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L. P. HUNTER

2,604,496

SEMICONDUCTOR RELAY DEVICE

Filed Feb. 8, 1951

Fig. 1.

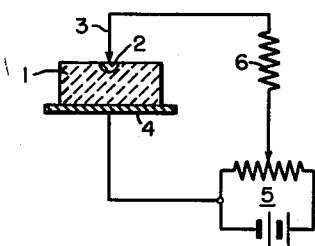


Fig. 2.

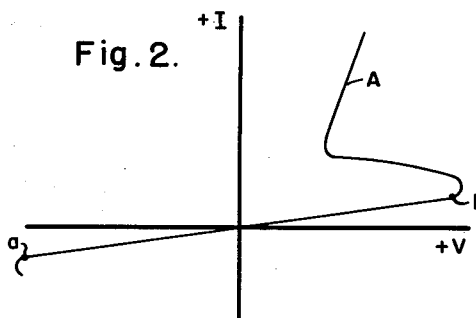


Fig. 3.

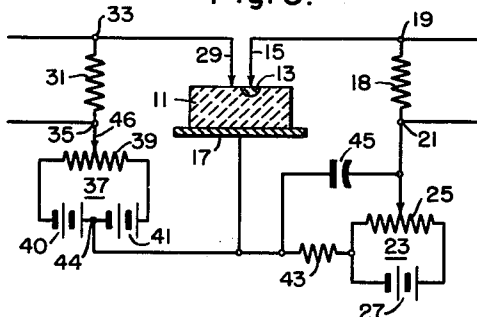


Fig. 4.

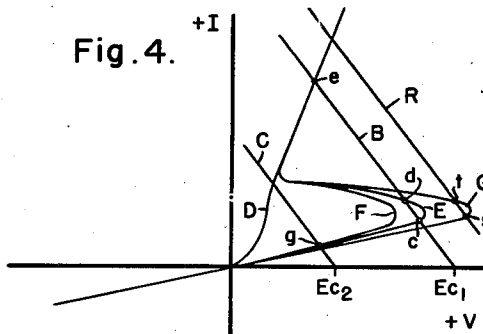


Fig. 5.

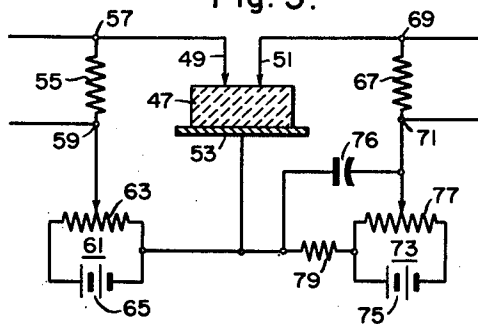
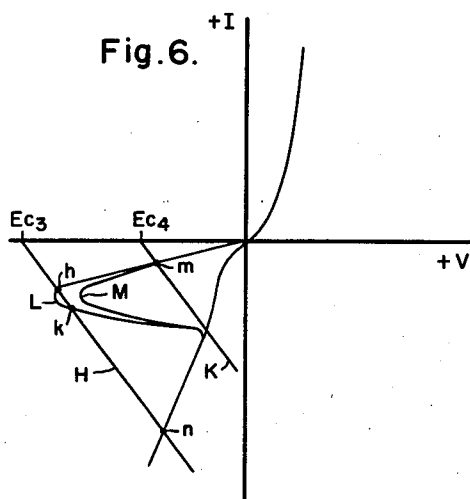


Fig. 6.



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SEMICONDUCTOR RELAY DEVICE

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Application February 8, 1951, Serial No. 209,948

51 Claims. (Cl. 171-97)

1

This application is a continuation-in-part of my application, Serial No. 150,243, filed March 17, 1950, now abandoned, and assigned to Westinghouse Electric Corporation.

My invention is related generally to electronic relay devices, and more particularly to electronic relay devices of the triggered type, in which there is utilized a semi-conductive device having a plurality of electrodes associated therewith.

It has been conventional practice for many years to utilize electric discharge tubes of various types, as the basic element of electronic relay devices. One of the electric discharge tubes commonly used in relay devices of the triggered type is the thyatron. While thyatrons are generally satisfactory for triggered type relay service where the power requirements are relatively high, they are subject to a number of disadvantages in applications in which relay apparatus having extremely low power handling capability can be utilized. Principal among these disadvantages are comparatively long re-set time (of the order of several microseconds), relative large size and complexity, and the requirement for a filament power supply.

Recent developments in the art of semi-conductors have resulted in the introduction of a new device, termed a transistor, which is known to be capable of performing some of the functions of a vacuum tube. The transistor comprises a body or block of semi-conductive material, which may be silicon or germanium, with which are associated three electrodes. Two of these electrodes, called the emitter and collector are rectifying electrodes, usually in the form of pin-pointed conductive probes, located in proximity, in contact with the semi-conductive material. The third electrode, called the base electrode, is a non-rectifying electrode located elsewhere on the semi-conductive body, usually a plate of conductive material, placed contiguous to the semi-conductive body or the block. The transistor is very small in size, simple in structure, does not require a filament power supply, and is operable at extremely low power levels. These characteristics suggest the desirability of finding some way to utilize the transistor, or a similar device as the basic element of a triggered type relay.

It is, accordingly, an object of my invention to provide an improved triggered type relay apparatus for use at very low power levels which shall utilize, as its basic element, a device comprising a body or block of semi-conductive material having three electrodes associated therewith.

2

Another object of my invention is to provide an improved electronic relay device which does not require a filament power supply.

Another object of my invention is to provide an improved electronic relay apparatus which is of very simple, small, and compact structure.

A further object of my invention is to provide an improved electronic relay device of the triggered type, which can be triggered by either a positive or negative pulse without changing the polarity of other circuit parameters.

A further object of my invention is to provide an improved electronic translating apparatus of the triggered type, which shall utilize a semi-conductive device having three electrodes, and which can be thermally triggered.

A further object of my invention is to provide an improved triggered type electronic relay device which shall have an extremely short re-set time.

A still further object of my invention is to provide an electronic relay apparatus utilizing a body or block of semi-conductive material having three electrodes and in which an A. C. re-set potential can be effectively used.

