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[54] **ADAPTER FOR TERMINATING MULTICONDUCTOR SIGNAL TRANSMISSION CABLE**

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[52] **U.S. Cl.** ..... **324/58 R,** 324/58 A, 324/58 B, 324/158 F, 333/22 R, 333/8, 339/29 R, 339/143 R, 339/198 E

[51] **Int. Cl.** **G01r 27/04**

[58] **Field of Search** ..... 333/1, 8, 9, 22, 333/79; 324/58 A, 58 B, 158 F; 339/29, 107, 143 R, 176 MF, 198 R, 198 C, 198 E; 179/175 R; 178/69 R, 69 G

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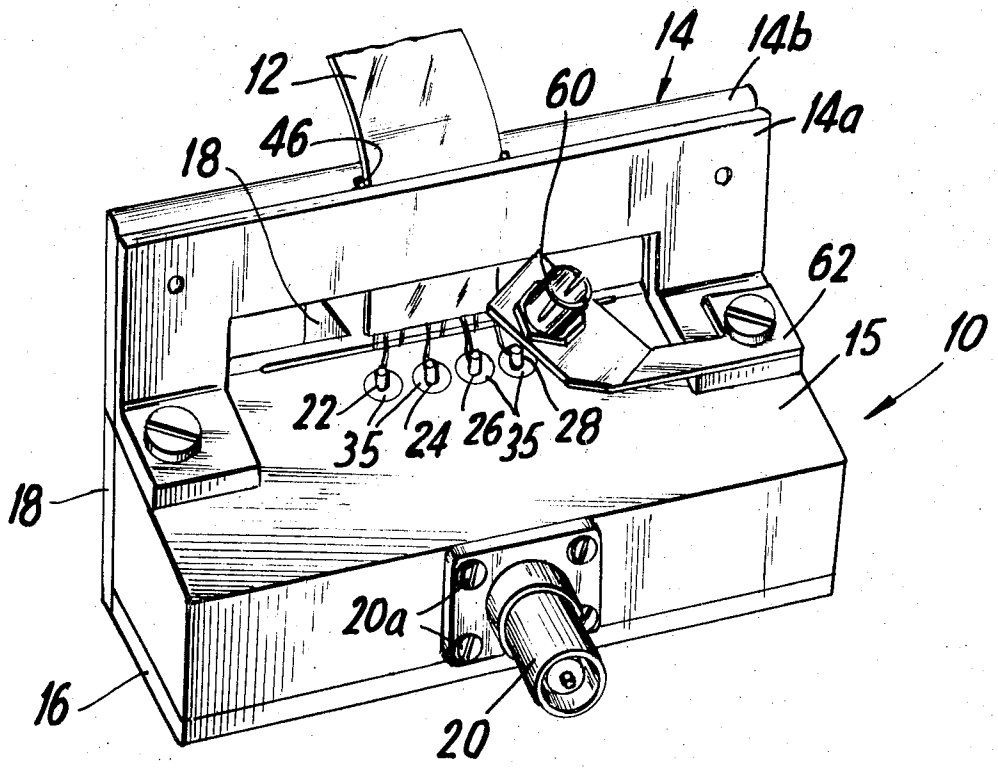
Primary Examiner—Paul L. Gensler

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[57] **ABSTRACT**

An adapter for terminating the conductors of a multiconductor signal transmission cable with matched impedances and including a conductive terminating block carrying removable impedance elements disposed in bores within the block and providing exterior terminals to which driven signal conductors of the cable may be connected. An external connector on the block is internally connected through another suitable input impedance element so that an input signal may be simultaneously impressed, via the impedance elements, on selected conductors of the cable to be driven. An output terminal provided by a quiet line load impedance carried within the block is disposed to accept a conductor of the cable upon which output signals are to be measured.

