

April 29, 1952

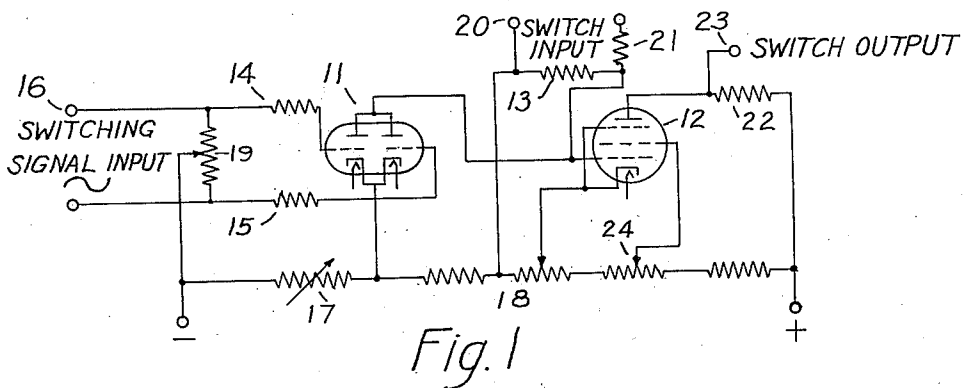
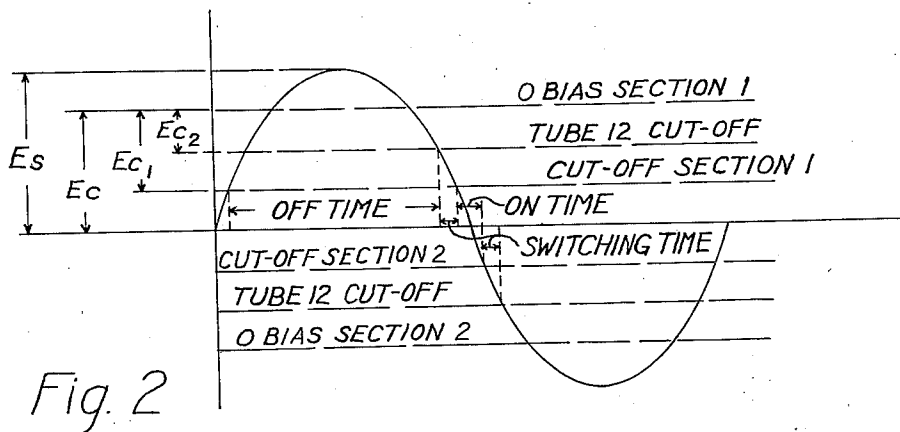
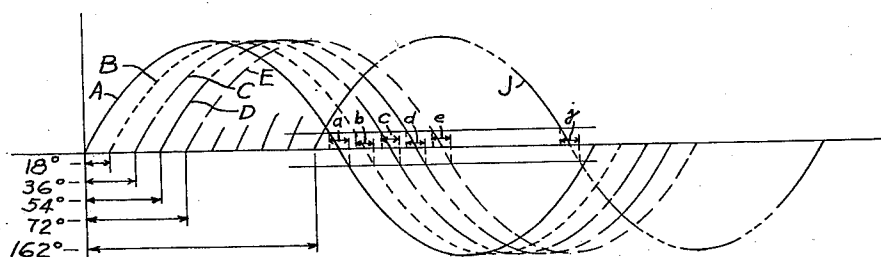
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2,594,535