There is shown in Fig. 1 of the drawing, a device well known in the prior art as a photo-peak diode. This device comprises a block of "N" type semi-conductive material, such as germanium, in which there is a small "P" type inclusion 2. A collector probe electrode 3 is placed near the "P-N" boundary, in contact with the inclusion 2. A base electrode 4 is located on the opposite face of the block 1. The collector electrode 3 is biased positively with respect to the base electrode 4 by a variable D. C. potential source 5, in series with a load impedance 6. The current which flows due to this positive voltage bias is defined herein as a positive current bias. If an electrode is biased negatively with respect to the base electrode, the current which flows as a result of this bias is herein defined as a negative current bias. If a plot is made with collector current, I , as ordinate, and collector voltage, V , as abscissa, the result will be a collector characteristic having a peak voltage such as is shown by the curve A of Fig. 2 of the drawing. The value of the collector characteristic peak voltage in the positive direction is known to be dependent upon the location and pressure of the collector probe on the inclusion. If the collector probe is properly located, this peak can be made to substantially disappear by increasing the probe pressure. The voltage of this peak is also affected by the temperature of the probe-inclusion junction region and by intensity of light

3

falling in the area near the probe-inclusion junction. It is from this latter effect that the name "photo-peak" was derived. It is known empirically that the collector characteristic peak always occurs at substantially the same collector current magnitude. A fully satisfactory explanation for this phenomena has not as yet been found. It is generally accepted, however, that light and temperature affect the number of current carriers present in the semi-conductor material (holes in the filled band, electrons in the conductor band). For the theory of conduction in solids as it is now understood, reference is made to such works as Torrey and Whitmer, *Crystal Rectifiers*, McGraw-Hill, 1948, and a detailed discussion therefore will not be attempted here.

The "photo-peak" diode differs from the ordinary semi-conductor diode, in which the semi-conductor is all either "P" type or "N" type, in that the "photo-peak" diode has a high resistance in both the positive and negative directions, in the region from the origin substantially to the peaks. This region is indicated as being between the points *a* and *b* on curve A of Fig. 2.

The back resistance (the probe-semi-conductor contact resistance in the normally low current direction) of a pure "N" or "P" type semi-conductor can be varied by placing a second probe electrode near the collector electrode and injecting either holes or electrons respectively into the semi-conductive material. This is the principal of transistor action. In an ordinary "P" type transistor, the back resistance is caused to decrease by the injection of electrons (which is done by biasing the emitter electrode negatively with respect to the base electrode, when the collector voltage is positive). In the case of an "N" type transistor, the same effect is obtained by injection of holes (which is done by biasing the emitter electrode positively with respect to the base electrode when the collector voltage is negative). Thus it is noted that in the case of "P" type semi-conductive material, the back resistance is decreased by the injection of electrons.

I have discovered that if the collector probe pressure on a photo-peak diode is adjusted so that the collector characteristic peak substantially disappears, and a second probe is placed on the "N" type material near the "N-P" boundary, that the peak can be caused to reappear by causing electrons to flow from the second probe into the "N" type material. This action is anomalous to the expected result, because it means that the back resistance of "P" type material has been increased, rather than decreased, by electron injection. I have also found that as the negative bias on the second probe is continuously increased, (more electrons injected into the "P" type material through the barrier between the "N" type material and the "P" type material) the voltage of the peak of the collector characteristic curve increases, reaches a maximum, and then decreases. On the other hand, if the pressure and location of the collector probe is adjusted such that a peak appears initially in the collector characteristic, the magnitude of this peak can be made to decrease by injection of holes from the second probe into the "N" type material. I have found further that the breakdown voltage in the back direction of an ordinary semi-conductor diode can be varied by current carrier (holes or electrons, as the case may be) injection.

In accordance with the broad aspects of my invention, I utilize the discovery that the collector

4

characteristic peaks, in the case of a photo-peak semi-conductor diode (or the voltage at which breakdown occurs in the back direction, in the case of an ordinary semi-conductor diode), can be caused to vary by injection of current carriers from a second probe, to provide a novel and improved triggered type relay device.

It is to be understood that the principles of my invention may be applied to various forms of appropriate semi-conductive devices. In order that my invention be clearly understood, however, I will describe it in connection with specific embodiments in which a semi-conductive device taking the general form of the so-called type "A" transistor, is utilized.

My invention, together with other objects and advantages thereof, will be best understood from the following description, when read in connection with the accompanying drawing, in which:

Figure 1 is a schematic diagram showing a conventional photo-peak diode;

Fig. 2 is a curve showing the collector characteristic of a photo-peak diode such as that of Fig. 1;

Fig. 3 is a schematic diagram showing a preferred embodiment of my invention;

Fig. 4 is a curve showing the collector diode characteristic of the semi-conductive device of Fig. 3 for various conditions;

Fig. 5 is a schematic diagram showing a further embodiment of my invention; and

Fig. 6 is a curve showing the collector diode characteristic of the semi-conductive device of Fig. 5, for various reasons.

With reference to Fig. 3, a triggered type relay device may be constructed in accordance with my invention by utilizing a block 11 of an "N" type semi-conductive material having on one face thereof a small "P" type inclusion 13. The semi-conductive material may be of any suitable type but is preferably germanium. The preferred method of forming the "P" type inclusion is by high energy particle bombardment of an "N" type semi-conductive block. However, if it is desired, "N" type crystal blocks having "P" type inclusions can be selected from a large melt of semi-conductive material. A point contact collector probe 15 is located in contact with the inclusion 13 and near the "P-N" boundary of the semi-conductive block 11. A base electrode 17 is placed contiguous to the opposite face of the block 11 in such a manner as to secure a relatively large electrical contact area. A suitable output impedance 18 having terminals 19, 21, is connected in series with a source of variable potential 23 between the collector electrode 15 and the base electrode 17. This variable potential is shown as a potentiometer 25 shunted by a battery 27 to place a positive bias on the collector electrode 15. However, an A. C. collector bias potential may be used in some applications, as will be hereinafter more fully explained. A second point contact electrode 29, which will be hereinafter referred to as the emitter electrode, is placed in contact with the "N" type material 11 proximate to the collector electrode 15. An input impedance 31 having terminals 33, 35 is connected in series with a variable source of D. C. potential 37 between the emitter and base electrodes 29, 17. This D. C. potential is shown for convenience as a potentiometer 39 shunted by a pair of series connected batteries 40, 41. The sliding contact 43 of the potentiometer 39 is connected to the lower

5

input impedance terminal 35 and the battery junction 44 is connected to the base electrode 17. The polarity of the source 37 is made selectively positive or negative depending upon the position of the potentiometer sliding contact 46. It is emphasized that the arrangement just described is schematic and is intended only to serve as an aid in the understanding of some of the possible forms which my invention may take, and is not intended to necessarily represent any particular commercial form which my invention may take.

