United States Patent

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[73] Assignee **Beckman Instruments, Inc.**

[54] **ATTENUATOR SWITCHES HAVING DEPOSITED LAYER-TYPE CIRCUITRY**
18 Claims, 12 Drawing Figs.

[52] **U.S. Cl.** ..... **338/190,** 333/81 R, 338/201
[51] **Int. Cl.** **H01c 9/04**
[50] **Field of Search** ..... 333/81 R, 81 A, 81 B, 81 C; 338/200, 201, 190, 185

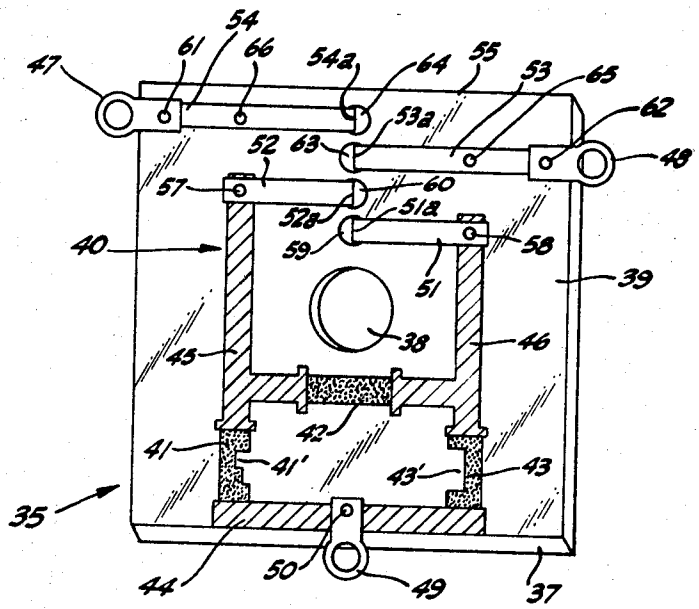
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ABSTRACT: Attenuator switches having deposited layer-type resistors, conductors, and switch pads. In one embodiment, a step attenuator comprises a plurality of π attenuator sections formed of resistive and conductive films disposed on stationary ceramic wafers. Relatively rotatable ceramic wafers carry conductive film switch pads which cooperate with switch contacts extending from the stationary wafers to bypass or insert selected π sections into an electrical circuit. A bridged-T embodiment includes an electrically insulative wafer having interconnected film-type resistors and switch pads on both faces thereof. A set of rotatable wiper contacts cooperates with the pads to control the effective attenuation of the bridged-T circuit.



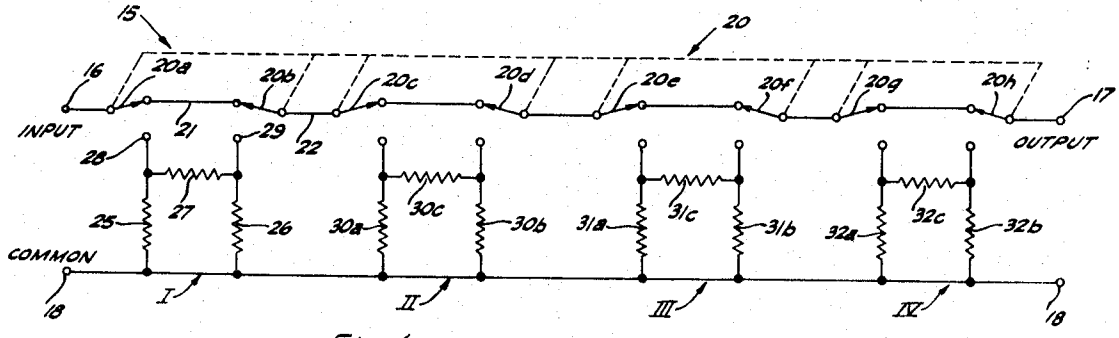


Fig 1

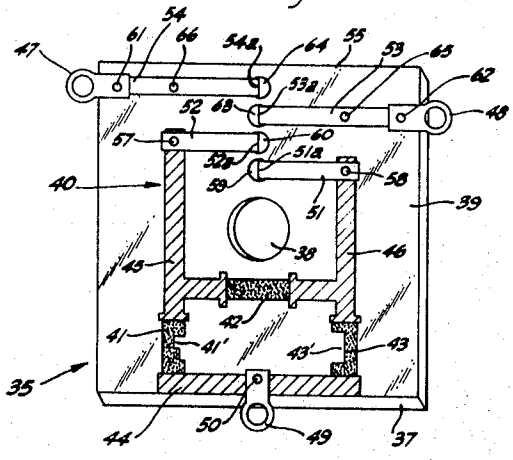


Fig 2

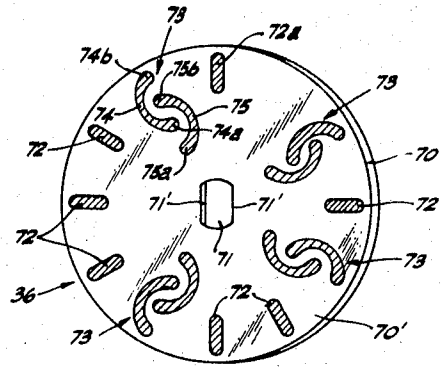


Fig 3

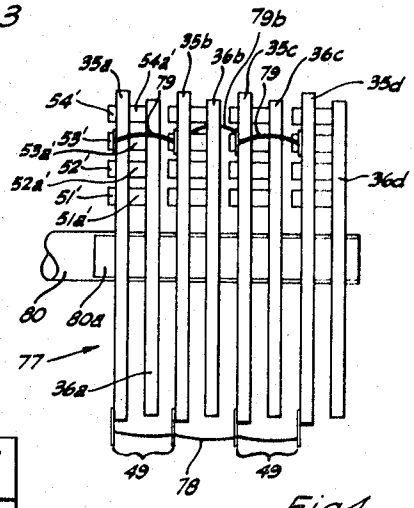


Fig 4

SWITCH POSITION	ATTENUATION IN db	WAFER 35a	WAFER 35b	WAFER 35c	WAFER 35d
1	0	B	B	B	B
2	1	I	B	B	B
3	2	B	I	B	B
4	3	B	B	I	B
5	4	B	B	B	I
6	5	I	B	B	I
7	6	B	I	B	I
8	7	B	B	I	I
9	8	I	B	I	I
10	9	B	I	I	I
11	10	I	I	I	I

WHERE I = INSERTED, B = BY-PASSED

Fig 5

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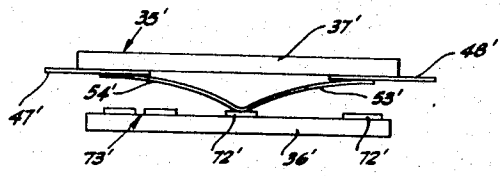