MULTIPLE CHANNEL ELECTRONIC SWITCH

Filed April 26, 1944

2 SHEETS—SHEET 1



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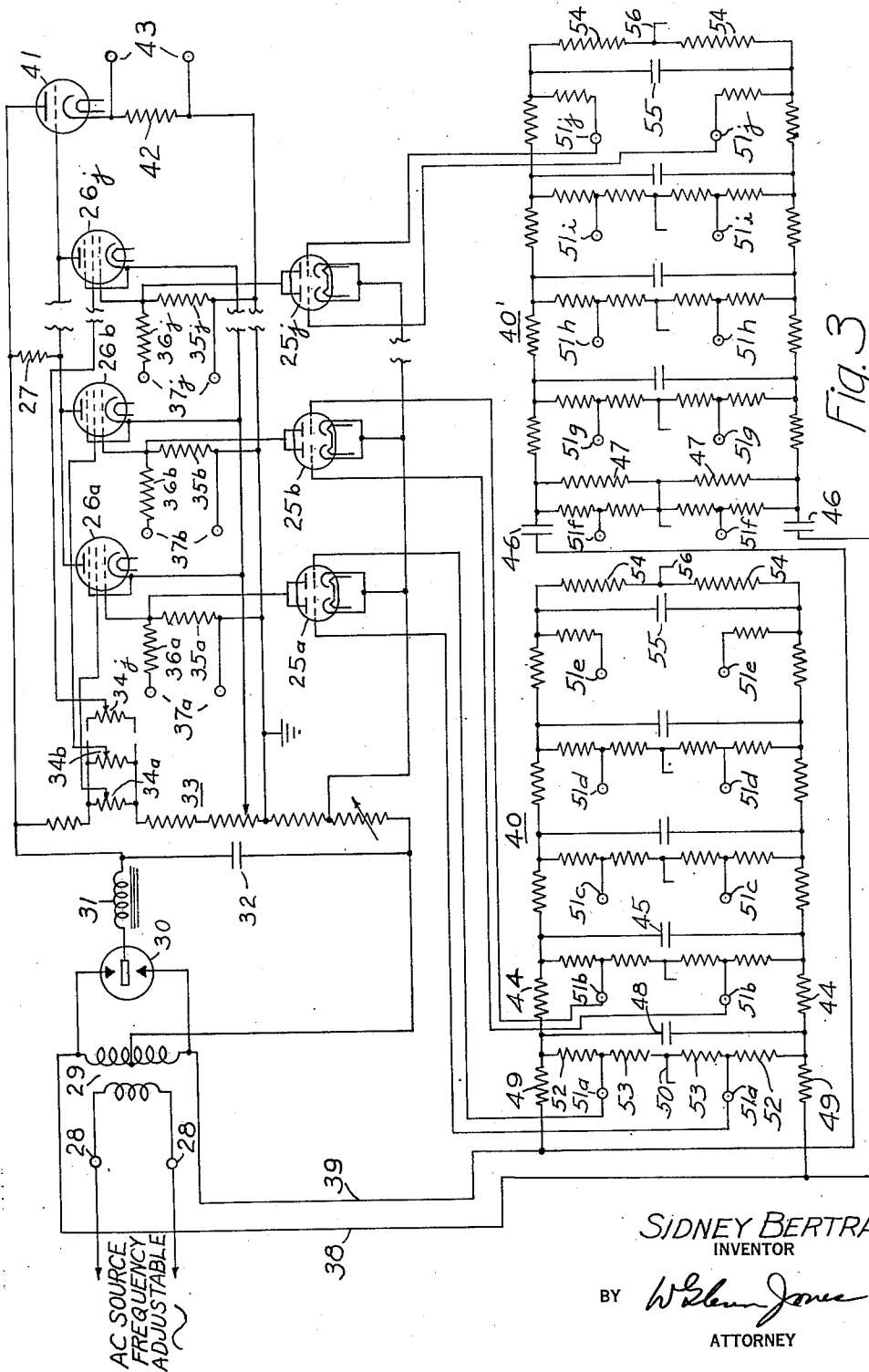
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2 SHEETS—SHEET 2



UNITED STATES PATENT OFFICE

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MULTIPLE CHANNEL ELECTRONIC SWITCH

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Application April 26, 1944, Serial No. 532,915

1 Claim. (Cl. 250—27)

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This invention relates to a multi-channel electronic switch.

In the past, many methods of switching multi-channel devices have been suggested but they have, in general, been rather complicated and inflexible. When it is desired to scan the outputs of a plurality of channels (or conversely, distribute the output of a signal channel) at relatively high frequencies, my invention provides an excellent means for doing so.