The operation of the arrangement shown in Fig. 3 will be best explained by reference to the curve of Fig. 4 in which I have plotted collector current, I , as ordinate and the collector voltage V_c as the abscissa, for the various operating conditions. A load line, B, has been drawn for a collector voltage of E_{c1} and a load impedance of X ohms. A load line, C, has been drawn for a collector voltage E_{c2} and a load impedance of X ohms. If it is desired to produce a control pulse at the terminals 19, 21 of the output impedance 18, the collector probe 15 is adjusted in location and pressure such that in the absence of an emitter bias the peak in the diode characteristic substantially disappears, as shown by curve D of Fig. 4. The potentiometer sliding contact 46 is then located so as to place a negative bias on the emitter electrode 29, causing the peak to reappear. This negative bias is adjusted so that the collector characteristic curve E is intersected by the load line at at least three points c, d, e , the point of highest voltage c being just below the voltage of the peak of curve E, so that point c becomes the operating point. Now a positive pulse of sufficient magnitude to reduce the collector characteristic peak voltage sufficiently to cause the load line, B, to intersect the diode collector characteristic, now curve F, at only one point e , is applied to the input impedance terminals 33, 35. The collector operating current which was established at a relatively low magnitude by the load line, B, at point c now jumps instantaneously to a new operating point of relatively high magnitude, as determined by the load line, B, at e . This jump in collector current magnitude is substantially instantaneous. I have found in actual practice that the collector current will jump from a magnitude of 1 milliamperes to about 10 milliamperes in less than $\frac{1}{10}$ of a microsecond. The voltage change in the emitter circuit required to cause this trigger action is somewhat less than 1 volt.

Once the circuit has been triggered, it can be reset after restoring the initial emitter bias, by reducing the collector voltage sufficiently that the load line, C, will now intersect the collector characteristic (curve E) at only one point, g . Once the collector voltage has been sufficiently reduced, the circuit is reset substantially instantaneously (the reset time being of the same order of magnitude as the trigger time, or less than $\frac{1}{10}$ of a microsecond). The collector voltage can be automatically reduced to reset the circuit by various conventional means. For example, the capacitor 45, resistance 43 arrangement shown in Fig. 3 serves this purpose. The resistance 43 is inserted between the base electrode 17 and the negative terminal of the collector potential source 23, and the capacitor 45 is shunted across the potential source 23 and the resistance 43. In this case the circuit may be used as a relaxation oscillator. Such an oscillator may be either pulsed

6

or free running, by proper adjustment of either emitter or collector bias. The circuit may also be made to reset automatically by the use of an alternating current collector potential.

If the emitter bias is initially made sufficiently negative, the maximum collector characteristic peak voltage indicated by curve G of Fig. 4 may be reached, so that increased negative bias will cause a decrease in the peak voltage. The negative emitter bias may be increased sufficiently that the peak voltage will decrease to correspond to curve E. In this case the circuit can be triggered by placing across the input impedance terminals 33, 35 a negative trigger pulse of sufficient magnitude to further reduce the collector characteristic peak to correspond to curve F. The collector current will then jump from a relatively low magnitude c to a relatively high magnitude e . Also, if the emitter is biased negatively so that the maximum collector characteristic peak voltage appears (curve G, Fig. 4) and the collector voltage is set so that a load line, B, will intersect the collector characteristic peak at points s and t , just below the peak voltage, then the device may be triggered by either a positive or negative pulse applied across the input impedance terminals 33, 35. It is apparent that the arrangement of Fig. 3 may be adapted to operate as any conventional trigger circuit within its range of parameters. It may also be operated as a relaxation oscillator, or a pulse generator. If it is desired, a "P" type semi-conductive block having an "N-P" inclusion on one face thereof may be used with the same results, except that all polarities will then be reversed.

For another type of operation of the arrangement of Fig. 3, the pressure of the collector electrode may be adjusted (decreased) so that initially a peak appears in the collector characteristic. In this case the potentiometer slider 46 is adjusted so as to place a positive bias on the emitter electrode 29. This positive bias tends to decrease the magnitude of the collector characteristic peak voltage and it may be adjusted so that the peak appears as curve E of Fig. 4. If a positive trigger pulse is now applied to the input impedance terminals 33, 35 and is of such magnitude as to reduce the collector characteristic peak voltage sufficiently that the load line B, will intersect the collector characteristic curve F, at only one point e the circuit will again be triggered, and the collector current will jump instantaneously from a relatively low to a relatively high magnitude as in the case previously described. It is possible to use a "P" type semi-conductive block with an "N" type inclusion in the same manner as in the operation last described, except that all polarities would be reversed.

In Fig. 5 there is shown an ordinary transistor comprising a block 47 of "N" type semi-conducting material and having emitter, collector, and base electrodes 49, 51, 53 associated therewith in the conventional manner. An input impedance 55 having terminals 57, 59 is connected in series with a source 61 of variable D. C. potential shown as a potentiometer 63 in shunt with a battery 65 between the emitter and base electrodes 49, 53. An output impedance 67 having terminals 69, 71 is connected in series with a source 73 of variable D. C. potential shown as a battery 75 in shunt with a potentiometer 77 between the collector and base electrodes 51, 53. To operate the arrangement shown in Fig. 5 as a trigger circuit, the collector electrode 51 is biased negatively to

a predetermined value, E_{c3} , as indicated on the graph of Fig. 6. A load line, H, has been drawn in Fig. 6, assuming an output impedance of X ohms, and a collector bias of E_{c3} . Another load line K, has been drawn for a collector bias of E_{c4} and an output impedance of X ohms. The emitter bias is then made sufficiently positive to cause the collector characteristic peak voltage curve, L, to intersect the load line, H, at at least three points h, k, n , Fig. 6. The circuit can then be triggered by the application of a positive pulse to the input impedance terminals, 57, 59 of sufficient magnitude to reduce the collector characteristic peak voltage sufficiently that it corresponds to curve, M, which is intersected by the load line, L, at only one point N. The collector current will then jump substantially instantaneously from its operating point of relatively low collector current magnitude h to an operating point n of relatively high collector current magnitude. The circuit can be reset, after the initial emitter bias has been restored, by reducing the collector voltage sufficiently that the load line, K, intersects the collector characteristic curve, L, at only one point m . If a D. C. collector potential is used, the circuit may be reset by a capacitor 76-resistor 79 arrangement as shown in Fig. 5. The resistance 79 is inserted between the base electrode 53 and the positive terminal of the collector potential source 73 and the capacitor 76 is shunted across the resistance 79 and the potential source 73. Such a circuit may be operated as a relaxation oscillator. An alternating current collector potential could also be used but is not preferred, because the forward resistance is sufficiently low to cause power dissipation of undesirable magnitude on the positive half-cycles of the A. C. collector potential supply. The ordinary transistor action just described may be adapted for use, in accordance with my invention, as any conventional type trigger circuit, as a relaxation oscillator, or a pulse generator. If it is desired, a "P" type crystal may be used with the same results, except that the polarities will be reversed.

