had to be found. Pin 7 of Pl can send a signal through diode Dl to Jl pin 25. On the output side, J2 pin 25 goes to Pl pin 18 which can sense the output. The diode ensures that Jl pin 25 will not pull up any line to which it is shorted and give a false indication.

Building the circuit

The circuit can be built on perfboard. Begin by soldering a 5-inch length of solid No. 24 wire to each of the 25 pins of two female DB-25 connectors (Jl and J2). Then solder a 5-inch length of No. 24 solid wire to pins 1-6, 9-14, 17, 18, 23. and 25 of a second female DB-25 connector (this will be Pl).

The circuit can also be built on a solderless breadboard with at least 50 rows of connection points and two vertical rows for power distribution. The circuit should be housed in a case that provides support for the panel-mount DB-25 connectors. It is

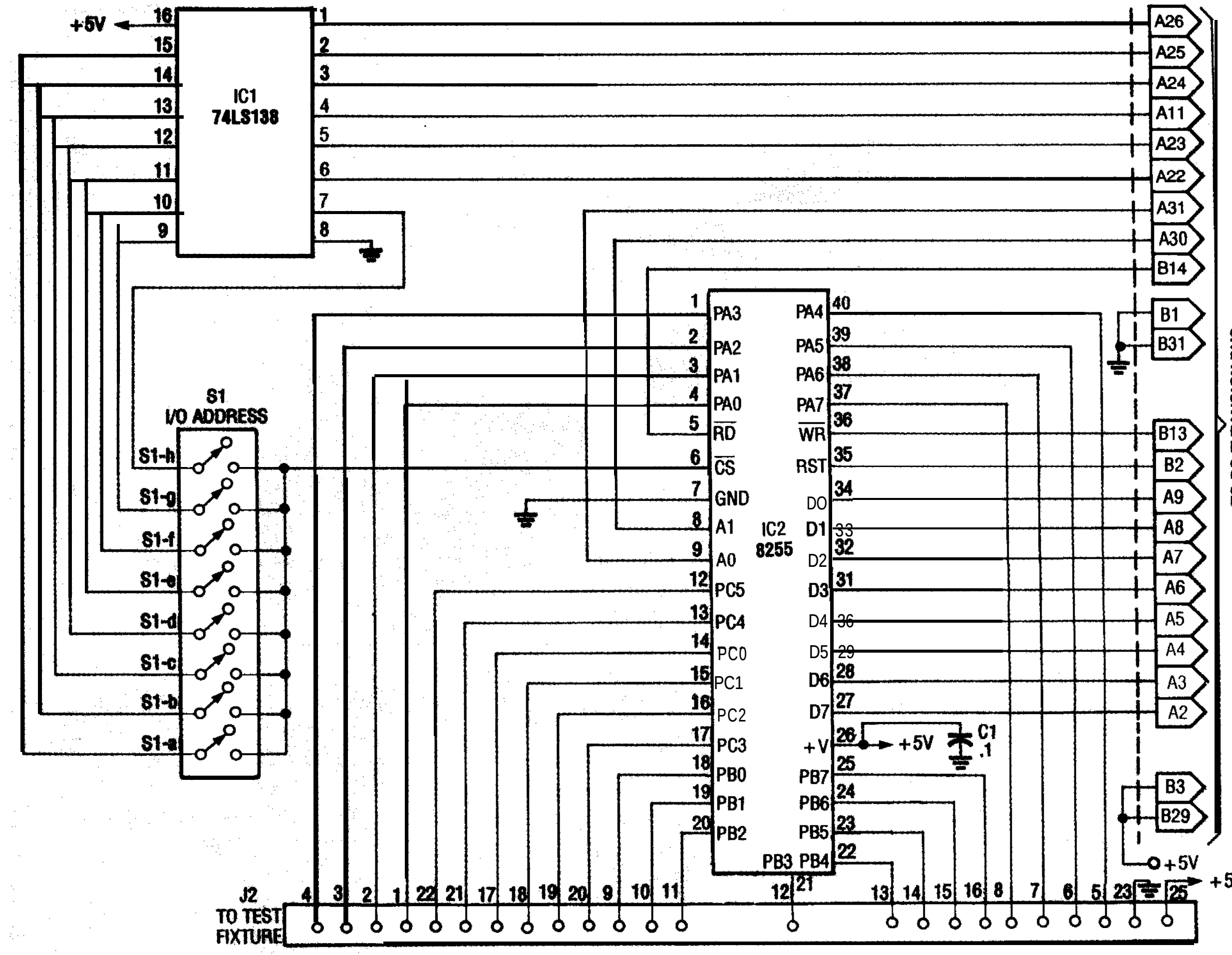

FIG. 4-THE PC I/O INTERFACE was described in detail in Radio Electronics, July 1991. This is the original circuit.

recommended that you mount the connectors to the case before wiring them.