Fig 6

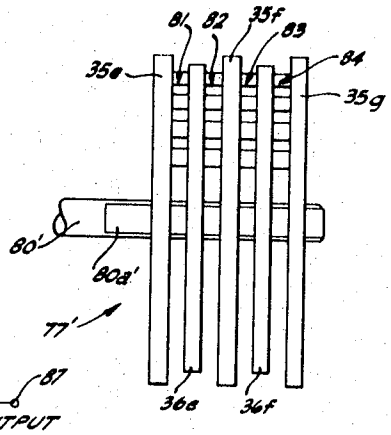


Fig 7

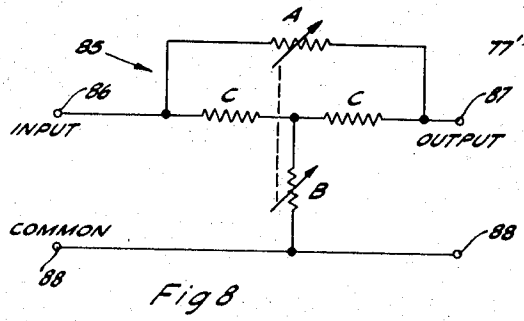


Fig 8

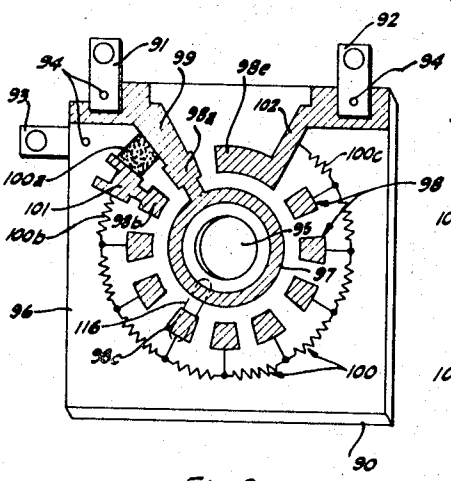


Fig 9

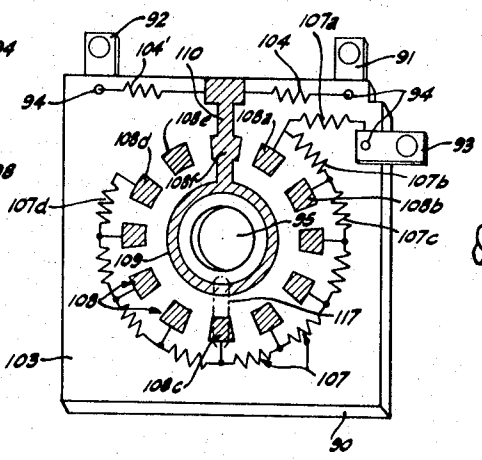


Fig 10

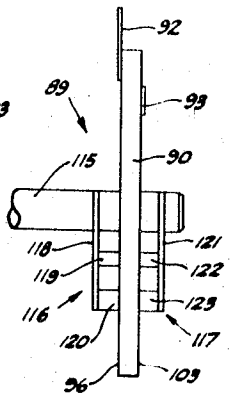


Fig 11

ATTENUATION IN db	$K=\frac{V_{IN}}{V_{OUT}}$	$A=Z(K-1)$	ΔA (FROM TERMINAL 92)	$B=\frac{Z}{K-1}$	ΔB (FROM TERMINAL 93)
0	1	0(SHORT)	—	∞(OPEN)	—
1	1.12	6	6	417	225
2	1.26	13	7	192	70
3	1.41	20.5	7.5	122	36
4	1.58	29	8.6	86	22
5	1.78	39	10	64	13.5
6	1.99	49.5	10.5	50.5	10.2
7	2.24	62	12.5	40.3	7.2
8	2.51	75.5	13.5	33.1	5.6
9	2.82	91	15.5	27.5	4.4
10	3.16	108	17	23.1	23.1

Fig 12

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ATTENUATOR SWITCHES HAVING DEPOSITED LAYER-TYPE CIRCUITRY

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to attenuator switches having deposited layer-type circuitry, and more particularly to step attenuators utilizing film-type resistors, conductors and switch pads disposed on ceramic or like electrically insulative wafers.

2. Description of the Prior Art

Step attenuator switches have found widespread use for the accurate level control of signals in audio and higher frequency ranges. Such switches offer the advantage of precision since, unlike slide-contact potentiometers, a definite amount of attenuation is inserted for a given switch setting. Moreover, step attenuators are free of noise such as that generated in a potentiometer as the contact slides over a resistive element. For these reasons, step attenuators are particularly well suited for use in high-quality audio systems and for instrument and like applications wherein accurate, precise attenuation is required.

In the past, step attenuator switches primarily have employed a plurality of fixed, discrete resistors, often individually wire wound, mounted in a single housing. The resistors are connected to one or more rotary switches typically employing heavy duty silver alloy contacts and multileaf switch blades to insure minimum contact resistance. The switches are used to insert appropriate sets of the resistors into an electrical circuit with which the attenuator is employed.

Prior art attenuator switches of the type just described are expensive and complicated to manufacture. This results in part because of the difficulty of tailoring discrete, wire-wound resistors to precise values. Moreover, heavy duty silver alloy switches themselves are expensive, and the required hand assembly of the attenuator is both costly and time consuming. The use of discrete resistors, individually connected by soldered, welded, or pressure connections to the switch contacts, significantly decrease the reliability of such prior art attenuators. Further, such attenuators are inherently of relatively large physical size and exhibit considerable effective capacitance and/or inductance which severely limits the use of such devices in high-frequency applications.

These and other shortcomings of the prior art are overcome by the inventive attenuator switches having deposited layer-type resistors, conductors, and switch pads. The attenuator switches are considerably simpler to manufacture than attenuators of the prior art, and are significantly less expensive, smaller, and more compact than existing switches. By minimizing the use of soldered, welded, or pressure connections, reliability of the devices is considerably improved. Further, the compact size, the absence of wire-wound resistors, and the reduced lead lengths characteristic of the inventive attenuator switches result in markedly reduced inherent inductance and/or capacitance, permitting the attenuators to be utilized in high-frequency applications.

SUMMARY OF THE INVENTION

In accordance with the present invention, there are provided attenuator switches utilizing deposited layer-type resistors, conductors and switch pads. The attenuator switches are easy to fabricate, inexpensive of high precision, and exhibit low effective capacitance and/or inductance. Exemplary embodiments include a step-attenuator having resistive π sections, and a bridged-T attenuator.

The step-attenuator embodiment of the invention includes a plurality of attenuator sections each formed of deposited layer-type resistors and conductors disposed on the face of a stationary, electrically insulative wafer. Typically, the wafer comprises a refractory substrate of steatite or alumina, on a face of which are disposed layer-type resistors of noble metal film, glass-metal (cermet) material, conductive plastic, or like resistive material. The resistors are interconnected in π T or any other common attenuator resistance array or configuration by means of film-type electrical conductors of palladium and gold, platinum and gold, cermet conductive materials or like material. Each water also includes input, output and common terminals. Switch contacts of conductive spring material such as beryllium-copper extend from the wafer and are electrically connected to the input terminal, the output terminal and to resistor junctions in the respective attenuator section.

Associated with each such stationary wafer is a relatively rotatable wafer of like ceramic material having a pattern of conductive switch pads disposed thereon. The switch pads cooperate with the spring metal contacts selectively to bypass or insert the associated attenuator section into an electrical circuit. When, for example, the attenuator section is a π array of resistors, separate stationary and rotary wafers may be utilized for each attenuator section. Alternatively, a single stationary wafer may include individual π sections on both major faces thereof, and a single rotary wafer may include two sets of switch pads cooperating with a pair of stationary wafers each containing a π attenuator section.

In a bridged-T embodiment of the invention, the resistor array is preferably fabricated on a single electrically insulative, ceramic wafer. The fixed resistors and the resistive elements comprising one of the adjustable resistors of the bridged-T circuit are disposed on a first major face of the wafer. The resistive elements comprising the other adjustable resistor of the bridged-T circuit may be disposed on the opposite face of the wafer. All resistive elements are fabricated of thick films of a material such as cermet or conductive plastic compatible with the ceramic substrate. Further, switch pads and electrical conductors interconnecting the resistive elements are formed of film-type conductive material disposed on the wafer faces. A set of contacts rotatable with respect to the ceramic wafer cooperate with the switch pads on both wafer faces to permit selection of the effective resistance of the bridged-T components and hence control the attenuation of the device.