4 Claims, 7 Drawing Figures



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2 Sheets-Sheet 1

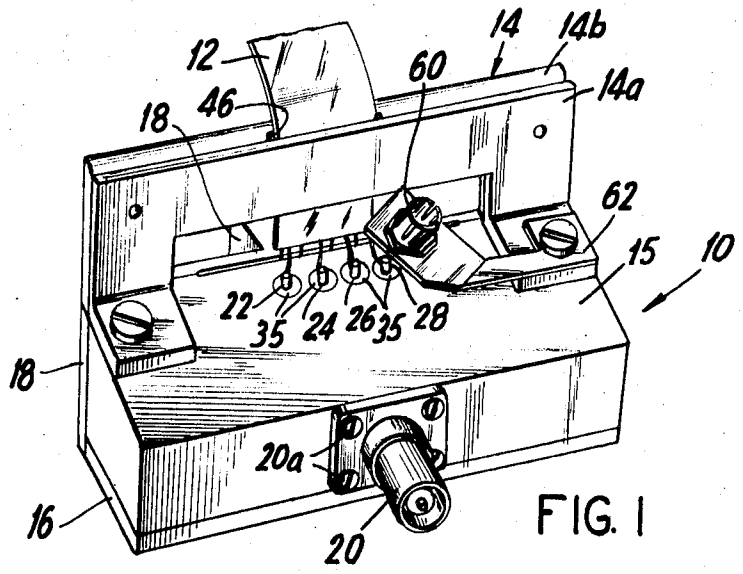


FIG. 1

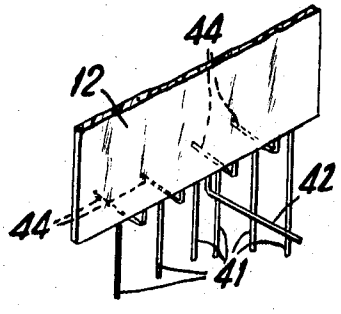


FIG. 1A

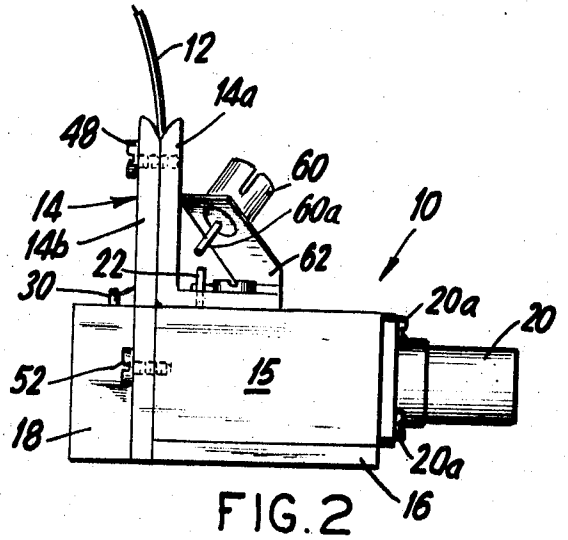


FIG. 2

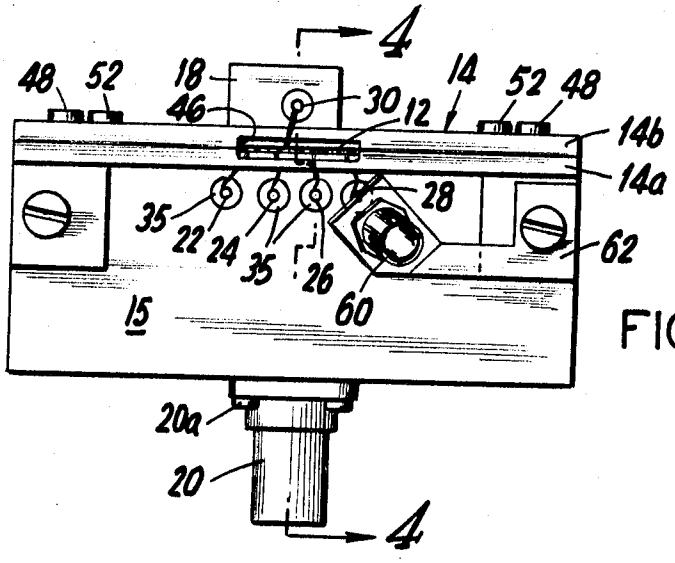


FIG. 3

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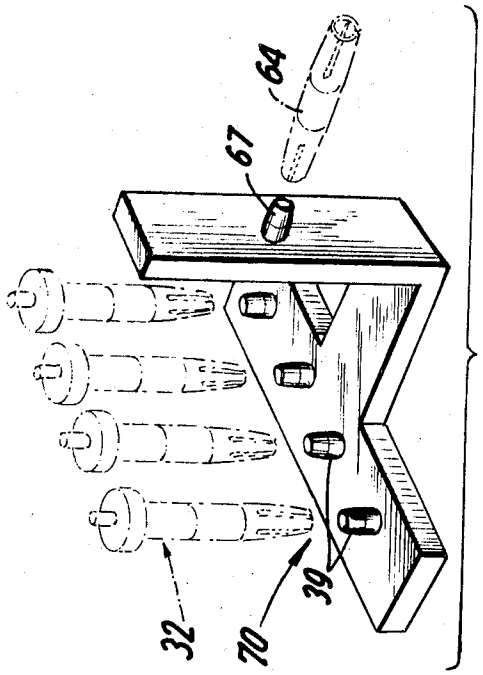


