Aug. 25, 1964 J. W. SPALLONE 3,146,357
HIGH FREQUENCY SOLID STATE SWITCH EMPLOYING DIODES WITH
SHIFTABLE BIAS TO CONTROL SIGNAL TRANSMISSION
Filed Feb. 23, 1962

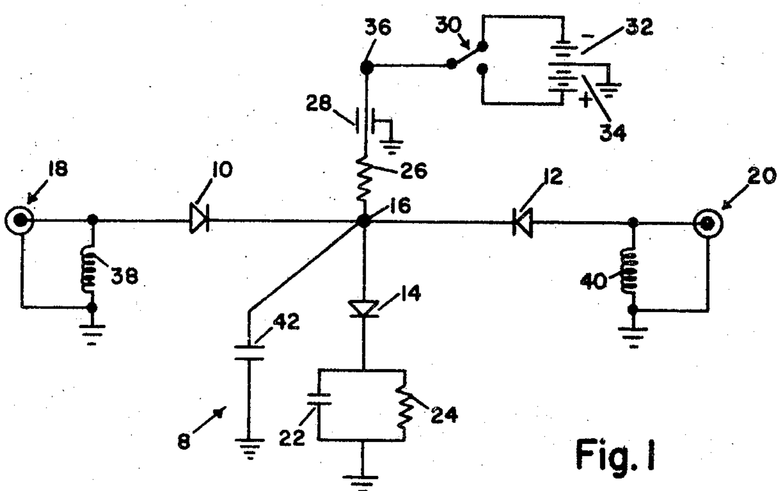

Fig. 1

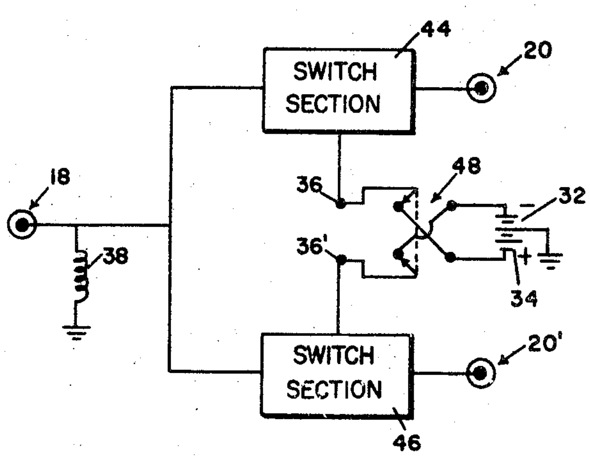

Fig. 2

John W. Spallone
INVENTOR

United States Patent Office

3,146,357
Patented Aug. 25, 1964

3,146,357

HIGH FREQUENCY SOLID STATE SWITCH EMPLOYING DIODES WITH SHIFTABLE BIAS TO CONTROL SIGNAL TRANSMISSION

John W. Spallone, Deer Park, N.Y., assignor to Sanders Associates, Inc., Nashua, N.H., a corporation of Delaware

Filed Feb. 23, 1962, Ser. No. 175,164
4 Claims. (Cl. 307—88.5)

This invention relates to a "solid state" switch adapted for use at high frequencies. More specifically, it relates to a switch in which series-and-parallel-connected diodes in the transmission path are biased in the forward or reverse direction depending on whether or not transmission along the path is desired. The switch is particularly well suited for use with transmission lines.

The so-called "solid state" switch, a device using semiconductors to replace the physically moveable contacts of conventional switches, has several attributes which make it desirable for use in high frequency systems. For example, the switching time is less by several orders of magnitude. Also, there is no problem of contact wear or entry of foreign matter between contacts, factors which are particularly troublesome at high frequencies.

A principal object of the present invention is to provide an improved solid state switch for use at high frequencies.

Another object of the invention is to provide a switch of the above type having a short switching time and providing a high degree of reliability.

A further object of the invention is to provide a switch of the above type characterized by compatibility with conventional transmission lines.

Yet another object of the invention is to provide a switch of the above type having a low insertion loss.

A still further object is to provide a switch of the above type characterized by simplicity and relatively low cost of construction.

Another object is to provide a switch which may be operated in a reverse direction with equal efficiency.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the features of construction, combinations of elements, and arrangements of parts which will be exemplified in the construction hereinafter set forth, and the scope of the invention will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawings, in which:

FIG. 1 is a schematic representation of a single throw switch embodying the present invention, and

FIG. 2 is a simplified schematic diagram of a double throw switch.