One of the outstanding advantages offered by my invention is the manner and ease with which the switching sequence is obtained. It differs from many prior switches in that no oscillating circuit is built into it, the switching signal being obtained from an external sinusoidal source. A phase shifting network is utilized to produce the switching sequence so that each switch element receives a switching signal displaced in phase by an amount corresponding to its position in the switching cycle.

Another advantage of my invention is that the various switch elements are inherently independent of one another; with interaction between switch elements made negligible.

A further advantage of my invention is that the basic switch element is very simple and contains but two tubes.

Still another advantage and object of my invention is that the "on" time of any switch point can be varied, if desired, to separate adjacent points or to cause them to overlap.

Yet another advantage and object of my invention is an electronic switch controlled by a sinusoidal input, the versatility of which makes it available for a wide variety of purposes.

A still further object is an electronic switch composed of a simple basic element to which additional identical elements may be easily added for any desired number of channels.

A yet further object of my invention is a multiple electronic switch containing no thyatron tubes and which is relatively free from noise.

And yet another object of my invention is an electronic switch which may be utilized for a variety of purposes, including distribution, wave analysis, monitoring, multiplex signalling, and secret communications, etc.

Another object is to provide an electronic switching system in which the rate of switching from one element to another in the system may be varied by the simple expedient of varying the frequency of the applied control source.

Still another object is to provide an electronic switching system in which the "on" time of each

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element in the system is controlled with exceedingly great exactitude.

A more specific object is to provide an electronic switching system in which all switch channels are controlled from a single sinusoidal source of voltage, such voltage being supplied to each of the various channels through a phase shifting network whereby the steep portion of the voltage wave can be used to very accurately control the "on" time of all switch channels in the system.

In the drawings:

Fig. 1 is a schematic diagram of the basic switch element.

Fig. 2 is a diagram graphically illustrating the operation of the basic switch element.

Fig. 3 is a schematic diagram of a ten-channel switch, with seven channels omitted, and

Fig. 4 is a diagram showing the phase shifts introduced in the control voltage source by the type of phase shift network used with the ten channel switch shown in Fig. 3.

The basic switch element, shown in Fig. 1, is designed for use on a single channel and the complete switch is constructed with a plurality of elements identical with it together with an appropriate phase-shifting network. It is comprised of two tubes 11, 12. Tube 11 is a high mu duplex triode and I have found that a 6SN7 performs satisfactorily. Tube 12 is a pentode voltage amplifier tube of the sharp cutoff type, such as a 6SJ7. The plates of tube 11 have a common connection to the control grid of tube 12 and a resistor 13 is connected commonly into the plate circuit of tube 11 and the grid circuit of tube 12.

The two grids of tube 11 are connected through high resistors 14 and 15 to the switching signal input terminals 16. Static bias for the grids of tube 11 is obtained from a rheostat 17 at the lower end of voltage divider 18. This connects to the grids of tube 11 through center tapped resistor 19 which provides an electrical center for the signal input. Of course, if the signal input is balanced about an available central point, resistor 19 is unnecessary.

The switch input, supplied at terminals 20, is applied to the grid of tube 12 through a resistor 21. This should be a high resistance and while this decreases the sensitivity, it is necessary to prevent a low impedance device feeding the circuit from short circuiting the switching pulse. A plate load resistor 22 is included in the plate circuit of tube 12 and the individual switch output is taken from this resistor at terminal 23. The suppressor grid of tube 12 is tied to its

cathode and screen bias is supplied by a variable connection 24 to voltage divider 18.

The operation of the basic switch element is exceedingly simple. Tube 11 is biased beyond cutoff when no switching signal is applied, and thus since tube 11 has no effect upon it, tube 12 operates like a normal amplifier. If, as is the case, a sinusoidal switching signal is supplied at terminals 16, both sections of tube 11 are cut off during the portion of the cycle in the neighborhood of zero. However, there will be considerable portions of the cycle during which the sections of tube 11 become conducting, one section conducting during positive swings of the cycle and one during negative swings. In either case, when this occurs, the plate current of tube 11 flowing through resistor 13 causes the bias on tube 12 to increase beyond the cutoff value.