FIG. 5

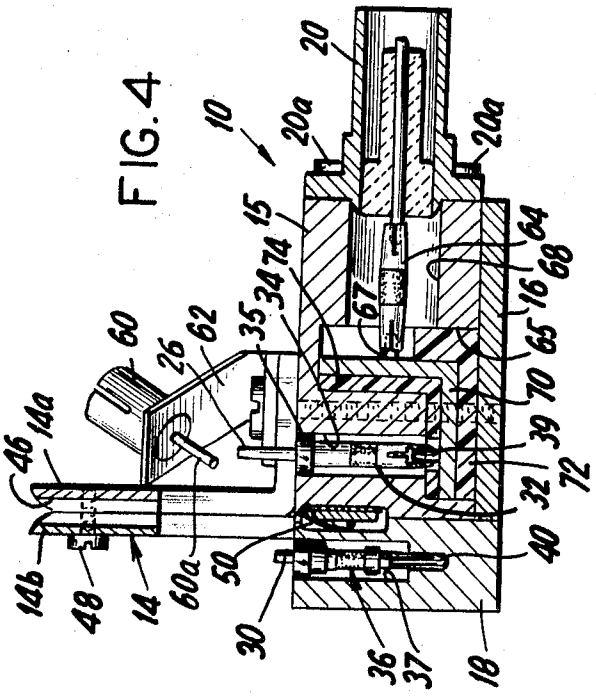


FIG. 4

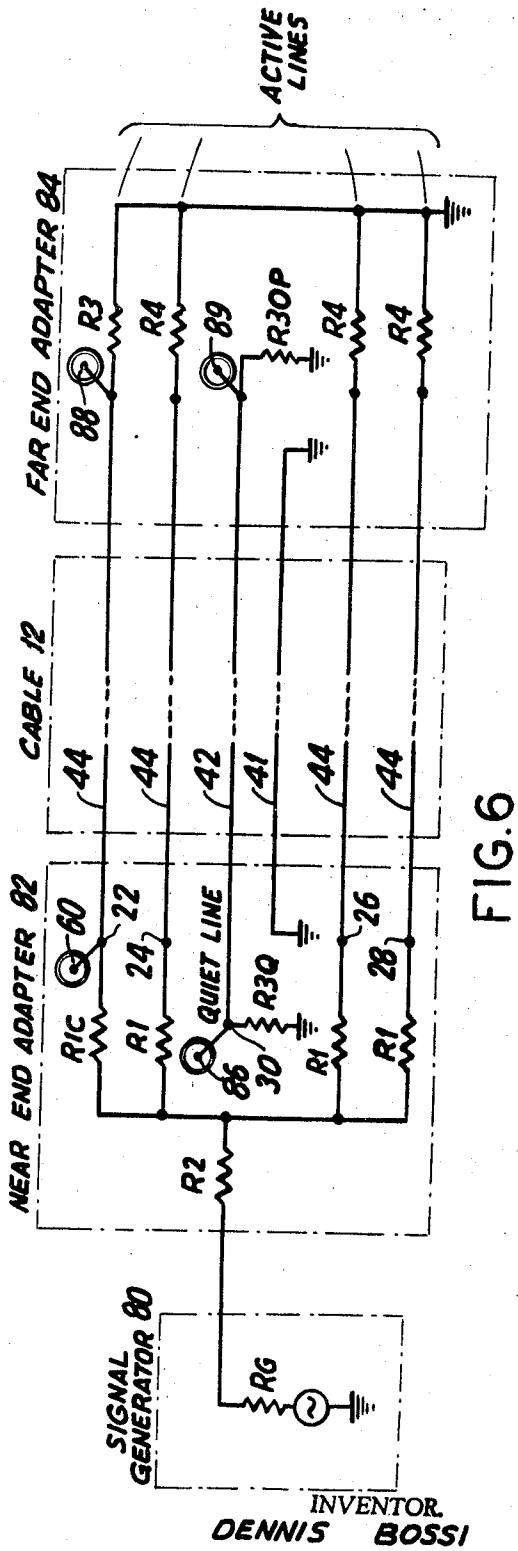


FIG. 6

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ADAPTER FOR TERMINATING MULTICONDUCTOR SIGNAL TRANSMISSION CABLE

BACKGROUND OF THE INVENTION

This invention relates to adapters suitable for terminating signal conductors in a desired manner. Specifically, it relates to a novel test adapter which provides terminal connections to several conductors of a signal transmission cable so that signal measurements and other tests may be obtained time and again in a consistent manner.

Although there has been substantial increased use of multiconductor signal transmission cables and, particularly, cables of this general category called flat (tape) cable, there are no means by which such cable can be examined for various important small signal parameters to obtain meaningful, consistent results. Such parameters include cross-talk, reflection constants, distributed impedance, attenuation, propagation and velocity. In this regard, it is generally quite critical that the cable be terminated properly, that is, in its characteristic impedance and that, in so doing, excessive lumped impedances are not inserted into the network by the connectors, solder joints, connecting wires and the like. Moreover, it is extremely time consuming to fabricate custom impedance terminations of each length of multiconductor cable to be tested. Essentially, that is the practice as it has existed prior to this invention.