Basically, a single section switch embodying our invention comprises three diodes connected as a T network, two of the diodes being in series with the line and the other one in parallel or across it. Transmission through the switch section takes place when the series diodes are biased to present a low impedance and the parallel diode presents a high impedance. Conversely, a shift of the bias voltages to provide a high series impedance and a low parallel impedance prevents transmission through the section.

The use of diodes in a T configuration is not new with our switch. Rather, it is the manner in which the switching diodes are interconnected with other circuit elements that is the subject of the invention. Our circuit arrangement, which is described in detail below, is simple and yet it provides a short switching time together with a low insertion loss when the switch is conducting and a high degree of isolation when it is open.

More specifically, as seen in FIG. 1, a switch **8** embodying our invention includes a pair of series diodes **10** and **12** and a parallel diode **14** connected together at a junction **16**. Like electrodes of the diodes **10** and **12** are connected to the junction and the opposite electrode of the diode **14** is connected thereto. In the illustrated circuit, these electrodes are, respectively, the cathodes of the diodes **10** and **12** and the anode of the diode **14**.

The anodes of the diodes **10** and **12** are connected to the inner conductors of transmission line connectors schematically indicated at **18** and **20**. The cathode of the diode **14** is connected to the other side of the transmission line, i.e., the outer conductors of the connectors **18** and **20**, by way of a ground connection through a capacitor **22**. A resistor **24** in parallel with the capacitor **22** provides a direct current path through the diode **14** to ground. A resistor **26** having one end connected to the junction **16** is connected by way of a by-pass capacitor **28** to a switch, generally indicated at **30**. The switch **30**, in turn, is connected to a power supply, illustratively depicted as a pair of batteries **32** and **34**, in such manner that manipulation of this switch changes the polarity of the power supply voltage applied to the terminal **36** at which the switch is connected to the resistor **26**.

With further reference to FIG. 1, assume that the switch **30** is in the position shown, so that a negative potential is applied to the terminal **36**. The junction **16** is then also negative and therefore the diodes **10** and **12** conduct by way of inductors **38** and **40**. Thus, their operating points are on the lower resistance, forward portions, of their resistance characteristics and they present a low impedance between the connectors **18** and **20**. At the same time the negative potential at junction **16** reverse biases the diode **14**, which is thus in the high resistance, reverse current portion of its characteristic. This effectively isolates the junction **16** from ground. The switch **8** therefore has a low series impedance and at the same time a low parallel admittance, the requisites for efficient transmission between the connectors **18** and **20**.

If the position of the switch **30** is reversed, a positive voltage is applied to the terminal **36** and therefore also to the junction **16**. This reverse biases the diodes **10** and **12**, thereby effectively cutting them off, and at the same time it causes forward conduction through the diode **14** to provide a low impedance path therethrough. The capacitor **22** bypasses the resistor **24** at the transmission line frequency, thus providing a low impedance path across the line from the junction **16** to ground.

The battery voltages and the resistances of the resistors **24** and **26** are preferably chosen so that when the switch **8** conducts, the currents through the series diodes **10** and **12** are sufficient to provide operation along a portion of the diode characteristic having a relatively low incremental resistance. This, in combination with the high resistance of the reverse-biased diode **14**, provides a low insertion loss. The internal capacitance of diode **14** does not adversely affect insertion loss. In fact, in some cases, we prefer to include a capacitor **42** between the junction **16** and ground for additional capacitance so as to provide a desirable characteristic impedance in the switch.

The resistors **24** and **26** are so proportioned that a substantial reverse bias is imposed on the series diodes **10** and **12** when the switch is "open." The internal capacitance of a junction diode decreases as the reverse bias is increased and therefore, within limits, the series impedance in the switch is increased by an increase in bias voltage. There is an upper limit on the reverse bias which results from the fact that once a certain point is reached the incremental resistance decreases with increasing voltage.

By way of illustration, we have found the following circuit values to provide highly satisfactory operation of the switch **8**:

Diode **10**	2 type CGD 1062 diodes connected in parallel.
Diode **12**	2 type CGD 1062 connected in parallel.
Diode **4**	Type CGD 1062.
Resistor **24**	1500 ohms.
Resistor **26**	220 ohms.
Capacitor **22**	0.001 microfarad.
Capacitor **28**	0.001 microfarad.
Capacitor **42**	Selected according to the potting medium.
Inductors **38** and **40**	1000 microhenries at 100 kc.
Battery **32**	12 volts.
Battery **34**	12 volts.

With the above circuit values we have obtained an insertion loss of less than 2 db at 200 megacycles when the switch **8** is in the conducting state and isolation of greater than 55 db when it is in the non-conducting state. A switching speed of 50 nanoseconds is readily obtained.