Thus, it is an object of the present invention to provide attenuator switches having deposited layer-type circuit elements.

Another object of the present invention is to provide step attenuator switches utilizing deposited layer-type resistors, conductors and switch pads.

It is another object of the present invention to provide π section and bridged-T step attenuators using refractory substrates having deposited layer-type resistors, conductors and switch pads disposed thereon.

Still another object of the present invention is to provide a step attenuator including a plurality of selectively insertable attenuator resistor arrays, each comprising deposited layer-type resistors and conductors disposed on a ceramic wafer and cooperating with switch pads disposed on another, relatively positionable ceramic wafer.

It is yet another object of the present invention to provide a step attenuator switch having a plurality of relatively stationary ceramic wafers each containing a deposited layer-type resistive attenuator array, and a plurality of relatively rotatable ceramic wafers, the rotary wafers containing switch pads cooperating with contacts extending from the stationary wafers for selectively bypassing or inserting the associated attenuator arrays into an electrical circuit.

A further object of the present invention is to provide a bridged-T attenuator switch having deposited layer-type elements.

It is a still further object of the present invention to provide a bridged-T attenuator incorporating resistors, conductors and switch pads of deposited layer materials disposed on the faces of one or more ceramic wafers, and including means for selecting the effective attenuation of the bridged-T circuit.

BRIEF DESCRIPTION OF THE DRAWINGS

Still other objects, features and attendant advantages of the present invention will become apparent to those skilled in the art from a reading of the following detailed description of the

preferred embodiments constructed in accordance therewith, taken in conjunction with the accompanying drawings wherein like numerals designate like parts in the several figures and wherein:

FIG. 1 is an electrical schematic diagram of a step attenuator employing resistive π attenuator resistor arrays or sections;

FIG. 2 is a front elevation view of a switch stationary wafer having a resistive π section comprising deposited layer-type resistors and conductors disposed thereon;

FIG. 3 is a front elevation view of a switch rotary wafer having conductive switch pads of deposited layer materials disposed thereon;

FIG. 4 is a side elevation view of a step attenuator switch in accordance with the present invention and utilizing a plurality of stationary and rotary wafers of the type shown respectively in FIGS. 2 and 3;

FIG. 5 is a table setting forth attenuation as a function of switch position for a typical step attenuator switch as shown in FIG. 4;

FIG. 6 is a top plan view of cooperating stationary and rotary wafers employing a switch contact configuration alternative to that shown in FIG. 2;

FIG. 7 is a side elevation view of a step attenuator switch in accordance with the present invention and utilizing the switch contact configuration of FIG. 6;

FIG. 8 is an electrical schematic diagram of a bridged-T attenuator;

FIGS. 9 and 10 respectively are front and rear elevation views of a single stationary switch wafer having elements of a bridged-T circuit disposed thereon, the elements comprising film-type resistors, conductors and switch pads;

FIG. 11 is a side elevation view of a bridged-T attenuator in accordance with the present invention and incorporating the wafer of FIGS. 9 and 10 together with appropriate rotary wiper contacts for controlling the attenuation of the device; and

FIG. 12 is a table setting forth typical resistance and attenuation values for a bridged-T attenuator of the type shown in FIGS. 9 through 11.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the figures, and particularly to FIG. 1 thereof, there is shown an electrical schematic diagram of a step attenuator 15 incorporating a plurality of conventional attenuator sections, such s the π resistor arrays I through IV. Attenuator 15 includes an input terminal 16, an output terminal 17, and a common terminal 18.

While the invention is particularly useful in attenuator devices employing π and bridged-T type attenuation resistor arrays, which are described in the preferred embodiments disclosed herein, it will be understood that other resistor arrays may be employed, such as the conventional T-type array, the closed π or O-array, or the H-resistor array and variations thereof. Also, while the specific attenuator arrays or sections are shown and described as purely resistive-type arrays it will be understood that the arrays may also include other reactive-type components such as capacitors or inductors which may be formed of deposited layer conductive materials.

Each of attenuator sections I through IV can be bypassed or connected in electrical circuit between input terminal 16 and output terminal 17 by means of a ganged switch 20 having switch section 20*a*, 20*b*, ...20*h*. In the switch position shown in FIG. 1, all of π attenuator sections I through IV are bypassed. For example, switch sections 20*a*, and 20*b* electrically connect input terminal 16 via a line 21 to another line 22, thus bypassing attenuator section I.

Attenuator section I (FIG. 1) includes three resistors 25, 26, and 27 connected in π configuration. The junction of resistors 25 and 27 is connected to a terminal 28 associated with switch section 20*a*; similarly, the junction of resistors 26 and 27 is connected to a terminal 29 associated with switch section 20*b*. The other ends of resistors 25 and 26 are electrically connected to common terminal 18. To insert only π attenuator section I between input terminal 16 and output terminal 17, switch sections 20*a* and 20*b* are brought into electrical circuit respectively with terminals 28 and 29, and switch sections 20*c* through 20*h* are maintained in the positions shown in FIG. 1.

Attenuator section II includes resistors 30*a*, 30*b*, and 30*c* (FIG. 1) and is bypassed or inserted between input terminal 16 and output terminal 17 by means of switch sections 20*c* and 20*d*. Attenuator section III includes π connected resistors 31*a*, 31*b*, and 31*c*, and is associated with switch sections 20*e* and 20*f*. Similarly, attenuator section IV includes π connected resistors 32*a*, 32*b*, and 32*c*, and is associated with switch sections 20*g* and 20*h*.

The values of the resistors of attenuator sections I through IV readily may be calculated, in a manner well known to those skilled in the attenuator art, to provide a selected amount of attenuation (in decimals) for each section. In an exemplary embodiment discussed hereinbelow in conjunction with FIG. 5, sections I through IV may exhibit attenuation values of 1 db., 2 db., 3 db., and 4 db., respectively. Such a configuration permits step attenuator 15 to provide a range of attenuation from zero to 10 db. in steps of 1 db. Of course, the signal to be attenuated is applied between input terminal 16 and common terminal 18, and the attenuated signal is obtained between output terminal 17 and common terminal 18.

FIGS. 2, 3, and 4 illustrate a π section step attenuator in accordance with the present invention. This attenuator, while embodying the electrical circuit of FIG. 1, is of novel physical design and construction, utilizing one or more stationary wafers 35 (FIG. 2) having deposited layer-type resistors and conductors, together with one or more rotary wafers 36 (FIG. 3.) having deposited layer-type switch pads.

Referring now to FIG. 2, stationary wafer 35 includes an electrically insulative substrate 37 of steatite, ceramic or like material and having a circular, central opening 38 therethrough. Disposed on the front face 39 of wafer 35 is a film-type π attenuator section 40. Attenuator section 40 includes three resistors 41, 42, and 43, each formed of a film or deposited layer of resistive material disposed atop substrate 37. Typically, resistors 41, 42, 43 each may comprise a thick film of metallized ceramic (cermet), conductive plastic, or other resistive material which is compatible with the material of substrate 37.

Resistors 41, 42, 43 are connected in π configuration by means of deposited layer-type electrical conductors 44, 45, and 46 also disposed on, and of a material compatible with substrate 37. The layout of π section 40 is arranged to minimize effective capacitance and inductance, and typically, but not necessarily, may have the modified-H form illustrated in FIG. 2.