In accordance with another aspect of my invention, it is not necessary to apply an external trigger pulse to the input impedance in the arrangements hereinbefore discussed with reference to Figs. 3 and 5. It has been stated above that the value of the collector peak voltage of a photo-peak diode is affected by the number of current carriers present in the vicinity of the probe contact. Since temperature is one of the quantities which affects the number of current carriers present, it is clear that if the collector voltage were set at a predetermined value and the temperature slowly raised until the voltage of the peak dropped below this value, the collector current would be suddenly increased. However, individual semi-conductive crystals vary considerably in their temperature response, and most of these have a sufficiently high threshold of the temperature effect that their use directly as temperature trigger devices would be very limited. However, the resistance in the back direction of an "N" type semi-conductor diode is an inverse function of temperature, for temperatures below the intrinsic range of the semi-conductor. Therefore, for example, a circuit arranged, such as shown in Fig. 3 may be used as a thermally triggered relay device. One way of doing this, is with the collector bias set to E_{c1} , Fig. 4, to adjust the collector probe pressure and location so that the collector characteristic peak

is initially made to disappear. Then the emitter bias is adjusted negative sufficiently to bring the collector characteristic peak voltage up to the magnitude corresponding to curve E. Now if the temperature of the semi-conductor in the vicinity of the emitter probe is lowered slightly, so that the resistance in the emitter circuit is increased to decrease the emitter current, and in effect, decrease the negative emitter bias sufficiently to cause the collector characteristic peak voltage to be reduced to correspond to curve F, Fig. 4, the device will trigger. With the conditions as just described except that the negative emitter bias is increased sufficiently that the maximum collector characteristic peak voltage is exceeded and the peak decreased with increasing bias to correspond to curve E, Fig. 4, the device will trigger when the temperature in the emitter probe vicinity is raised sufficiently to cause, in effect, increased negative emitter bias to bring the collector characteristic to correspond to curve F. Also, if the emitter is biased negatively so that the maximum collector characteristic peak voltage appears (curve G, Fig. 4) and the collector voltage is set so that a load line, R, will intersect the collector characteristic peak at points s and t , just below the peak voltage, then the device will be triggered by either an increase or a decrease in the temperature of the emitter probe contact region. Further, if the collector probe pressure and location is initially adjusted so that a peak appears in the collector characteristic, and the emitter bias is then adjusted positive so the peak is reduced to correspond to curve E of Fig. 4, then a rise in either the emitter or collector probe temperature will further lower the peak to correspond to curve F, of Fig. 4, and will cause the device to be triggered. In the three cases described immediately above, a "P" type semi-conductive block having an "N" type inclusion could also be used, but the polarities would be reversed.

An ordinary semi-conductive diode, instead of a photo-peak diode, can also be used to make a thermally triggered device. The various methods in which this could be done are believed to be apparent from the foregoing description.

It is noted that thermostatic devices which conventionally employ such temperature responsive elements as bimetallic strips, mercury contacts, or gas pressure, perform their ultimate function by closing a physical electrical contact. These contacts invariably at some stage cause trouble. On the other hand, a thermally triggered relay device constructed in accordance with the teachings of my invention, will provide a discrete current step without making a physical electrical contact.

I wish to point out, for reasons of clarity, that in all cases hereinbefore described, in order to establish an initial operating point of low current magnitude, it is necessary that the collector diode characteristic upon which it is desired to operate be first obtained, by adjustment of emitter bias, or otherwise, as the case may be, before the collector bias voltage is applied.

I am aware that many modifications of the embodiments shown and described are possible without departing from the scope of my invention, I desire, therefore, to be limited only as is necessitated by the prior art and the spirit of the appended claims.

I claim as my invention:

1. A relay device, comprising a block of "N" type semi-conductive material having a small "P"

type inclusion on one face thereof, an emitter electrode placed on "N" type material near said inclusion, a collector electrode placed on said inclusion, a base electrode placed on the opposite face of said block, an input circuit comprising an input impedance connected in series with a source of adjustable negative D. C. bias potential between said emitter and base electrodes, and an output impedance connected in series with a positive D. C. bias potential between said collector and base electrodes.

2. A relay device, comprising a block of "N" type semi-conductive material having a small "P" type inclusion on one face thereof, an emitter probe placed on said block, near said inclusion, a collector probe placed on said inclusion, a base electrode placed on the opposite face of said block, means for biasing said collector probe positive with respect to said base electrode, the diode volt-ampere characteristic of said collector being of the photo-peak type, the location and pressure of said collector electrode with respect to said inclusion being such that the photo-peak of said collector characteristic is removed, and means for applying bias to make said emitter electrode negative with respect to said base electrode, whereby the peak of said collector characteristic is caused to reappear.

3. A relay device, comprising a block of "N" type semi-conductive material having a small "P" type inclusion on one face thereof, an emitter probe placed on said block, near said inclusion, a collector probe placed on said inclusion, a base electrode placed on the opposite face of said block, means for biasing said collector probe positive with respect to said base electrode, the diode characteristic of said collector being of the photo-peak type, the location and pressure of said collector electrode with respect to said inclusion being such that the photo-peak of said collector characteristic is removed, and means for applying bias to make said emitter electrode negative with respect to said base electrode, whereby the peaks of said collector characteristic re-appear and as said last-mentioned bias is made still more negative, said collector characteristic reaches a maximum peak, and as said negative bias is further increased, said collector characteristic recedes from the maximum peak magnitude.

4. In combination, a block of "N" type semi-conductive material having a small "P" type inclusion on one face thereof, a collector probe placed in contact with said inclusion, a base electrode in contact with another face of said block, means for biasing said collector probe positive with respect to said base electrode, the location and contact pressure of said collector probe being adjusted so that no voltage peak appears in the collector characteristic, means for controlling said collector characteristic to produce voltage peaks therein, said means including an emitter electrode placed on said block near said inclusion and a bias source which may be applied to bias said emitter electrode negative with respect to said base electrode to a selectable degree.