Testing

To test the continuity tester your PC must be equipped with a PC I/O card, a male-to-male DB-25 cable, and a logic probe or voltmeter. Connect the cable from the PC I/0 board to Pl and turn on the computer. Check for about + 5 volts on pin 16 of each 4051, and ground on pins 7 and 8. Type in and run the output test program in Listing 1 using GWBASIC. BASICA or QUICK-BASIC. Alternatively, the programs are available on the Gernsback BBS as part of a file called CONTTEST.TXT

When running that program, enter each pin number (1 through 25) in turn. When "Press any key to continue..." appears, check that pin for a

LISTING 1

```
1  CLEAR : CLS :  DEFINT A, E, I-K, 0: DIM INH(4). I(625), O(625)
2  INH(1)48:      INH(2)INH(3)    =
3
4  REM:PcI/O                C            a              r            d
5  OUT ADD + 3, 137: REMl:      PCI0   F CA=OUT, B=OUT,    C = I N
6                        (C)   1 9 9 2Barbarello
7  INPUT "Which Jl      (1..25)...";   W H I C H
8  IF WHICH >               <   9   T H E N   I C   =   1
9  IF WHICH > 8             <   1 7   T H E N   I C   =   2
10 IF WHICH >                 <   2 5   T H E N   I C   =   3
11 IF WHICH = 25 THEN IC = 4
12 IMASK             - (IC - 1) * 8 -   1  INH(IC)
13                         IMASK   =   6 4   +   5 6
14 OUT ADD, IMASK
15 PRINT "Press any key to continue...";
16                                :  P R I N T
17    ASC(A$)   =   2 7   T H E N   E N D
18 GOT0 6
```

high signal. Then press a key and enter another pin number. Continue this until you've verified the operation of all 25 pins.

'lb check the output side, type in and run the input test program in Listing 2. Connect one end of a jumper wire to the junction point of pin 3 of ICl-IC3 Rl.

J2 (1..25)...," p l a

the pin number you want to test. While holding it there, en-

next line you'll see a "1" or a "0." A "1"

LISTING 2

```
1  CLEAR : CLS : DEFINT A, E, I-K, 0: DIM INH(4), I(625), O(625)
2  INH(1) = 48: INH(2) = 40: INH(3) = 24
3  DEFUSR = 64: ADD = 640
4  REM: Change ADD if necessary to match the address of your PcI/O Card.
5  OUT ADD t 3, 137: REM: Set PCIO For A=OUT, B=OUT, C=IN
6  REM: INPUT TEST (c) 1992 JJ Barbarello
7  INPUT "Which J2 Pin (1..25)..." WHICH
8  IF WHICH > 0 AND WHICH < 9 THEN IC = 1
9  IF WHICH > 8 AND WHICH < 17 THEN IC = 2
10 IF WHICH > 16 AND WHICH < 25 THEN IC = 3
11 IF WHICH = 25 THEN IC = 4
12 IMASK = WHICH - (IC - 1) * 8 - 1 + INH(IC)
13 IF WHICH = 25 THEN IMASK = 56: A = 2: OUT ADD, 64 + IMASK ELSE A = 
14 OUT ADD t 1, IMASK
15 PRINT INP(ADD + 2) AND A, IMASK
16 PRINT ; "Press Any key to continue...";
17 A$ = INPUT$(1): PRINT : PRINT
18 IF ASC(A$) = 27 THEN END
19 GOT0 6
```