The techniques by which deposited layer-type circuitry 40 may be fabricated upon wafer 35, and the types of materials used therefor, are generally well known in the film circuitry art. By way of example only, wafer substrate 37 typically may comprise a refractory material such as alumina, steatite or beryllia. Resistors 41, 42, 43 may be formed by screening and firing a metallized ceramic (cermet) or like material onto substrate 37.

Typically, such a cermet may comprise a mixture of silver oxide or palladium oxide, free silver and/or free palladium, the ratio of ingredients determining the resistivity of the cermet. Alternatively, the cermet may include indium oxide or thallium oxide. Generally, the metal or metal oxide is combined with an organic binder and a glass frit.

Cermets or like resistive inks may be screened onto the surface of substrate 37 through a photomask having apertures corresponding to the desired shape, size, and location of the resistors being fabricated. Subsequent to screening, the resistive material is fired to form the resistors. During the firing process, most of the organic binder evaporates, leaving a resistive film which is quite adherent to the substrate. Typically, film thicknesses of from 0.001 to 0.010 inch are employed, but the invention is by no means limited to deposited layers of this thickness range.

The resistance value is determined by the resistivity of the cermet and by length, width and thickness of the film, and can be calculated quite closely in advance of fabrication. However, for high precision applications, it is possible to tailor individual resistors, after they have been fired, by abrading away a portion of the resistor while measuring the effective resistance thereof. Sufficient material is removed to obtain the desired precise resistance value. In FIG. 2, the regions designated 41' and 43' represent such abraded areas.

Deposited layer-type conductive strips 44, 45, 46 typically may be fabricated of a mixture of palladium and gold or platinum and gold, although other metals may be used. These materials also may be combined with an organic binder and a glass frit if desired or required. Alternatively, the conductors may be formed of the same cermet materials used to form deposited layer resistors, but with a higher proportion of metal. Such conductive material also is applied to substrate 37 by screening through a photomask followed by firing.

For certain applications, deposited layer resistors and/or conductors may be formed by vapor deposition techniques or by reducing metallic compounds to a pure metal.

Referring again to FIG. 2, stationary wafer 35 is provided with input-output terminals 47 and 48 and a common terminal 49, each projecting from a respective edge of substrate 37. Terminal 49 is attached mechanically to substrate 37 by means of a rivot or eyelet fastener 50 which also extends through deposited layer-type conductor 44. Fastener 50 thus also insures electrical connection between common terminal 49 and deposited layer-type conductor 44.

Four spring-metal contacts 51, 52, 53, and 54 are attached to wafer 35 (FIG. 2) in generally spaced parallel relation with an edge 55 of substrate 37. Typically, contacts 51–54 are formed of an electrically conductive spring material such as a beryllium-copper alloy, a palladium-platinum-gold-silver-copper alloy, or the like. An eyelet fastener 57 extending through one end of contact 52, through film-type conductor 45 and through substrate 37 mechanically attaches contact 52 to wafer 35, and ensures electrical connection between conductor 45 and contact 52. Similarly, a fastener 58 provides mechanical attachment for contact 51 to substrate 37, and ensures electrical contact between conductor 46 and contact 51. The free ends 51*a*, 52*a*, of spring-metal contacts 51 and 52 are bent rearward of wafer 35, and respectively project through a pair of holes 59, 60 spaced radially with respect to the center of opening 38.

A first end of spring-metal contact 54 is attached by means of a rivot or eyelet fastener 61 to terminal 47 and to substrate 37. Similarly, a fastener 62 mechanically attaches one end of spring-metal contact 53 to substrate 37, and ensures electrical connection between contact 53 and terminal 48. The free ends 53*a*, 54*a* of spring-metal contacts 53 and 54 are bent rearward of wafer 35 and project through a pair of holes 63, 64 radially spaced with respect to holes 59 and 60 and with respect to the center of opening 38.

An additional pair of rivots or eyelet fasteners 65, 66 extend through respective spring-metal contacts 53 and 54. Fasteners 65 and 66 are separated from respective holes 63 and 64 by distances equal to the spacing between holes 59 and 60 and respective fasteners 58 and 57. This ensures that the spring force exerted by each of contact ends 51*a*, 52*a*, 53*a*, and 54*a*, extending respectively through holes 59, 60, 63 and 64 is approximately equal.

Referring now to FIG. 3, it may be seen that typical rotary wafer 36 comprises a circular substrate 70 of electrically insulative material such as alumina, steatite, beryllia, or the like. Wafer 36 has a central opening 71 having a modified circular form concentric with substrate 70 and having a pair of flat, parallel sides 71'.

Disposed in a generally circular arrangement on the front face 70' of substrate 70 is a set of deposited layer-type switch pads 72, 73. Each of switch pads 72 comprises a single, radially extending region of conductive film positioned to permit electrical connection, as described below, to spring-metal contacts 53 and 54 on stationary wafer 35. That is, the minimum radial spacing between each switch pad 72 and the center of wafer 70 is approximately equal to the radial spacing between the center of opening 38 in stationary wafer 35 and the edge of hole 63 nearest thereto. Similarly, the maximum radial spacing of each switch pad 72 with respect to the center of wafer 36 is equal to the radial spacing between the center of opening 38 in wafer 35 and the edge of hole 64 furthest therefrom.

Note that wafer 36 (FIG. 3) has several contact pads 72 disposed at various angular positions about the center of substrate 70. As will become apparent hereinafter, this permits the electrical bypassing of the associated π attenuator section when wafer 36 is rotated to an angular position at which one of switch pads 72 is an electrical circuit with the associated spring contacts 53 and 54.

Still referring to FIG. 3, wafer 36 also includes a plurality of switch pads 73. Each switch pad 73 includes an offset, interdigitated pair of generally C-shaped deposited layer-type conductive regions 74 and 75. The spacing between the end portions 74*a* and 74*b* of pad region 74 is approximately equal to the spacing between spring-metal contacts 52 and 54 of wafer 35. Similarly, the spacing between the end portions 75*a* and 75*b* of pad region 75 is approximately equal to the spacing between spring-metal contacts 51 and 53 of wafer 35. Switch pad regions 74 and 75 are interdigitated, with end portions 75*a*, 74*a*, 75*b*, 74*b* respectively spaced along the same radius of wafer 36. The radial distances between the center of wafer 36 and the respective end portions 75*a* 74*a* 75*b* 74*b* are approximately equal to the radial spacings between the center of hole 38 on wafer 35 and the centers of holes 59, 60, 63, and 64 respectively.

Several switch pads 73 (FIG. 3) are disposed at different angular positions on rotary wafer 36. When one of these positions is in alignment with contact ends 51*a*–54*a*, as discussed below, switch pads 73 permit insertion of the associated π attenuator section into an electrical circuit. In particular, switch pad region 74 electrically connects contact 52 to contact 54, while switch pad 75 electrically connects contact 51 to contact 53.

A plurality of stationary wafers 35 (FIG. 2) and rotary wafers 36 (FIG. 3) may be combined as shown in FIG. 4 to implement a step-attenuator switch 77. Such a switch 77 may be represented schematically by the electrical diagram of FIG. 1.

Switch 77 comprises four stationary wafers 35*a*, 35*b*, 35*c*, and 35*d* (each similar to wafer 35 described above) mounted in spaced parallel relation with the deposited layer-type circuitry of each wafer facing to the left as shown in FIG. 4. Such mounting may be facilitated by a conventional frame (not shown) which holds wafers 35*a*–35*d* in coaxial alignment with the common terminal 49 of each projecting downward. A wire 78 is soldered or otherwise attached to each terminal 49, which wire serves as the electrical common terminal of step attenuator 77, corresponding to common terminal 18 of FIG. 1. Further, wafers 35*a*–35*d* are electrically series connected by means of wires 79 and 79*b* attached between appropriate input/output terminals 47, 48.