This operation is illustrated diagrammatically on Fig. 2. The two sections of tube 11 are designated section 1 and section 2, where:

- E_c = the static grid bias on tube 11
- E_{c1} = the cutoff voltage on tube 11
- E_{c2} = the grid voltage on tube 11 when tube 12 is effectively cut off.
- E_s = the peak amplitude of the switching signal.

As has been stated, tube 12 operates normally when both sections of tube 11 are biased beyond cutoff. For instantaneous values of signal voltage (e_s) greater than the difference between E_c and E_{c1} (the static bias and cutoff bias of tube 11), but less than the difference between E_c and E_{c2} (the static bias and cutoff bias of tube 12), the bias of tube 12 is changing but it is not cut off. Therefore, this region of the cycle represents the switching time. This time may obviously be varied as desired by changing the peak value of the switching signal E_s (thus changing its slope). When the instantaneous value (e_s) of the switching voltage increases beyond the difference between E_c and E_{c2} , tube 12 is cut off and remains so until the switching signal again decreases below this value. The same sequence of events occurs on the negative portion of the switching cycle with respect to section 2 of tube 11. It should be noted in this connection, that the steep portion of the sinusoidal curve is being utilized which obviously gives a very accurate control as to the time at which the tube is switched on and off.

In connection with the switching time it should be noted that resistor 13 should be small enough so that residual tube currents beyond effective cutoff of tube 11 do not detrimentally affect the operation of tube 12. Additionally, the plate voltage of tube 11 should be kept low to increase the effective mutual conductance of the tube for low plate currents.

Since the "on" and "off" time of the basic switch element is controlled by the phase of the sinusoidal switching signal, this same signal can be utilized to operate a plurality of identical elements or channels in sequence, providing a phase shift is introduced into that signal before it is applied to each next adjacent switch element. A plurality, namely, ten of such channels are illustrated in Fig. 3, although it is to be understood that any desired number could be utilized.

In Fig. 3, only the first two and last of the ten channels in the switch are illustrated, the diagram being broken between the second and last channels. However, the remaining seven channels are the same as the ones shown. Tubes 25a and 25b, in the first two channels and tube

25j in the tenth channel correspond to tube 11 in Fig. 1 and similarly tubes 26a, 26b and 26j correspond to tube 12. Although only one switch tube such as 26a operates from switching tube 25a, it is obvious that a plurality of such switch tubes could be so operated if desired.

A plate load resistor 27 is made common to all ten elements and the cathodes of tubes 25a-25j are tied together.

A sinusoidal source of potential which functions as a switching signal is supplied at terminals 28 and feeds the primary of transformer 29. One set of taps on the secondary of transformer 29 is connected to rectifier 30 to supply direct current to the screen and plate of tubes 26a-26j in their respective channels.

A filter composed of choke 31 and capacitor 32 serves to eliminate hum from the direct current supply.

Voltage divider 33 corresponds in function to divider 18 in Fig. 1. Screen bias to tubes 26a-26j is supplied by variable connections 34a-34j off divider 33.

Resistors 35a-35j correspond to resistor 13 in Fig. 1, resistors 36a-j correspond to resistor 21 and switch input terminals 37a-j correspond to terminals 20.

Another set of taps on the secondary of transformer 29 feeds over conductors 38, 39 to a phase shifting network having two parts 40 and 40'.

The output of all of the channels is supplied to the grid of a cathode follower tube 41. Thus the outputs of all ten channels can be taken across cathode resistor 42 of this tube and supplied to the multi-switch output terminals 43.

In order that the proper phase shift be introduced into the switching signal, so that each element operates in its proper sequence during the switching cycle, the phase shifting network 40-40' is used to supply the properly phased voltages to the respective grid inputs of tubes 25a-25j.