5. A relay device, comprising a collector probe in contact with a small "P" type inclusion in a block of "N" type semi-conductive material having a base electrode which is biased negatively with respect to said collector electrode, the pressure and location of said collector probe having been adjusted so that no peak appears in the collector characteristic, a load impedance in circuit with said collector probe, an emitter electrode in contact with said block near said inclu-

sion, an adjustable bias which may be applied to bias said emitter electrode negatively with respect to said collector electrode to the desired degree, whereby a peak may be caused to appear in said collector characteristic, means for placing a positive bias on said collector electrode, whereby a load line may be drawn to establish a first operating point on said collector characteristic, and means for reducing said emitter negative bias, whereby a second operating point may be substantially instantaneously established on said collector characteristic.

6. A relay device, comprising a block of "N" type semi-conductive material, a small "P" type inclusion on one face of said block, a collector electrode in contact with said inclusion, a base electrode on the opposite face of said block, said collector electrode being adjusted in location and contact pressure such that no peak appears in the collector characteristic, an emitter electrode located on "N" type material near said inclusion, means for biasing said emitter electrode negative with respect to said base electrode, said emitter bias being so adjusted that a peak appears in the collector characteristic, means for biasing said collector electrode positive with respect to said base electrode to establish an operating point on said collector characteristic of relatively low collector current, and means for momentarily reducing said emitter bias to cause a substantially instantaneous jump to an operating point of relatively high collector current, and means to thereafter reduce said collector electrode positive bias sufficiently to cause a return to said operating point of relatively low collector current.

7. A relay device, comprising a block of "N" type semi-conductive material, a small "P" type inclusion on one face of said block, a collector electrode in contact with said inclusion, a base electrode in contact with the opposite face of said block, the location and contact pressure of said collector electrode being adjusted such that no peak appears in the diode characteristic of said collector electrode, an emitter electrode in contact with "N" type material on said block near said inclusion, a source of D. C. potential for biasing said emitter electrode negatively with respect to said base electrode, a load impedance in circuit with said collector electrode, means for biasing said collector electrode positively with respect to said base electrode, whereby an operating point of relatively low load impedance current is established on said collector characteristic, an input impedance in circuit with said emitter electrode, means for applying a momentary potential to said input impedance in a sense, depending upon the magnitude of emitter negative bias, such that the load impedance current will substantially instantaneously rise to a relatively high magnitude, and means for reducing said collector positive bias sufficiently to return said load impedance current to a relatively low magnitude.

8. A relay device, comprising a block of "P" type semi-conductive material having a small "N" type inclusion on one face thereof, an emitter probe placed on said block, near said inclusion, a collector probe placed on said inclusion, a base electrode placed on the opposite face of said block, means for biasing said collector probe negative with respect to said base electrode, the diode characteristic of said collector being of the photo-peak type, the location and pressure of said collector electrode with respect to said inclusion being such that the photopeak of said

collector characteristic is removed, and means for applying bias to make said emitter electrode positive with respect to said base electrode, whereby the peak of said collector characteristic is caused to re-appear.

9. In combination, a block of "P" type semi-conductive material having a small "N" type inclusion on one face thereof, a collector probe placed in contact with said inclusion, a base electrode in contact with another face of said block, means for biasing said collector probe negative with respect to said base electrode, the location and contact pressure of said collector probe being adjusted so that no voltage peak appears in the collector characteristic, means for controlling said collector characteristic to produce voltage peaks therein, said means including an emitter electrode placed on said block near said inclusion and a bias source which may be applied to bias said emitter electrode positive with respect to said base electrode to a selectable degree.

10. A relay device, comprising a block of "P" type semi-conductive material, a small "N" type inclusion on one face of said block, a collector electrode in contact with said inclusion, a base electrode on the opposite face of said block, said collector electrode being adjusted in location and contact pressure such that no peaks appear in the collector characteristic, an emitter electrode located on "P" type material near said inclusion, means for biasing said emitter electrode positive with respect to said base electrode, said emitter bias being so adjusted that a peak appears in the collector characteristic, means for biasing said collector electrode negative with respect to said base electrode to establish an operating point on said collector characteristic of relatively low collector current, and means for momentarily reducing said emitter bias to cause a substantially instantaneous jump to an operating point of relatively high collector current, and means to thereafter reduce said collector electrode negative bias sufficiently to cause a return to said operating point of relatively low collector current.

11. A relay device, comprising a block of "P" type semi-conductive material, a small "N" type inclusion on one face of said block, a collector electrode in contact with said inclusion, a base electrode in contact with the opposite face of said block, the location and contact pressure of said collector electrode being adjusted such that no peak appears in the diode characteristic of said collector electrode, an emitter electrode in contact with "P" type material on said block near said inclusion, a source of D. C. potential for biasing said emitter electrode positively with respect to said base electrode, a load impedance in circuit with said collector electrode, means for biasing said emitter electrode negatively with respect to said base electrode, whereby an operating point of relatively low load impedance current is established on said collector characteristic, an input impedance in circuit with said emitter electrode, means for applying a momentary potential to said input impedance in a sense, depending upon the magnitude of emitter positive bias, such that the load impedance current will substantially instantaneously rise to a relatively high magnitude, and means for reducing said collector negative bias sufficiently to return said load impedance current to a relatively low magnitude.

12. In combination, a block of "N" type semi-conductive material having a small "P" type inclusion on one face thereof, a collector probe

placed in contact with said inclusion, a base electrode in contact with another face of said block, means for biasing said collector probe positive with respect to said base electrode, the location and contact pressure of said collector probe being adjusted so that a voltage peak appears in the collector characteristic, means for controlling said collector characteristic to remove voltage peaks therein, said means including an emitter electrode placed on said block near said inclusion, and a bias source which may be applied to bias said emitter electrode positive with respect to said base electrode to a selectable degree.

13. A relay device, comprising a block of "N" type semi-conductive material, a small "P" type inclusion on one face of said block, a collector electrode in contact with said inclusion, a base electrode on the opposite face of said block, said collector electrode being adjusted in location and contact pressure such that peaks appear in the collector characteristic, an emitter electrode located on "N" type material near said inclusion, means for biasing said collector electrode positive with respect to said base electrode, means for biasing said emitter electrode positive with respect to said base electrode, said emitter bias being so adjusted that a peak in the collector characteristic establishes an operating point of relatively low collector current, and means for momentarily increasing said emitter bias so cause a substantially instantaneous jump to an operating point of relatively high collector current, and means to thereafter reduce said collector electrode positive bias sufficiently to cause a return to said operating point of relatively low collector current.