Interspersed between and coaxially aligned with wafers 35*a*–35 are four rotary wafers 36*a*, 36*b*, 36*c*, 36*d*, each of the type generally shown in FIG. 3, but not necessarily with the same arrangement of conductive switch pads 72, 73 as shown therein. A shaft 80 having parallel flat portions 80*a* extends through each of holes 38 in stationary wafers 35*a*–35*d* and through holes 71 in rotary wafers 36*a*–36*d*. The flat portions 80*a* of shaft 80 fit snugly against the flat sides 71' of hole 71, so that when shaft 80 is rotated, it will rotate with it each of wafers 36*a*–36*d*.

A conventional detent mechanism (not shown) ensures proper indexing between the spring-metal contacts 51 through 54 of each wafer 35*a*–35*d* and the associated switch pads 72, 73 of rotary wafers 36*a*–36*d*. In this regard, notice in FIG. 4 that spring contact ends 51*a*', 52*a*', 53*a*' and 54*a*' extend rearwardly of stationary wafer 35*a* and rub against the switch pads on the front of associated rotary wafer 36*a*. The spacing

between stationary wafer 35*a* and rotary wafer 36*a* is slightly less than the rearward projection of these spring contact ends so as to cause slight forward flexure of the associated spring contacts 51', 52', 53', 54' (as indicated in FIG. 4). The spring force resulting from this flexure maintains reasonable contact pressure against the pads on wafer 36*a* to ensure good, low-resistance electrical connection thereto. Rotary wafers 36*b*–36*d* are similarly spaced with respect to stationary wafers 35*b*–35*d*.

By way of example, assume that step-attenuator 77 is to provide a maximum of 10 db. of attenuation in steps of 1 db. each. This may be accomplished by designing the π attenuator section of wafer 35*a* (corresponding to π section I in FIG. 1) to provide an attenuation of 1 db. Similarly, wafers 35*b* 35*c* and 35*d* respectively may provide values of 2 db., 3 db., and 4 db. of attenuation; these wafers thus would correspond to π attenuator sections II, III and IV of FIG. 1. Approximate resistance values (in ohms) for each of the resistors of wafers 35*a*–35 are set forth in table 1 hereinbelow.

TABLE 1

Wafer	Attenuation in db.	Resistors 41 and 43	Resistor 42
35*a*	1	870	5.7
35*b*	2	436	11.6
35*c*	3	292	17.6
35*d*	4	221	23.9

By inserting or bypassing selected ones of the π attenuator section on wafers 35*a* –35*d* in accordance with the table of FIG. 5, the desired ten 1 db. steps of attenuation may be achieved. In FIG. 5, the designation B indicates that the corresponding π attenuator section has been bypassed, i.e., that spring contacts 53 and 54 have been short-circuited, thereby directly connecting input-output terminals 47 and 48 of the specified one of wafers 35*a*–35*d*. The letter I indicates that the corresponding π attenuator section has been inserted. For example, 2 db. of attenuation is achieved by inserting the π section of wafer 35*b* and bypassing the other three π attenuator sections. Similarly, 5 db. of attenuation is achieved by inserting the π attenuator sections of wafers 35*a* and 35*d*, and by passing or short-circuiting the π sections of wafers 35*b* and 35*C*.

Note that the switch pad 72, 73 configuration shown in FIG. 3 is the same as that specified in the table of FIG. 5 for rotary wafer 35*a* of step attenuator switch 77. Further, switch pad combinations other than those given in FIG. 5 are possible. For example 7 db. attenuation may be realized by inserting the π attenuator sections on wafers 35*a*, 35*b*, and 35*d* instead of wafers 35*c* and 35*d* as listed in FIG. 5. Further, it is apparent that the attenuation values other than those listed in the table of FIG. 5 may be employed. Nor is the invention limited to step attenuator embodiments having four sections and fewer or more sections may be employed.

In the embodiment of FIG. 4, step attenuator 77 employs four separate stationary wafers 35*a* –35*d* and four separate rotary wafers 36*a*–36*d*. A somewhat simplified version of a π section step attenuator in accordance with the present invention is shown in FIGS. 6 and 7. Referring first to FIG. 6 there is shown wafer 35' similar to wafer 35 of FIG. 2. However, in wafer 35' the spring-wire contacts do not project rearwardly through holes in the wafer substrate, but rather project forwardly in somewhat arcuate fashion from the front face of the wafer. Thus in the embodiment of FIG. 6, spring contacts 53' and 54' (corresponding respectively to contacts 53 and 54 in FIG. 2) project forwardly from a substrate 37' and are attached respectively to terminals 48' and 47'. The associated rotary wafer 36' is spaced so that the conductive deposited layer-type switch pads 72', 73' thereon face wafer 35' and make electrical connection with contacts 53', 54'.

Wafers 35', 36' of the type shown in FIG. 6 may be incorporated into a step attenuator 77' as shown in FIG. 7. As indicated therein, step attenuator 77' includes three stationary wafers 35*e*, 35*f*, 35*g* cooperating with two rotary wafers 36*e*, 36*f*. Each of the stationary wafers 35*e* and 35*g* has a single π attenuator section disposed on a face thereof, configured generally as shown in FIG. 2 but with the forwardly extending contact configuration depicted in FIG. 6. Central stationary wafer 35*f* is provided with two such π attenuator sections, one being disposed on the front face of wafer 35*f*, the other on the rear face.

Each of rotary wafers 36*e* and 36*f* contains two sets of switch pads (corresponding to pads 72, 73 of FIG. 3, but not shown in FIG. 7). The switch pads on the front face of rotary wafer 36*e* cooperate with the contacts 81 of stationary wafer 35*e*, while the switch pads on the rear face of rotary wafer 36*e* cooperate with the switch contacts 82 on the forward face of stationary wafer 35*f*. Similarly, two sets of switch pads on rotary wafer 36*f* cooperate respectively with the switch contacts 83 extending from the rear face of central stationary wafer 35*f* and with contacts 84 on the front face of stationary wafer 35*g*. Rotary wafers 36*e* and 36*f* simultaneously are rotated by means of a shaft 80' having flat portions 80*a*'.

Thus, step attenuator switch 77' (FIG. 7) represents a more compact version of a deposited layer-type attenuator in accordance with the present invention. Attenuator switches 77 (FIG. 4) and 77' both offer the ease of construction, small physical size, and high reliability inherent in film-type circuitry. Further, switches 77 and 77' exhibit minimal contact resistance and low inductance and/or capacitance, the latter feature permitting switches 77 and 77' to be employed in high frequency as well as audio applications.

Another embodiment of a step attenuator having deposited layer-type resistors, conductors and switch pads is shown in FIGS. 9 through 11. This attenuator is of bridged-T configuration, and may be represented schematically by the electrical circuit diagram of FIG. 8.

Referring to FIG. 8, there is shown a bridged-T attenuator 85 having an input terminal 86, an output terminal 87 and a common terminal 88. As is well known to those in the attenuator art, bridged-T attenuator 85 includes a pair of fixed resistors, each designated *c*, connected in series between input terminal 86 and output terminal 87. Also connected between input terminal 86 and output terminal 87 is a first variable resistor *A*. A second variable resistor *B* is electrically connected between the junction of fixed resistors *C* and common terminal 88. Resistors *A* and *B* are ganged together for simultaneous adjustment. Analysis of this circuit produces the following identities:

$C=Z$

$A=Z(K-1)$

$B=Z/K-1$ where Z represents the characteristic impedance of bridged-T attenuator 85 and K equals the ratio of the input voltage V_{in} to the output voltage V_{out} for attenuator 85.