It has been the procedure, in testing flat multiconductor cable, for example, to utilize a printed circuit board and to solder to the terminals of the board the individual conductors of the cable. Any terminating impedances are connected directly to the board, along with the reference potential conductors (usually called the ground conductors) and signals from a suitable signal source are injected into the cable by way of the various connections and terminals on the printed circuit board. This procedure can be made to work satisfactorily for each individual cable under test; however, it is often found necessary to alter or change impedances or the positions of the various conductors mounted to the printed circuit board in order to ensure the closest possible match of the cable to its characteristic impedance. This task becomes increasingly difficult, as deviations in the values of the effective terminating impedances due to variations in the laboratory test set-up can approach critical values (particularly reactive values) of the characteristic impedance of the cable.

In general, there has been no universal adapter for terminating consistently and accurately multiconductor cable and etched circuitry. Although laboratory testing set-ups, once adjusted, work satisfactorily, they are unreliable at very high frequencies. Because signal transmission cables and etched circuit conductors are finding increased use in computers, the transient response of such cables and circuits must meet increasingly stringent standards. It has been found that the printed circuit board set-ups cannot be relied upon for consistently accurate measurements where the rise time requirements fall below 10 nanoseconds. That is, the printed circuit test set-ups are not truly satisfactory for making test measurements where the signal rise time is less than 5 or 10 nanoseconds. Using the adapter of the present invention, however, reliable measurements may be taken using signal rise times of 1 nanosecond or less.