14. A relay device, comprising a block of "N" type semi-conductive material, a small "P" type inclusion on one face of said block, a collector electrode in contact with said inclusion, a base electrode in contact with the opposite face of said block, the location and contact pressure of said collector electrode being adjusted such that a peak appears in diode characteristic of said collector electrode, an emitter electrode in contact with "N" type material on said block near said inclusion, a source of D. C. potential for biasing said emitter electrode positively with respect to said base electrode, a load impedance in circuit with said collector electrode, means for biasing said collector electrode positive with respect to said base electrode, whereby an operating point of relatively low load impedance current is established on said collector characteristic, an input impedance in circuit with said emitter electrode, means for applying a momentary positive potential to said input impedance, to cause said load impedance current to rise substantially instantaneously to a relatively high magnitude, and means for thereafter reducing said collector positive bias sufficiently to return said load impedance current to a relatively low magnitude.

15. In combination, a block of "P" type semi-conductive material having a small "N" type inclusion on one face thereof, a collector probe placed in contact with said inclusion, a base electrode in contact with another face of said block, means for biasing said collector probe positive with respect to said base electrode, the location and contact pressure of said collector probe being adjusted so that a voltage peak appears in the collector characteristic, means for controlling said collector characteristic to remove voltage

13

peaks therein, said means including an emitter electrode placed on said block near said inclusion and a bias source which may be applied to bias said emitter electrode negative with respect to said base electrode to a selectable degree.

16. A relay device, comprising a block of "P" type semi-conductive material, a small "N" type inclusion on one face of said block, a collector electrode in contact with said inclusion, a base electrode on the opposite face of said block, said collector electrode being adjusted in location and contact pressure such that peaks appear in the collector characteristic, an emitter electrode located on "P" type material near said inclusion, means for biasing said collector electrode negative with respect to said base electrode, means for biasing said emitter electrode negative with respect to said base electrode, said emitter bias being so adjusted that a peak in the collector characteristic establishes an operating point of relatively low collector current, and means for momentarily increasing in said emitter bias to cause a substantially instantaneous jump to an operating point of relatively high collector current, and means to thereafter reduce said collector electrode negative bias sufficiently to cause a return to said operating point of relatively low collector current.

17. A relay device, comprising a block of "P" type semi-conductive material, a small "N" type inclusion on one face of said block, a collector electrode in contact with said inclusion, a base electrode in contact with the opposite face of said block, the location and contact pressure of said collector electrode being adjusted such that a peak appears in the diode characteristic of said collector electrode, an emitter electrode in contact with "P" type material on said block near said inclusion, a source of D. C. potential for biasing said emitter electrode negatively with respect to said base electrode, a load impedance in circuit with said collector electrode, means for biasing said collector electrode negative with respect to said base electrode, whereby an operating point of relatively low load impedance current is established on said collector characteristic, and input impedance in circuit with said emitter electrode, means for applying a momentary negative potential to said input impedance, to cause said load impedance current to rise substantially instantaneous to a relatively high magnitude, and means for thereafter reducing said collector negative bias sufficiently to return said load impedance current to a relatively low magnitude.

18. A thermostatic device, comprising a block of "N" type semi-conductive material, a small "P" type inclusion on one face of said block, a collector electrode in contact with said inclusion, a base electrode on the opposite face of said block, said collector electrode being initially adjusted in location and contact pressure such that no peak appears in the diode characteristic of said collector electrode, an emitter electrode located on "N" type material near said inclusion, means for biasing said emitter electrode negative with respect to said base electrode, said emitter bias being so adjusted that a peak appears in said collector characteristic, means for biasing said collector electrode positively to a predetermined magnitude with respect to said base electrode, said collector characteristic peak voltage being of such magnitude that a load line will intersect said characteristic at points just below said peak voltage magnitude to establish

14

an operating point of relatively low collector current, whereby a small increase of ambient temperature will lower the voltage of said peak to a magnitude less than said collector bias, and an operating point of relatively high collector current will be substantially instantaneously established.

19. A thermostatic device, comprising a block of "N" type semi-conductive material, a small "P" type inclusion on one face of said block, a collector electrode in contact with said inclusion, a base electrode on the opposite face of said block, said collector electrode being initially adjusted in location and contact pressure such that no peak appears in the diode characteristic of said collector electrode, an emitter electrode located on "N" type material near said inclusion, means for biasing said emitter electrode negative with respect to said base electrode, said emitter bias being so adjusted that the peak which is caused by said emitter bias, to appear in said collector characteristic has passed through a maximum and decreases in magnitude with increased emitter bias, means for biasing said collector electrode positively to a predetermined magnitude with respect to said base electrode, said base being only slightly greater in magnitude than the voltage between said collector and base electrodes, to establish an operating point of relatively low collector current, whereby a small increase of ambient temperature will lower the voltage of said peak to a magnitude less than the voltage between said collector and base electrodes, and an operating point of relatively high collector current will be substantially instantaneously established.

20. A thermostatic device, comprising a block of "N" type semi-conductive material, a small "P" type inclusion on one face of said block, a collector electrode in contact with said inclusion, a base electrode in contact with the opposite face of said block, the location and contact pressure of said collector electrode being initially so adjusted that no peak appears in its diode volt-ampere characteristic, an emitter electrode in contact with "N" type material on said block near said inclusion, means for biasing said emitter electrode negatively with respect to said base electrode, a load impedance in circuit with said collector electrode, said emitter negative bias being adjusted such that the collector characteristic peak is of maximum magnitude, means for biasing said collector electrode to a positive magnitude with respect to said base electrode such that the load line will intersect said collector characteristic at points just below said maximum peak magnitude to establish an operating point of relatively low load impedance current, whereby a slight change in emitter probe contact temperature in either sense, will cause said collector characteristic peak to be reduced to a magnitude such that the load line will intersect said collector characteristic at only one point, whereby an operating point of relatively high load impedance current is substantially instantaneously established.

21. A thermostatic device, comprising a block of "P" type semi-conductive material, a small "N" type inclusion on one face of said block, a collector electrode in contact with said inclusion, a base electrode on the opposite face of said block, said collector electrode being initially adjusted in location and contact pressure such that no peaks appear in its diode volt-ampere characteristic, an emitter electrode located on

15

"P" type material near said inclusion, means for biasing said emitter electrode positive with respect to said base electrode, said emitter bias being so adjusted that a peak appears in said collector characteristic, means for biasing said collector electrode negatively to a predetermined magnitude with respect to said base electrode, said collector characteristic peak voltage being of such magnitude that the load line will intersect said collector characteristic at points just below said peak magnitude to establish an operating point of relatively low collector current, whereby a small increase of ambient temperature will lower the voltage of said peak to a magnitude less than said collector bias, and an operating point of relatively high collector current will be substantially instantaneously established.