The basic element of each of the network parts 40, 40' is a π section composed of series resistors 44 and capacitor 45. This section is designed to give the desired phase shift ($180^\circ/N$, where N is the number of basic elements or channels in the switch), which in the illustrated case is 18° , when properly terminated in its characteristic impedance. These sections are connected together and it is seen that individual capacitors 45 operate in adjacent π sections. Since there is a large attenuation inherent in such networks, it is formed into two parts in order to get the total 180° coverage. This requires an input phase shifting arrangement consisting of capacitors 46 and resistors 47 to initially shift the phase of network 40' ahead of that of the source at terminals 28 by 45° , and capacitor 48 and resistors 49 to shift the phase of the other network 40 behind 45° . Thus a 90° shift between corresponding points on the two network parts is obtained.

Network parts 40, 40' are balanced and a center tap 50 from each section is led back (but not shown on the schematic) to the center tap on the secondary of transformer 29.

The voltages to the grid terminals of the switching tubes 25a-25j are taken respectively from adjacent sections of the network parts 40, 40' at terminals 51a-51j through high, grid current limiting resistors 52.

For all except the last section of each network part, bleeder resistors 53 are used to equalize the signal voltage to tubes 25a-25j, thus compensating for the attenuation inherent in the

phasing network. Thus resistors 52, 53 perform the function of resistors 14, 15 and 19 described in connection with the basic switch element shown in Fig. 1. Resistors 54 serve as the resistance parts of the terminating impedances for the network parts 40, 40'. Capacitors 55 combine the functions of shunt impedances for the last section of each of the network parts 40, 40' and the reactive elements of the terminating impedances.

If desired, resistors 54 could be made to provide an electrical center 56 for all the network sections, in which case resistors 53 in each section could be combined into a single resistor and the other center taps 50 in each section eliminated.

In the operation of the embodiment shown in Fig. 3, the sinusoidal switching voltage wave from the source applied to terminals 28 and transformer 29 is impressed across the phase shifting network parts 40 and 40'. The individual sections of these networks apply this voltage to the grids of tubes 25a-25j but with different degrees of phase shift as previously explained. That is to say, and by reference to Fig. 4, wave A in phase with the voltage source is applied to the grid of tube 25a; wave B shifted 18° applied to tube 25b; wave C shifted 36° applied to tube 25c; wave D shifted 54° applied to tube 25d; wave E shifted 72° applied to tube 25e and so on with progressively increasing phase shift through all ten channels, tube 25j in the tenth channel receiving a grid input voltage J 162° out of phase with the voltage applied to the first section of the phase shifting network part 40.

Tubes 26a-26j will therefore be switched on and off and in succession for periods a to j respectively as seen from Fig. 4, twice during each cycle of the applied voltage wave as explained in connection with Fig. 1. As each of tubes 26a-26j are switched on in succession, any input signal appearing at terminals 37a-37j of these tubes will be amplified in the tubes, and then applied in succession to the grid of tube 41. These signals then appear, in order, across output terminals 43.

In connection with the apparatus shown in Fig. 3, the speed of switching can be varied by changing the frequency of the A. C. source by any well known means.

The invention disclosed herein may be utilized in many ways. One use for which it has proven very successful is as an analyzer for a sound-frequency spectroscopy. In this case, it is connected to scan the output of a plurality of fixed frequency analyzers to present the information thus obtained on the screen of a cathode-ray tube. For this use the linear sweep of the cathode-ray tube is synchronized at double the frequency of the switching signal. The control voltage for such purpose is obtained from the plates of one of the tubes 25a-25j in the several channels or, in the case of line frequency switching, from the rectifier tube.

It may also be used as an analyzer or distributor, in which case the inputs of the switch elements are connected to a common channel whose output is to be distributed. The outputs of the various switch elements are applied to separate channels. Thus, the input signal will be distributed amongst the output channels in a periodic time sequence.