SUMMARY OF THE INVENTION

The present invention remedies the shortcomings associated with the previously used techniques for testing multiconductor cable by providing a unitary adapter applicable to the termination of many types of cables and etched circuitries and providing, in a single unit, all terminating impedances and connectors for the conductors of the cable undergoing test. Broadly, the adapter provides a connection terminal for at least one conductor of the cable upon which an imput signal can be impressed and a second connection terminal for another conductor of the cable upon which any induced signals are to be measured and terminating impedance means associated with each of those terminals.

Although the invention can take certain alternate forms, the preferred form of the invention implements removable terminating impedances received within bores in a conductive block of the adapter. Thus, each impedance element is located to have a consistent physical relation to the other and, moreover, shielded from the other impedances by the conductive block itself. These impedances may be implemented in both a sending end adapter and a receiving end adapter, similarly constructed, and may be used to terminate the input (drive) conductors, as well as the quiet (output) conductor upon which cross-talk and interference are measured.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the invention, reference should be made to the following detailed description of preferred embodiments, and to the drawings, in which:

FIG. 1 is a perspective view of an adapter according to the invention;

FIG. 1A is a perspective view of the terminal end of a cable to be tested;

FIG. 2 is an end view of the adapter of FIG. 1;

FIG. 3 is a plan view of the FIG. 1 device;

FIG. 4 is a cross-sectional view of the adapter, taken generally along the lines 4—4 of FIG. 3;

FIG. 5 is a perspective view of one of the internal elements of the adapter; and

FIG. 6 is an electrical schematic diagram of the invention connected to a cable under test.

DESCRIPTION OF THE PREFERRED EMBODIMENT

An adapter according to the invention for terminating a flat multiconductor signal transmission cable is shown in FIG. 1. It includes a conductive, unitary block 10 which contains all the elements necessary for proper termination of the cable 12 under test. In general, the device should provide correct termination impedances at both ends of the cable. Thus, the adapters are generally used in pairs, and, although the units used at the sending end (the near end) and the receiving end (the far end) may be physically identical, the two units generally will be different in certain minor respects, as will later become apparent. The adapter of FIG. 1 is intended to represent the sending end device and its purpose is to provide proper termination of each signal conductor of interest at the near end of the cable under test, and to present to the signal source a load enabling the signal generator to produce satisfactory signals. For example, the load presented to a step pulse generator

often affects the rise time of the pulse, and most generators are designated to operate with a specified load of, for example, 50 ohms.

When a cable is properly terminated for testing, each conductor of the cable is loaded at the far end with its characteristic impedance Z_0. Likewise, each signal conductor of the cable at the near end, looking toward the driving source (or generator), is terminated in the characteristic impedance Z_0. The signal generator, on the other hand, at the input terminal to the adapter should encounter a specified impedance, usually equal to the internal impedance of the generator.

In FIG. 1 the flat cable conductor **12** is shown electrically and physically attached to appropriate terminals provided on the terminal block **10.** The cable **12** is clamped between the two sections **14***a*, *14b* of a support bracket, suitably secured to the front half **15** of the terminal block **10.** The terminal block also includes a lower plate **16,** a back closure section **18** and a coaxial input connector **20** to which the signal output connector of a suitable driving source, such as that contained in a time domain reflectometer, may be attached.

The front section **15** of the terminal block contains internally several impedance elements, among those being four mutually spaced resistances **32** (See FIG. 5) providing exposed, external terminals **22, 24, 26** and **28.** To each of these terminals may be connected one of the signal conductors in the cable **12,** specifically, those conductors which are to serve as the driven, or active, signal lines. It is on each of these conductors that an input signal is impressed simultaneously in order to obtain a reliable measurement of cross-coupling or interference on one or more other conductors. Although it is possible to employ more or fewer such terminals for the driven lines, the use of four driven lines has come to be common, if not universally accepted, practice.

The back section **18** of the block **10** carries a terminal **30** for the connection of the quiet, or signal output, line upon which cross-talk measurements may be obtained. This terminal **30** may be best seen in FIGS. **2–4.**

All of the terminals **22–30** in the embodiments shown are formed at the ends of interchangeable impedance elements that correctly load the cable conductors. These impedance elements, for most lines, may be purely resistive, although it is within the scope of this invention to provide impedances that are reactive. The impedances **32** are relatively uniform in size and each is received within a bore **34** in the front section **15** of the terminal block and insulated therefrom by the dielectric bushing **35.** These impedances **32** are connected to the driven conductors. The impedance **36** is received within a similar bore **37** in the rear section **18** of the block and is connected to the quiet line during testing.