It will be observed that since the batteries **32** and **34** have the same voltage they may be replaced by a single battery connected between the terminal **36** and ground by a polarity-reversing switch **30**. The bias switch **30** may be an electronic switch and such construction is, of course, highly desirable when high speed operation is contemplated.

In FIG. 2 we have illustrated a double throw switch embodying our invention. The switch includes sections **44** and **46**, each of which has the same construction as the switch **8** of FIG. 1. The sections **44** and **46** share the same conector **18** and inductor **38** at one end and at their other ends they have separate connectors **20** and **20'** respectively. Their bias terminals **36** and **36'** are connected to the batteries **32** and **34** by a double pole, double throw switch generally indicated at **48**.

In the position of the switch **48** shown in FIG. 2, positive potential of the battery **34** is applied to the junction **36** and the negative potential of the battery **32** is applied to the junction **36'**. Accordingly, the connector **20'** of the section **46** is connected to the connector **18** and the connector **20** of the section **44** is isolated therefrom. Reversal of the switch **48** provides transmission between the connectors **18** and **20** and isolation of the connector **18** from the connector **20'**.

It will be apparent that more switch positions may be provided by means of additional switch sections connected to the connector **18** of FIG. 2. Alternatively, each of the terminals **20** and **20'** may have a further pair of switch sections connected thereto according to the well known "Christmas tree" switch configuration.

Each switch is preferably housed in a metallic box with the series elements extending through the box in the manner of a transmission line inner conductor. By way of example, each section of a multiple section switch may occupy a compartment having a length of 2.75 inches, a width of 1.25 inches and a height of 0.75 inch. Cross partitions in each compartment aid in supporting the various components. It is significant to note that the cross partitions also serve a highly important shielding function. The switch is preferably potted, a suitable potting material being Eccofoam, made by the Emerson and Cumings company, Canton, Massachusetts. With this potting material and a value of 2.7 picofarads for the capacitor **42**, the above physical arrangement can provide a close match to a 50 ohm transmission line, the voltage standing wave ratio being about 1.1 with the inductor characteristics set forth below. Where higher capacitance potting materials are used, the capacitor **42** may be eliminated.

More specifically, the frequency of the signal handled by the switch is preferably above the self-resonant frequency of the inductors **38** and **40**. The inductors thus behave as capacitors at the signal frequency while providing the desired D.-C. paths to ground. The resultant capacitive loading within the switch aids in approximating characteristics of the transmission lines connected to the switch terminals.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained, and, since certain changes may be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention, which, as a matter of language, might be said to fall therebetween.

What is claimed is:

1. A high frequency switch comprising:
(*a*) first, second and third terminals,
(*b*) first and second diodes connected in series between said first and second terminals and connected together at a junction,
(*c*) said first and second diodes having the same direction of conduction with respect to said junction,
(*d*) a third diode,
(*e*) a first resistor in series with said third diode between said junction and said third terminal,
(*f*) the direction of conduction of said third diode with respect to said junction being opposite to that of said first and second diodes,
(*g*) a first capacitor in parallel with said first resistor and having an impedance substantially less than the impedance of said first resistor at the frequency of the signals transmitted by said switch,
(*h*) a second resistor connected between said junction and a fourth terminal,
(*i*) a voltage source,
(*j*) means for applying voltage from said source to said third and fourth terminals alternatively in opposite polarities,
(*k*) a second capacitor connected between said junction and said third terminal,
(*l*) a first inductor connected between said first terminal and said third terminal,
(*m*) a second inductor connected between said second terminal and said third terminal.

2. A multiple section switch comprising:
(*a*) a first terminal,
(*b*) a plurality of second terminals,
(*c*) switch sections connected between said first terminal and the respective second terminals,
(*d*) each of said switch sections comprising:
 (1) first and second diodes connected in series between said first terminal and the second terminal connected to said section,
 (2) each of said first and second diodes conducting in the same direction with respect to said junction,
 (3) a third diode,

(4) a first resistor in series with said third diodes between said junction and a third terminal,

(5) the direction of conduction of said third diode with respect to said junction being opposite to that of said first and second diodes,

(6) a capacitor in parallel with said first resistor and having a substantially lower impedance than said first resistor at the frequency transmitted by said switch,

(7) a second resistor connected between said junction and a fourth terminal,

(*e*) a voltage source,

(*f*) switching means for applying voltage from said source to the third and fourth terminals of the respective sections with variable predetermined polarities.

3. The combination defined in claim 2 in which said third terminals are connected together and including an inductor connected between said first terminal and said third terminals.

4. The combination defined in claim 3 including an inductor connected between each of said second terminals and said third terminals.

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