22. A thermostatic device, comprising a block of "N" type semi-conductive material, a small "P" type inclusion on one face of said block, a collector electrode in contact with said inclusion, a base electrode on the opposite face of said block, means for biasing said collector electrode positively to a predetermined magnitude with respect to said base electrode, said collector electrode being initially adjusted in location and contact pressure such that a peak appears in its diode volt-ampere characteristic, an emitter electrode located on "N" type material near said inclusion, means for biasing said emitter electrode positively with respect to said base electrode, said emitter bias being so adjusted that the collector peak is of a magnitude such that a load line will intersect said collector characteristic at points just below said peak magnitude to establish an operating point of relatively low collector current, whereby a slight increase in ambient temperature will lower said peak to a magnitude such that the load line will intersect said characteristic at only one point, and an operating point of relatively high collector current will be substantially instantaneously established.

23. A relay device, comprising a block of "N" type semi-conductive material having emitter and collector probes located in proximity on one face thereof and a base electrode in contact with the opposite face, a source of D. C. bias in circuit with said emitter probe, said emitter bias being adjusted positive with respect to said base electrode and of magnitude so as to establish a first collector peak voltage characteristic, said collector bias being adjusted negative with respect to said base electrode and of magnitude such that a load line will intersect said collector peak characteristic at three points, and means for increasing said emitter bias sufficiently to establish a second collector peak characteristic which is intersected by said load line at only one point, whereby the collector current will jump instantaneously to a comparatively large magnitude.

24. A relay device, comprising a block of "N" type semi-conductive material having emitter and collector probes located in proximity on one face thereof and a base electrode in contact with the opposite face, a source of D. C. bias in circuit with said emitter probe, said emitter bias being adjusted positive with respect to said base electrode and of magnitude so as to establish a first collector peak voltage characteristic, said collector bias being adjusted negative with respect to said base electrode and of magnitude such that the load line will intersect said collector peak

16

characteristic at three points, means for increasing said emitter bias sufficiently to establish a second collector peak characteristic which is intersected by said load line at only one point, which is of relatively high collector current magnitude, whereby the collector current will jump instantaneously to a comparatively large magnitude, means for restoring the original magnitude of emitter bias, means for thereafter reducing said collector bias sufficiently that the load line is moved to intersect the collector peak characteristic at only one point, which is of relatively low collector current magnitude, whereby the collector current will be reduced to the initial magnitude.

25. A relay device, comprising a block of "P" type semi-conductive material having emitter and collector probes located in proximity on one face thereof and a base electrode in contact with the opposite face, a source of D. C. bias in circuit with said emitter probe, said emitter bias being adjusted negative with respect to said base electrode and of magnitude so as to establish a first collector peak voltage characteristic, said collector bias being adjusted positive with respect to said base electrode and of magnitude such that the load line will intersect said collector peak characteristic at three points, and means for increasing said emitter bias sufficiently to establish a second collector peak characteristic which is intersected by said load line at only one point, whereby the collector current will jump instantaneously to a comparatively large magnitude.

26. A relay device, comprising a block of "P" type semi-conductive material having emitter and collector probes located in proximity on one face thereof and a base electrode in contact with the opposite face, a source of D. C. bias in circuit with said emitter probe, said emitter bias being adjusted negative with respect to said base electrode and of magnitude so as to establish a first collector peak voltage characteristic, said collector bias being adjusted positive with respect to said base electrode and of magnitude such that the load line will intersect said collector peak characteristic at at least one point, means for increasing said emitter bias sufficiently to establish a second collector peak characteristic which is not intersected by said load line, whereby the collector current will jump instantaneously to a comparatively large magnitude, means for restoring the original magnitude of emitter bias, means for thereafter reducing said collector bias sufficiently that the load line intersects the collector peak characteristic at only one point, which is not a tangent, whereby the collector current will be reduced to the initial magnitude.

27. A thermostatic device, comprising a body of "N" type semi-conductive material containing an inclusion of "P" type semi-conductive material partially exposed on the external surface of said body, an emitter electrode placed on the "N" type material near said inclusion, a collector electrode placed on said inclusion, a base electrode placed on said "N" type material and spaced from said emitter electrode, said collector electrode being initially adjusted in location and contact pressure such that no peak appears in the diode characteristic of said collector electrode, means for biasing said emitter electrode negative with respect to said base electrode, said emitter electrode being so adjusted that a peak appears in said collector characteristic, means for biasing said collector electrode positively to a predetermined magnitude with respect to said

base electrode, said peak being only slightly greater in magnitude than the voltage between said collector and base electrode, to establish an operating point of relatively low collector current, whereby a small decrease of temperature in the vicinity of the emitter electrode will lower the voltage of said peak to a magnitude less than the voltage between the collector and base electrode, and an operating point of relatively high collector current will be substantially instantaneously established.

28. A relay device, comprising a body of "N" type semi-conductive material containing an inclusion of "P" type semi-conductive material partially exposed on the external surface of said body, and emitter electrode placed on the "N" type material near said inclusion, a collector electrode placed on said inclusion, a base electrode placed on said "N" type material and spaced from said emitter electrode, an input circuit comprising means for applying an adjustable negative D. C. current bias through the emitter electrode and means for applying a signal to said emitter electrode, and an output impedance connected in series with a positive D. C. bias potential between said collector and base electrodes.

29. A relay device, comprising a body of "N" type semi-conductive material containing an inclusion of "P" type semi-conductive material partially exposed on the external surface of said body, a collector electrode in contact with said inclusion, a base electrode placed on the "N" type material, said collector electrode being adjusted in location and contact pressure such that no peaks appear in the collector characteristic, an emitter electrode in contact with the "N" type material on said body near said inclusion, means for biasing said emitter electrode negatively with respect to said base electrode, said emitter bias being so adjusted that a peak appears in said collector characteristic, a load impedance in circuit with said collector electrode, means for biasing said collector electrode positively with respect to said base electrode, said peak being only slightly greater in magnitude than the voltage between said collector and base electrodes to establish an operating point of relatively low load impedance current on said collector characteristic, and means for rendering said emitter electrode less negative with respect to said base electrode whereby the load impedance current will jump substantially instantaneously to a relatively high magnitude.