At the lower ends of the bores **34–37** are miniature pins **39, 40,** respectively, over which fit the radially expansible ends of the resistive impedances, these ends being conductive and, preferably, coated with a material of extremely high conductivity such as silver. The pin **40** is supported and electrically connected directly to the block **10.** (Although the invention is not limited to any particular kind of impedance, or any particular resistive element, representative interchangeable resistors are Nos. 5417 manufactured by Filmohm Corp., New York City, or No. 125R250BC manufactured by Pyrofilm Corp., of New Jersey.)

The individual conductors may be attached to the terminals **22–30** by any suitable method, such as soldering, clip connectors and wrapping; however, solder connections are preferred because certain types of connectors introduce excessive lump inductance and therefore affect the accuracy of the measurements.

The manner of connecting the conductors of the cable **12** to the adapter is best understood from inspection of FIG. 1A. Generally, multiconductor, small-signal flat cables contain a great number of fine wire conductors, many of which are ground or shield conductors, and these are commonly arranged to alternate with each signal conductor. When in use, these ground (reference potential) conductors are connected to a point of common potential, such as the ground bus bar or other grounding point. In the adapter, the ground conductors **41** are also connected to reference potential, in this case the reference point being the conductive terminal block **10** itself. As shown, these conductors **41** extend generally parallel to the cable. A quiet line conductor **42** is bent to one side of the cable **12** and four active conductors **44** are bent to the other side of the cable to avoid undue capacitive coupling between the quiet conductor **42** and the active conductors **44.** The active and quiet lines should be any five adjacent signal conductors of the cable, with two active lines being selected on each side of the quiet line.

To prepare a flat cable for testing, it is first cut to the desired length and the insulation is stripped from the final one-half inch or so of each end of the cable to leave an equal length of conductors exposed. It is recommended that all of the ground cable conductors **41** be pretinned to ensure best electrical contact to the grounding strip located within the adapter **10,** as will be explained momentarily. If the cable specimen to be tested is shielded or coaxially flat tape cable, the shield should be exposed to make electrical contact with the strain-relieving mounting brackets **14** which, in a preferred construction, are silver plated at the facing interior surfaces.

Referring to FIG. **3,** it is noted that the mounting bracket sections **14***a*, **14***b* are recessed to provide an opening **46** for receiving the cable **12.** During connection of the conductors to the terminals **22–30** of the adapter, the rear mounting bracket **14b** may be removed entirely, together with the back section **18.** This exposes a thin copper metallic grounding strip **50** (see FIG. **4**) located so that the individual ground conductors **41** of the cable may be soldered to that strip. In certain cases, it may be possible, (although not as reliable) to permit the resiliently mounted leaf conductor **50** to bear against the ground conductors when the back section **18** of the adapter is rejoined to the front section **15.** This back section is secured to the front section **15** by a screw or similar fastener **52** at the rear of the adapter. The active lines **44** are connected to the terminals **22–28,** whereas the quiet line is connected to the terminal **30,** as can be seen from inspection of FIGS. **1–3.** Once the conductors have been connected to the terminals, the removable section **14***b* of the bracket is placed into engagement with the cable **12** by tightening the screws **48** securing together the two sections of the mounting bracket.

The adapter also includes a coaxial receptacle connector **60** supported on a bracket **62** on the front section **15** of the adapter so that its signal terminal **60***a* is disposed in close proximity to one or more of the termi-

nals 22–28. When a probe is inserted into the receptacle 60 and the terminal 60*a* is connected to one of the signal terminals 22–28, the input signal actually entering the conductors of the cable may be monitored. For example, if it is desired to determine the propagation time of a pulse along the conductor 44 connected to the input terminal 28, the terminal 60*a* is electrically joined (by a small conductor) to the terminal 28. If a probe inserted into the connector 60 is then supplied to the vertical drive terminals of a oscilloscope, the input pulse can be monitored and compared for time displacement against a reflected pulse from the far end of the cable.