FIGS. 9, 10, and 11 indicate the manner in which a bridged-T attenuator 89 may be fabricated using deposited layer-type resistors, conductors and switch pads disposed on both sides of a single, electrically insulative substrate 90. Substrate 90, which typically comprises a refractory material such as alumina, steatite or the like is provided with an input terminal 91, an output terminal 92 and a common terminal 93 each attached to substrate 90 by an appropriate rivot or eyelet fastener 94. A circular opening 95 extends through wafer 90 at the middle thereof.

Disposed on a front face 96 of wafer 90, concentric with opening 95, is an annular, conductive layer switch pad 97. Also situated on wafer face 96, in a circular arrangement surrounding annular pad 97, are 11 conductive switch pads generally designated 98. A conductive strip 99 electrically connects annular switch pad 97 and a first one 98*a* of switch pads 98 to input terminal 91.

Ten resistors generally designated **100** are also formed on front wafer face **95** (FIG. **9**); resistors **100** together correspond to variable resistor *A* in the schematic diagram of FIG. **8**, While only one resistor (designated **100***a*) is depicted as an actual resistance layer on the wafer, it is to be understood that all of resistors **100** are fabricated of film-type metals or deposited-layer cermet resistive material, and are shown schematically in FIG. **9** for simplicity only.

The junctions between adjacent ones of resistors **100** are electrically connected by means of conductive strips to respective ones of switch pads **98**. For example, the junction between resistors **100***a* and **100***b* is connected to a switch pad **98***b* by means of a conductive strip **101** which may be formed of a conductive metal film or conductive cermet layer. The switch pad **98***e* at the other end of series connected resistors **100** is electrically connected to output terminal **92** by means of a conductive strip **102**.

The configuration of the rear face **103** of wafer **90** is illustrated in FIG. **10**. Referring thereto, a pair of resistors **104** and **104'** are connected in series between input terminal **91** and output terminal **92**. Although resistors **104** and **104'** are shown schematically in FIG. **10**, it is to be understood that deposited layer-type resistors actually are employed. Connections between resistors **104**, **104'** and respective terminals **91** and **92** are accomplished by means of conductive films (not shown) disposed atop face **103** and in contact with fasteners **94**.

Still referring to FIG. **10**, wafer face **103** also is provided with ten series connected resistors, generally designated **107**, which correspond to variable resistance *B* in the schematic diagram of FIG. **8**. Disposed in a circle concentric with central opening **95** are a set of conductive film-type switch pads generally designated **108**. A first one (designated **108***d*) of switch pads **108** is connected to a terminal one (designated **107***d*) of series connected resistors **107**. The remainder of switch pads **108** are connected to the junctions between adjacent ones of resistors **107**. For example, the junction between resistors **107***b* and **107***c* is connected to switch pad **108***b*. The other terminal resistor **107***a* is connected between switch pad **108***a* and common terminal **93**.

Also disposed on substrate surface **103**, between pads **108** and opening **95** is an annular, conductive film or layer switch pad **109**. Switch pad **109** is connected via a conductive strip **110** to the junction between resistors **104** and **104'**. Conductor **110** also is in contact with switch pad **108***f*.

Referring now to FIG. **11**, attenuator **89** comprises wafer **90** and the deposited layer-type circuitry thereon, together with a shaft **115** extending coaxially through opening **95**. A pair of wiper contacts **116**, **117**, are attached to shaft **115**. A conventional wafer mount and shaft detent mechanism (not shown) may be employed to maintain shaft **115** coaxial with opening **95** and to facilitate indexing of wiper contacts **116** and **117**.

Wiper contact **116** includes an arm **118** which extends radially from shaft **115** and a pair of contact members **119** and **120** projecting from arm **118** toward wafer face **96**. Member **119** wipes across and makes electrical contact to annular switch pad **97**, while contact member **120** wipes across and makes contact with individual ones of switch pads **98**. Thus in FIG. **9**, wiper contact **116** is shown in phantom making electrical contact between annular pad **97** and switch pad **98***c*.

Similarly, wiper contact **117** comprises an arm **121** extending radially from shaft **115** at the same angular orientation as arm **118**, and including a pair of contact members **122** and **123**. Contact member **122** wipes across annular switch pad **109** and is connected electrically to member **123** which wipes across switch pads **108** on wafer face **103**. In FIG. **10**, wiper contact **117** is shown in phantom making electrical contact between switch pad **108***c* and annular pad **109**.

It will be appreciated that as wiper contact **116** is rotated clockwise with respect to front face **96** of step attenuator **89**, wiper **117** will move counterclockwise across rear wafer face **103**. With such rotation, progressively more resistance will be inserted between input terminal **91**, which is directly connected to annular switch pad **97**, and output terminal **92**. Alternatively expressed, the effective resistance of variable resistor *A* (FIG. **8**) implemented by resistors **100** of attenuator **89**, will be increased. Such rotation of shaft **115** also will decrease the effective resistance of variable resistor *B* (FIG. **8**), as implemented by resistors **107** of attenuator **89**. As a result, the attenuation provided by step attenuator **89** will increase. Rotation of shaft **115** in the opposite direction reduces the attenuation provided by bridged-T attenuator **89**.

The values of the various resistors **100** and **107** for an exemplary embodiment of attenuator **89** having a 50-ohm characteristic impedance (*Z*) and exhibiting from zero to 10 db. of attenuation in steps of 1 db. are set forth in the table of FIG. **12**. The values shown therein are approximate and in practice would be calculated to a precision equal to the capability for tailoring individual ones of resistors **100** and **107**. Resistors **104**, **104'** each is 50 ohms.

Note in FIG. **12** that the column identified as $A = Z(K-1)$ specifies the total effective resistance for resistor *A* (FIG. **8**) necessary to achieve a given amount of attenuation. The column identified as ΔA (from terminal **92**) designates the values of each of resistors **100**. For example, the resistor **100***c* adjacent switch pad **98***e* (FIG. **9**) is 6 ohms, while resistors **100***b* and **100***a* respectively have the values 15.5 ohms, and 17 ohms. Similarly, the column (FIG. **12**) marked $B=(Z/K-1)$ indicates the values required for variable resistor *B* (FIG. **8**) for specified amounts of attenuation. The column identified as ΔB (from terminal **93**) specifies the values of each of resistors **107**. For example, resistors **107***a* and **107***b* (FIG. **10**) respectively have the values 23.1 ohms and 4.4 ohms, while resistor **107***d* has the value 225 ohms.

Of course, the invention is not limited to a bridged-T configuration having only 10 steps of attenuation (as shown in FIGS. **9** and **10**), nor is it limited to the values of resistance and attenuation listed in FIG. **12**. Clearly other configurations and values will be apparent to those skilled in the attenuator art. However, the present invention does envision the use of deposited layer-type circuit components, including resistors, conductors and switch pads as disclosed herein, arranged on refractory substrates in such a way as to minimize contact resistance and to minimize stray inductance and/or capacitance. Attenuator switches in accordance with the present invention thus are smaller, easier to fabricate, more reliable, and less costly than step attenuator switches of the prior art.