To adopt the switch for monitoring a set of circuits, as for example a ten meter system, a resistor would be placed in series with each meter

such that the voltage drops would normally all be equal. These ten voltages would be scanned by the switch and placed on a cathode-ray screen as is done in the sound spectroscopy. The horizontal sweep would be divided into ten sections with one section being allotted to each metering circuit. Deviation from the normal in any circuit would be evident on the cathode-ray screen and could be interpreted by means of a calibration.

Additionally, the switch is ideally suited for use in multiplex signaling. It would be used both as a selector and a distributor, and because the basic switch elements are independent, the individual channels could be assigned and located at widely scattered stations. Each station would have a distributor-type switch element placed on the channel assigned to it and the output of this switch might be made to actuate a speaker, relay or other receiving device. A selector-type switch element with a mechanical switch would be provided for each station so that the channel might be changed at will. Thus, if an operator at one station desired to signal another station, it could be done by connecting his selector-type switch to the channel assigned to the other station. In this way, an input at the operator's station would produce a response at the other station without affecting the stations assigned to the remaining channels.

The switch also is adapted for use in an audio-frequency communication system. In this case, the switching frequency would be made quite high with respect to the highest audio-frequency used, which fact would require the use of a wide-band communication channel. However, it would make possible the transmission of several messages on the same channel.

In conclusion, it is to be understood that various changes may be made in the illustrated embodiments of the invention without departing from the spirit and scope thereof.

For example, an alternative form of the basic switch element would utilize a tube with two or more controllable grids, such as a 6SA7, in place of tube 12. In this case, the switching signal would be applied to one control grid, while the switch input would be supplied to the second control grid. In the specific case of a 6SA7 tube, grids labeled 1 and 3, respectively, have been found very suitable for these purposes. This alternative form has the advantage of completely isolating the switch input from the switching signal.

Although the phase-shifting network described above produces excellent results, there may be cases in which slightly different system would prove more satisfactory. One such system includes taking the switching signal for the individual elements from the secondaries of separate transformers whose primaries contain R-C networks designed to shift the phase without changing the amplitude. Chokes might also be used in place of the transformers, but such a system would require more resistors and capacitors to provide a balance point.

Another phase-shifting system which can be utilized is an iterative network with series of capacitors and shunt resistors.

Another alternative system of phase-shifting would include the use of an R-C circuit, with or without a reactance tube, to provide a phase shift equal to the maximum required by the switch. Intermediate phase-shifts could then be obtained

by combination of the original with the shifted signal.

Additionally, a system might utilize a reactance tube for obtaining an essentially quadrature voltage to be combined with the original to obtain a voltage of any intermediate phase shift. This is one which could be made relatively independent of the switching frequency.

Having thus fully described my invention, I claim:

A multiple channel electronic switch comprising a plurality of pairs of switching tubes, each of said switching tubes containing at least an anode, a cathode, and a control grid, means connecting the cathodes of the tubes on each said pairs of switching tubes together and the anodes of the tubes in each of said pairs of switching tubes together, biasing means for rendering said switching tubes normally non-conducting, a switch tube for each of said pairs of switching tubes, each of said switch tubes having at least an anode, a cathode, and a control grid, means connecting the control grids of said switch tubes to the anodes of said pairs of switching tubes respectively, a plurality of resistances each having one end connected to the anodes of one of said pairs of switching tubes and the other end connected to the cathode of said associated switch tube, a plate load resistance for each switch tube having one end thereof connected to the anode of said switch tube, first and second sources of anode

power connected to said plate load resistances and to the cathode of said switching tubes respectively, whereby conduction of said switching tubes renders said switch tubes non-conducting.

- 5 a. source of alternating current, phase shifting means connected to said source of alternating current producing a plurality of individualized alternating current voltages having incremental phase displacements with respect to each other
- 10 and magnitudes in excess of that of said biasing means, and means for impressing said individualized alternating current voltages on the grids of said plurality of pairs of switching tubes respectively, whereby said switching tubes are sequentially rendered non-conducting when the alternating current voltage impressed on the grids of each of said pairs of switch tubes is near zero.

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