To the end of obtaining measurements on the quiet line 42, a similar connector (not shown) may be supported in close proximity to the quiet line terminal 30.

Signal inputs to the four driven conductors 44 are supplied through the signal terminal of the input connector 20 and an input resistor 64 disposed within a specially formed interior cavity 65 in the front section 15 of the terminal block. The impedance 64 may also be a resistor of the interchangeable type, to which access is attainable by removing the small screws 20*a*, securing the connector to the front of the block. One terminal of the input impedance 64 is connected directly to the signal terminal of the front connector 20, the other terminal engaging the small pin 67 supported in alignment with the channel 68 in the block 10. The pin 67 is connected electrically to the pins 39 receiving the impedances 32 by means of a thin L-shaped copper conductive strip 70. This strip has a T-shaped configuration in plan view, as best seen in FIG. 5. The T-shaped portion of the strip carries the pins 39, whereas the forward upstanding portion supports the pin 67 for the input resistor 64. This strip 70 is specially shaped so that its cross-section gradually increases toward the center of the strip and is designed so that it provides substantially the same impedance and voltage drop between the pin 67 and each of the pins 39 for the individual impedances 32.

It is observed that the individual impedances 32 are maintained in coaxial relation to the bores 34, at the upper ends by the small dielectric bushings 35, and at the lower ends by the locations of the pins 39, 40. These bushings contain an aperture through which the terminals 22–30 can project and, when the impedance element is lifted out of the bore for interchanging or replacement, the busing accompanies the impedance (FIG. 5), and may be inserted over impedances of other values.

Insulating the T-shaped strip from other parts of the block are pieces of dielectric material 72, 74 having an L-shaped cross-section and securely positioning the strip 70 within the chamber 65.

FIG. 6 illustrates schematically the test circuit for a multiconductor cable attached at the near end to the adapter of FIG. 1 and, at the far end, to a similar adapter which, however, need not contain an input connector 20. The resistors R1 and R1C correspond to the impedance elements 32 of FIGS. 1–4, whereas the resistor R3 corresponds to the quiet line impedance 36. At the far end, the impedances R3, R30P and R4 on the active lines correspond to the impedance elements 32 in FIGS. 1–4, whereas the quiet line impedance R3Q corresponds to the impedance element 36. Terminals 22–28 may be considered input terminals, and terminal 30 may be thought of as an output terminal. Resistors R3 and R4 are grounded at one terminal to the block.

The values of the various resistive elements shown in FIG. 6 for the four active conductor and one quiet conductor case, are given as follows:

$$R1 = Z_0 \times (400+Z_0)/(800-Z_0) \qquad 1\text{–}5$$

$$R2 = 50 - (R1+Z_0)/4 \qquad 1\text{–}5$$

$$R30P = 500Z_0/(500-Z_0)$$
$$R1C = (R1 + Z_0)/(Z_0 + 500) \qquad 1\text{–}5$$

$$R4 = Z_0 \qquad 1\text{–}5$$

The foregoing equations may be applied to determine the resistive impedance values required in order to properly match and terminate a multiconductor cable of which each driven conductor has a characteristic impedance of less than 200 ohms. Also, as seen in FIG. 6, the equations assume a signal source impedance of 50 ohms, which is standard. The impedances R3 are slightly larger than the characteristic impedance Z_0 and are selected by assuming that the probe or connector, e.g., the lead of connector 60 connected to a measuring instrument loads the line with a 500 ohm resistive impedance. This is also the assumption with respect to the resistance *R1C*.