While the invention has been described with respect to the preferred physical embodiments constructed in accordance therewith, it will be apparent to those skilled in the art that various modifications and improvements may be made without departing from the scope and spirit of the invention.

I claim:

1. An attenuator switch comprising:

first and second wafers of electrically insulative material, said second wafer being movable relative to said first wafer,

an attenuation circuit disposed on a face of said first wafer, said attenuation circuit comprising an impedance section having deposited-layer impedance components and conductors,

contact means, attached to said first wafer, for making electrical connection to said conductors of said attenuation circuit, said contact means having contact ends spring biased against said second wafer, and

conductive layer switch pads on said second wafer and cooperating with said contact ends of said contact means, for selectively inserting said attenuation circuit on said first wafer into an electrical circuit depending on the relative orientation of said first and second wafers.

2. An attenuator switch comprising:

first and second wafers of electrically insulative material, said second wafer being movable relative to said first wafer,

an attenuation circuit disposed on a face of said first wafer, said attenuation circuit comprising a resistor array having deposited-layer-type resistors and conductors,

contact means, attached to said first wafer, for making electrical connection to conductors of said resistor array, said contact means having contact ends spring biased against said second wafer, and

conductive film switch pads on said second wafer and cooperating with said contact ends of said contact means, for selectively inserting said resistor array in an electrical circuit depending on the relative orientation of said first and second wafers.

3. An attenuator switch as defined in claim 2 wherein said electrically insulative material comprises a ceramic and wherein said deposited layer-type resistors are fabricated of cermet or conductive plastic.

4. An attenuator switch as defined in claim 2 wherein said resistor array comprises first, second, and third resistors connected as a π section, and wherein said contact means comprises a first spring-metal contact electrically connected to the junction of said first and second resistors, and a second spring-metal contact electrically connected to the junction of said second and third resistors, said attenuator switch further comprising a common terminal electrically connected to the junction of said first and third resistors.

5. An attenuator switch as defined in claim 4 further comprising an input terminal and an output terminal, wherein said contact means further comprises a third spring-metal contact electrically connected to said input terminal and a fourth spring-metal contact electrically connected to said output terminal, and wherein said switch pads directly electrically connect said third contact to said fourth contact when said second wafer is in a first orientation, thereby bypassing said π section, and wherein aid switch pads connect said first contact to said third contact and said second contact to said fourth contact when said second wafer is in a second orientation, thereby inserting said π section into electrical circuit between said input and output terminals.

6. An attenuator switch as defined in claim 5 wherein said first wafer is stationary, wherein said second wafer is rotatable with respect to said first wafer, and wherein said wafers are disposed in spaced parallel relationship.

7. An attenuator switch as defined in claim 6 wherein the ends of said first through fourth contacts are disposed in spaced radial relationship with respect to the axis of rotation of said second wafer, and wherein said switch pads include a first radially extending pad dimensioned to interconnect said first and second contacts when said second wafer is in said first orientation and include a pair of interdigitated, generally C-shaped pads dimensioned to interconnect said first contact to said third contact and said second contact to said fourth contact when said second wafer is in said second orientation.

8. A device comprising:

a plurality of attenuator switches each as defined in claim 7, the input and output terminals of said switches being connected in series to form said electrical circuit, and

means for simultaneously rotating the second wafers of said switches, the second wafer of each switch including a plurality of switch pads disposed selectively to insert or bypass the π section of the associated first wafer depending on the common rotational orientation of said second wafers.

9. A device as defined in claim 8 wherein each such switch includes a separate first and second wafer.

10. A device as defined in claim 9 and including at least one second wafer having switch pads on both major faces thereof, an including a pair of first wafers respectively disposed to face opposite major faces of said at least one second wafer, said one second wafer thereby providing the switch pads for said pair of first wafers.

11. A step attenuator switch comprising:

a plurality of stationary wafers interspersed in spaced parallel relationship with a plurality of rotary wafers,

a shaft extending through an opening in the middle of each stationary wafer and cooperating to rotate simultaneously all of said rotary wafers,

a deposited layer-type attenuator section disposed on each of said stationary wafers, each attenuator section comprising deposited layer-type resistors and conductors,

a set of deposited layer-type conductive switch pads disposed on each rotary wafer, and

spring-metal contacts extending from each stationary wafer and electrically connected to the attenuator section thereof, said contacts cooperating with switch pads on an associated rotary wafer to insert or bypass said section depending on the rotational position of said shaft.

12. A step attenuator switch as defined in claim 11 wherein said deposited layer-type attenuator section is disposed on the front face of said stationary wafer and wherein ends of said contacts project rearwardly of said wafer through spaced holes therein.

13. A step attenuator switch as defined in claim 11 wherein said deposited layer-type attenuator section is disposed on the front face of said stationary wafer and wherein ends of said contacts project forwardly of said wafer.

14. A step attenuator switch as defined in claim 11 wherein each of said stationary wafers comprises:

a substrate of refractory material,

four spring-metal contacts extending in generally spaced parallel relationship, each contact being attached by a fastener spaced a selected distance from a free end of each contact,

said attenuator section comprising first, second, and third deposited layer-type resistors connected in π configuration, a first deposited layer-type conductor connecting the junction of said first and second resistors to one of said contacts, a second deposited layer-type conductor connecting the junction of said second and third resistors to a second of said contacts, the junction of said first and third resistors being connected to a common terminal by a third deposited layer-type conductor, and

a pair of input/output terminals electrically connected respectively to said third and said fourth contacts.

15. A bridged-T attenuator comprising:

a wafer of electrically insulative material,

portions of a bridged-T circuit disposed on both major faces of said wafer and formed of deposited layer-type components, and

wiper contact means rotatable with respect to said wafer and cooperating with said deposited layer-type components for controlling the attenuation of said attenuator.

16. A bridged-T attenuator as defined in claim 15 wherein said wafer comprises a refractory material and has a central opening therethrough, said wiper contact means being attached to a shaft extending through said opening, said attenuator further comprising an input terminal, an output terminal and a common terminal all attached to said wafer, a pair of deposited layer-type fixed resistors being connected in series by means of deposited layer-type conductors between said input and output terminals.

17. A bridged-T attenuator as defined in claim 16 further comprising:

a first annular deposited layer-type conductive switch pad disposed on one major face of said wafer surrounding said opening and electrically connected by means of a deposited layer-type conductive strip to said input terminal,

a first plurality of deposited layer-type conductive switch pads disposed in a circle on said one major face surrounding said central opening, a pair of said first plurality of switch pads being electrically connected respectively to said input and output terminals, and

a first plurality of deposited layer-type relative elements disposed on said one major face and electrically connected between adjacent ones of said first plurality of switch pads, said wiper contact means selectively electrically shorting one of said first plurality of switch pads to said first annular switch pad, thereby controlling the effective resistance of one portion of said bridged-T circuit.

18. A bridged-T attenuator as defined in claim 17 further comprising:

a second annular deposited layer-type conductive switch pad disposed on the other major face of said wafer surrounding said opening and electrically connected by means of a deposited layer-type conductive strip to the junction of said pair of fixed resistors,

a second plurality of deposited layer-type conductive switch pads disposed in a circle on said other major face surrounding said central opening

a second plurality of deposited layer-type resistive elements disposed on said other major face, one of said second plurality of resistive elements being electrically connected between one of said second plurality of switch pads and said common terminal, others of said second plurality of resistive elements being electrically connected between adjacent ones of said second plurality of switch pads, said wiper contact means selectively electrically shorting one of said second plurality of switch pads to said second annular switch pad, thereby controlling the effective resistance of another portion of said bridged-T circuit.