LISTING 3

```
1  CLEAR : CLS : DEFINT A, E, I-K, 0: DIM INH(4), I(625), O(625)
2  INH(1) = 48: INH(2) = 40: INH(3) = 24
3  DEFUSR = 64: ADD = 640
4  REM: Change ADD if necessary to match the address of your PcI/O Card.
5  OUT ADD + 3, 137: REM: Set PCIO For A=OUT, B=OUT, C=IN
6  REM: BASIC TESTER (c) 1991 JJ Barbarello
7  PRINT "Press Any key to begin...";: A$ = INPUTS(l): PRINT
8  ICNT = 0
9  FOR I = 1 TO 25
10 IF I = 1 THEN ICl = 1
11 IF I = 9 THEN ICl = 2
12 IF I = 17 THEN ICl = 3
13 IMASK = I - (ICl - 1) . 8 - 1 + INH(IC1)
14 IF I = 25 THEN IMASK = 64 + 56
15 OUT ADD, IMASK
16 FOR J = I TO 25
17 IF J >= 1 THEN IC2 = 1
18 IF J >= 9 THEN IC2 = 2
19 IF J >= 17 THEN IC2 = 3
20 IMASK2 = J - (IC2 - 1) * 8 - 1 + INH(IC2)
21 IF J = 25 THEN IMASK = 64 t 56
22 OUT ADD t 1, IMASK2
23 ISTATUS = (INP(ADD + 2) AND 1)
24 IF ISTATUS = 1 THEN ICNT = ICNT t 1: I(ICNT) = I: O(ICNT) = J
25 IF I = 25 AND J = 25 AND (INP(ADD t 2) AND 2) = 2 THEN ICNT = ICNT t 1:
     I(ICNT) = I: O(ICNT) = J
27  NEXT J
28 NEXT I
29 FOR I = 1 TO ICNT
30 PRINT I(I); "-"; O(I), : NEXT
```

number again. This time you should get a "0." Follow the same procedure for all 25 pins of the connector.

Basic use

The most basic use of the tester is checking DB-25 male-to-male cables. Connect the cable to be tested between J1 and J2 and run the basic tester program in Listing 3. A typical output from the program will show the connections found. Also, if the circuit has a short, say between pins 2 and 3, you'll see two additional entries, 2 - 3 and 3 - 2. If the circuit has an open, that pin will not be shown as a connection (for instance, there would be no 5 - 5 if there were an open on line 5). The complete test of all 625 possibilities will take only a few seconds.

Enhancements

With the basic program, you must determine which lines were connected, which are missing, and which are shorted by visually scanning the list. This is OK for a one-time check, but inefficient for repetitive testing of the same kind of circuit. One enhancement would be to have a data file that defines the desired connections and display PASS or FAIL with only the open or short circuits listed.

To check cables other than DB-25 male-to-male, you must make appropriate adapters. For example, to check a DB-9 cable. you would make two adapters as shown in Fig. 5. Connect the adapters to J1 and J2, and the DB-9 cable to the adapters.

You can also test bare PC boards. Here you create a "bed of nails," which is a base with pins that contact the PC board in specific spots. The PC board is placed on the base and the spring-loaded pins (called "pogo" pins) make contact with the test points on the board. You could then check to see if specific points are connected, open, or shorted. If more than 25 points have to be tested, you could make multiple bases for additional tests.

Attenuation can also be tested. For example, if the cable must have less than 10 ohms resistance, replace Rl and R2 with potentiometers. If you then temporarily place a 10 ohm resistor between pin 1 of Jl and J2, and run the input test program in Listing 2, you can adjust the voltage level so that the indication changes from a "1" to a "0." Then back off the potentiometer so the indication changes back to a "1." Now, any device with a resistance higher than 10 ohms will cause less voltage to be dropped across R2 and give a "0" indication. Ω

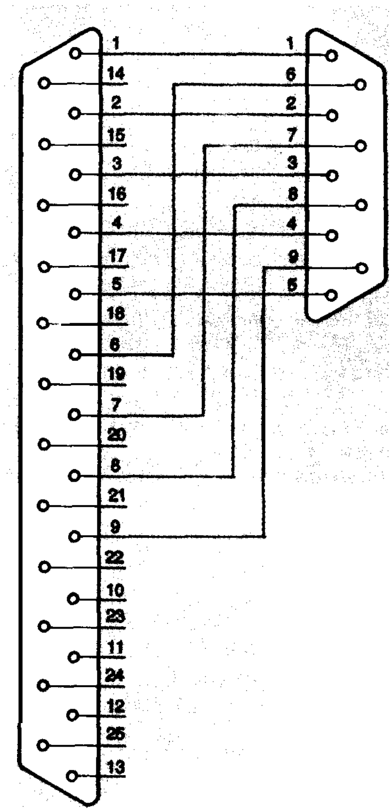

FIG. 5—TO CHECK A DB-9 CABLE, make two adapters and connect them to Jl and J2.