Referring to FIG. 6, the test arrangement includes a signal generator 80 having the internal resistance R_G a near end adapter 82, the cable 12 and a far end adapter 84. The far end adapter 84 may be identical in every respect to the near end adapter, except (as already noted) for the omission of the input signal connector and the compensating resistance R2 (which corresponds to the impedance 64 shown in FIG. 4). The probe connector 60 and an additional probe connector 86 on the near end adapter for measuring signals on the quiet line, as well as similar probe connectors 88, 89 at the far end adapter, are used to monitor and/or measure the characteristics of signals arriving or impressed upon the active and quiet cable conductors. These far end connectors may be attached to the far end adapter in the same manner described with reference to the near end adapter.

Several measurements may be made with the foregoing set-up, using a dual trace oscilloscope or a time domain reflectometer. For example, the propagation time of a cable specimen under test may be determined by observing and recording an imput pulse on the screen of the oscilloscope and noting or recording the arrival of a signal pulse at, for example, the terminals to which the probe receptacles 88 and 89 are connected at the far end. The time difference, as recorded on the screen, can then be determined, from the pulse separation and trace sweep rate. Attenuation can be determined from the same procedure by comparing the displayed pulse rise time at the input and at the output of the cable.

Cross-talk is easily determined with the adapters by injecting a pulse from the signal generator 80 on the four active lines 44 and measuring the signal appearing

at the terminal **30** at the near end, and also at the corresponding terminal connected to the probe socket **89** at the far end. The relative amplitude of the quiet line signal and the active line signals can be compared, for example, on a dual trace oscilloscope.

In addition to the foregoing simple and straightforward measurements possible with the adapters, the time domain reflectometer may be employed to determine discontinuities in any of the cable conductors or to determine other mismatches and imperfections. These techniques are known to those skilled in the art and therefore do not warrant special treatment here. In general, they involve examining the shape of the reflected pulse waveforms.

From the foregoing description, it should be realized that the invention presents many advantages in the testing of multiconductor cable. It gives consistent reliable results and eliminates most spurious reflections and undesired signal coupling due to faulty or careless test circuits. A cable may be consistently matched to not only a correct load, but to the signal source as well. It provides a rugged construction not easily damaged by physical abuse and a versatility of adaptation to several types of cable and measuring instrumentation.

Although the invention has been described with reference to specific embodiments, certain variations and modifications will occur to those skilled in the art. For example, the terminating block may take on different configurations other than those specifically illustrated herein. Further, it may be possible to render only certain parts of the terminating block conductive in order to accomplish the function of the all-metal terminating block. In this regard, a dielectric terminating block can be used if plated or otherwise coated with a conductive material to reduce interconductor coupling at the matching impedances or probes. The all-conductive block is, however, preferred. Certain other variations are also possible as, for example, different locations of the terminals on the block and with respect to the mounting bracket. Accordingly, all such modifications and variations are intended to be included within the scope of the appended claims.

What is claimed is:

1. An adapter for terminating multiconductor cable for testing purposes, comprising: a conductive terminating block having a plurality of cavities in at least one surface thereof; a plurality of impedance elements received within the respective cavities and providing exposed terminals near said one surface for the connection of cable signal conductors; and means providing an output signal terminal in spaced relation to said impedance elements for connection thereto of a conductor of the cable upon which signals may be measures; said terminating block includes first and second separable mating sections containing the impedance elements and the output terminal respectively.

2. An adapter as defined in claim **1** further comprising means disposed on said body for supporting a multiconductor cable in close proximity to said exposed terminals of said impedance elements.

3. An adapter as defined in claim **1** further comprising input means coupled to each of said plurality of impedance elements at their ends remote from said one surface of said terminating block whereby input signals can be supplied to said multiconductor cable.

4. An adapter for terminating multiconductor cable for testing purposes comprising: a conductive terminating block having a plurality of cavities in at least one surface thereof; a plurality of impedance elements received within the respective cavities and providing exposed terminals near said one surface for the connection of cable signal conductors; means providing an output signal terminal in spaced relation to said impedance elements for connection thereto of a conductor of the cable upon which signals may be measured; a terminating impedance element disposed within said terminating block and electrically coupled between said output signal terminal and the block; and signal probe means supported on said block to have a terminal thereof in close proximity to one of said conductor terminals.

* * * * *