* * * * *

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,626,352 Dated December 7, 1971

Inventor(s) Kenneth W. McCoig

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 11, Line 31, Claim 5, change "aid" -- to read -- said

Column 12, Line 67, Claim 17, change "relative" -- to read -- resistive --

Signed and sealed this 25th day of April 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents

Ten resistors generally designated **100** are also formed on front wafer face **95** (FIG. 9); resistors **100** together correspond to variable resistor *A* in the schematic diagram of FIG. 8, While only one resistor (designated 100*a*) is depicted as an actual resistance layer on the wafer, it is to be understood that all of resistors **100** are fabricated of film-type metals or deposited-layer cermet resistive material, and are shown schematically in FIG. 9 for simplicity only.

The junctions between adjacent ones of resistors **100** are electrically connected by means of conductive strips to respective ones of switch pads **98**. For example, the junction between resistors **100***a* and **100***b* is connected to a switch pad **98***b* by means of a conductive strip **101** which may be formed of a conductive metal film or conductive cermet layer. The switch pad **98***e* at the other end of series connected resistors **100** is electrically connected to output terminal **92** by means of a conductive strip **102**.

The configuration of the rear face **103** of wafer **90** is illustrated in FIG. **10**. Referring thereto, a pair of resistors **104** and **104'** are connected in series between input terminal **91** and output terminal **92**. Although resistors **104** and **104'** are shown schematically in FIG. **10**, it is to be understood that deposited layer-type resistors actually are employed. Connections between resistors **104**, **104'** and respective terminals **91** and **92** are accomplished by means of conductive films (not shown) disposed atop face **103** and in contact with fasteners **94**.

Still referring to FIG. **10**, wafer face **103** also is provided with ten series connected resistors, generally designated **107**, which correspond to variable resistance *B* in the schematic diagram of FIG. **8**. Disposed in a circle concentric with central opening **95** are a set of conductive film-type switch pads generally designated **108**. A first one (designated **108***d*) of switch pads **108** is connected to a terminal one (designated **107***d*) of series connected resistors **107**. The remainder of switch pads **108** are connected to the junctions between adjacent ones of resistors **107**. For example, the junction between resistors **107***b* and **107***c* is connected to switch pad **108***b*. The other terminal resistor **107***a* is connected between switch pad **108***a* and common terminal **93**.

Also disposed on substrate surface **103**, between pads **108** and opening **95** is an annular, conductive film or layer switch pad **109**. Switch pad **109** is connected via a conductive strip **110** to the junction between resistors **104** and **104'**. Conductor **110** also is in contact with switch pad **108***f*.

Referring now to FIG. **11**, attenuator **89** comprises wafer **90** and the deposited layer-type circuitry thereon, together with a shaft **115** extending coaxially through opening **95**. A pair of wiper contacts **116**, **117**, are attached to shaft **115**. A conventional wafer mount and shaft detent mechanism (not shown) may be employed to maintain shaft **115** coaxial with opening **95** and to facilitate indexing of wiper contacts **116** and **117**.

Wiper contact **116** includes an arm **118** which extends radially from shaft **115** and a pair of contact members **119** and **120** projecting from arm **118** toward wafer face **96**. Member **119** wipes across and makes electrical contact to annular switch pad **97**, while contact member **120** wipes across and makes contact with individual ones of switch pads **98**. Thus in FIG. **9**, wiper contact **116** is shown in phantom making electrical contact between annular pad **97** and switch pad **98***c*.

Similarly, wiper contact **117** comprises an arm **121** extending radially from shaft **115** at the same angular orientation as arm **118**, and including a pair of contact members **122** and **123**. Contact member **122** wipes across annular switch pad **109** and is connected electrically to member **123** which wipes across switch pads **108** on wafer face **103**. In FIG. **10**, wiper contact **117** is shown in phantom making electrical contact between switch pad **108***c* and annular pad **109**.

It will be appreciated that as wiper contact **116** is rotated clockwise with respect to front face **96** of step attenuator **89**, wiper **117** will move counterclockwise across rear wafer face **103**. With such rotation, progressively more resistance will be inserted between input terminal **91**, which is directly connected to annular switch pad **97**, and output terminal **92**. Alternatively expressed, the effective resistance of variable resistor *A* (FIG. **8**) implemented by resistors **100** of attenuator **89**, will be increased. Such rotation of shaft **115** also will decrease the effective resistance of variable resistor *B* (FIG. **8**), as implemented by resistors **107** of attenuator **89**. As a result, the attenuation provided by step attenuator **89** will increase. Rotation of shaft **115** in the opposite direction reduces the attenuation provided by bridged-T attenuator **89**.

The values of the various resistors **100** and **107** for an exemplary embodiment of attenuator **89** having a 50-ohm characteristic impedance (*Z*) and exhibiting from zero to 10 db. of attenuation in steps of 1 db. are set forth in the table of FIG. **12**. The values shown therein are approximate and in practice would be calculated to a precision equal to the capability for tailoring individual ones of resistors **100** and **107**. Resistors **104**, **104'** each is 50 ohms.

Note in FIG. **12** that the column identified as $A=Z(K-1)$ specifies the total effective resistance for resistor *A* (FIG. **8**) necessary to achieve a given amount of attenuation. The column identified as ΔA (from terminal **92**) designates the values of each of resistors **100**. For example, the resistor **100***c* adjacent switch pad **98***e* (FIG. **9**) is 6 ohms, while resistors **100***b* and **100***a* respectively have the values 15.5 ohms, and 17 ohms. Similarly, the column (FIG. **12**) marked $B=(Z/K-1)$ indicates the values required for variable resistor *B* (FIG. **8**) for specified amounts of attenuation. The column identified as ΔB (from terminal **93**) specifies the values of each of resistors **107**. For example, resistors **107***a* and **107***b* (FIG. **10**) respectively have the values 23.1 ohms and 4.4 ohms, while resistor **107***d* has the value 225 ohms.

Of course, the invention is not limited to a bridged-T configuration having only 10 steps of attenuation (as shown in FIGS. **9** and **10**), nor is it limited to the values of resistance and attenuation listed in FIG. **12**. Clearly other configurations and values will be apparent to those skilled in the attenuator art. However, the present invention does envision the use of deposited layer-type circuit components, including resistors, conductors and switch pads as disclosed herein, arranged on refractory substrates in such a way as to minimize contact resistance and to minimize stray inductance and/or capacitance. Attenuator switches in accordance with the present invention thus are smaller, easier to fabricate, more reliable, and less costly than step attenuator switches of the prior art.

While the invention has been described with respect to the preferred physical embodiments constructed in accordance therewith, it will be apparent to those skilled in the art that various modifications and improvements may be made without departing from the scope and spirit of the invention.

I claim:

1. An attenuator switch comprising:

first and second wafers of electrically insulative material, said second wafer being movable relative to said first wafer,

an attenuation circuit disposed on a face of said first wafer, said attenuation circuit comprising an impedance section having deposited-layer impedance components and conductors,

contact means, attached to said first wafer, for making electrical connection to said conductors of said attenuation circuit, said contact means having contact ends spring biased against said second wafer, and

conductive layer switch pads on said second wafer and cooperating with said contact ends of said contact means, for selectively inserting said attenuation circuit on said first wafer into an electrical circuit depending on the relative orientation of said first and second wafers.

2. An attenuator switch comprising:

first and second wafers of electrically insulative material, said second wafer being movable relative to said first wafer,

an attenuation circuit disposed on a face of said first wafer, said attenuation circuit comprising a resistor array having deposited-layer-type resistors and conductors,