30. A relay device, comprising a body of "P" type semi-conductive material containing an inclusion of "N" type semi-conductive material partially exposed on the external surface of said body, a collector electrode in contact with said inclusion, a base electrode placed on the "P" type material, said collector electrode being so adjusted in location and contact pressure so that no peaks appear in the collector characteristic, an emitter electrode in contact with "P" type material on said body near said inclusion, means for biasing said emitter electrode positively with respect to said base electrode, said emitter bias being so adjusted that a peak appears in said collector characteristic, a load impedance in circuit with said collector electrode, means for biasing said collector electrode negatively with respect to said base electrode, said peak being only slightly greater in magnitude than the voltage between said collector and base electrodes to establish an operating point of relatively low load impedance current on said collector character-

istic, and means for rendering said emitter electrode less positive with respect to said base electrode, whereby the load impedance current will jump substantially instantaneously to a relatively high magnitude.

31. A relay device, comprising a body of "N" type semi-conductive material containing an inclusion of "P" type semi-conductive material partially exposed on the external surface of said body, a collector electrode in contact with said inclusion, a base electrode placed on the "N" type material, said collector electrode being adjusted in location and contact pressure such that no peaks appear in the collector characteristic, an emitter electrode in contact with "N" type material on said body near said inclusion, means for biasing said emitter electrode negatively with respect to said base electrode, said emitter bias being so adjusted that the peak which is caused by said emitter bias, to appear in said collector characteristic has passed through a maximum and decreases in magnitude with increased emitter bias, a load impedance in circuit with said collector electrode, means for biasing said collector electrode positively to a predetermined magnitude with respect to said base electrode, said peak being only slightly greater in magnitude than the voltage between said collector and base electrodes, to establish an operating point of relatively low load impedance current on said collector characteristic, and means for rendering said emitter electrode still more negative with respect to said base electrode whereby the load impedance current will jump substantially instantaneously to a relatively high magnitude.

32. A relay device, comprising a body of "P" type semi-conductive material containing an inclusion of "N" type semi-conductive material partially exposed on the external surface of said body, a collector electrode in contact with said inclusion, a base electrode placed on the "P" type material, said collector electrode being adjusted in location and contact pressure such that no peaks appear in the collector characteristic, an emitter electrode in contact with "P" type material on said body near said inclusion, means for biasing said emitter electrode positively with respect to said base electrode, said emitter bias being so adjusted that the peak which is caused, by said emitter bias, to appear in said collector characteristic has passed through a maximum and decreases in magnitude with increased emitter bias, a load impedance in circuit with said collector electrode, means for biasing said collector electrode negatively with respect to said base electrode, said peak being only slightly greater in magnitude than the voltage between said collector and base electrodes to establish an operating point of relatively low load impedance current on said collector characteristic, and means for rendering said emitter electrode still more positive with respect to said base electrode, whereby the load impedance current will jump substantially instantaneously to a relatively high magnitude.

33. A relay device, comprising a body of "N" type semi-conductive material containing an inclusion of "P" type semi-conductive material partially exposed on the external surface of said body, a collector electrode in contact with said inclusion, a base electrode placed on the "N" type material, said collector electrode being adjusted in location and contact pressure such that a peak appears in the collector characteristic, an emitter electrode in contact with "N" type material

on said body near said inclusion, means for biasing said emitter electrode positively with respect to said base electrode, a load impedance in circuit with said collector electrode, means for biasing said collector electrode positively with respect to said base electrode, whereby an operating point of relatively low load impedance current is established on said collector characteristic, and means for rendering said emitter electrode still more positive with respect to said base electrode whereby the load impedance current will jump substantially instantaneously to a relatively high magnitude.

34. A relay device, comprising a body of "P" type semi-conductive material containing an inclusion of "N" type semi-conductive material partially exposed on the external surface of said body, a collector electrode in contact with said inclusion, a base electrode placed on the "P" type material, said collector electrode being adjusted in location and contact pressure such that a peak appears in the collector characteristic, an emitter electrode in contact with "P" type material on said body near said inclusion, means for biasing said emitter electrode negatively with respect to said base electrode, a load impedance in circuit with said collector electrode, means for biasing said collector electrode negatively with respect to said base electrode, whereby an operating point of relatively low load impedance current is established on said collector characteristic, and means for rendering said emitter electrode still more negative with respect to said base electrode, whereby the load impedance current will jump substantially instantaneously to a relatively high magnitude.

35. A relay device, comprising a body of "N" type semi-conductive material, a base electrode, a collector electrode, and an emitter electrode, in contact with said body, a source of D. C. bias in circuit with said emitter electrode, said emitter bias being adjusted positive with respect to said base electrode and of magnitude so as to establish a first collector peak voltage characteristic, said collector bias being adjusted negative with respect to said base electrode and of magnitude such that the load line will intersect said collector peak characteristic at at least two points, means for rendering said emitter electrode sufficiently more positive with respect to said base electrode to establish a second collector peak characteristic which is intersected by said load line at only one point, which is of relatively high collector current magnitude, whereby the collector current will jump instantaneously to a comparatively large magnitude, means for restoring the initial magnitude of emitter bias, means for thereafter reducing said collector bias sufficiently that the load line is moved to intersect the collector peak characteristic at only one point, which is of relatively low collector current magnitude, whereby the collector current will be reduced to the initial magnitude.

36. A relay device, comprising a body of "P" type semi-conductive material, a base electrode, a collector electrode, and an emitter electrode, in contact with said body, a source of D. C. bias in circuit with said emitter electrode, said emitter bias being adjusted to render said emitter electrode sufficiently negative with respect to said base electrode as to establish a first collector peak voltage characteristic, a source of D. C. bias in circuit with said collector electrode, said last mentioned bias being adjusted to render said collector electrode sufficiently positive with respect

to said base electrode that the load line will intersect the collector peak characteristic at at least two points, means for rendering said emitter electrode sufficiently more negative with respect to said base electrode as to establish a second collector peak characteristic which is intersected by the load line at only one point, which is of relatively high collector current magnitude, whereby the collector current will jump instantaneously to a comparatively large magnitude, means for restoring the original magnitude of emitter bias, means for thereafter reducing said collector bias sufficiently that the load line is moved to intersect the collector peak characteristic at only one point, which is of relatively low collector current magnitude, whereby the collector current will be reduced to the initial magnitude.

37. A thermostatic device, comprising a body of "N" type semi-conductive material containing an inclusion of "P" type semi-conductive material partially exposed on the external surface of said body, an emitter electrode placed on the "N" type material near said inclusion, a collector electrode placed on said inclusion, a base electrode placed on said "N" type material and spaced from said emitter electrode, said collector electrode being initially adjusted in location and contact pressure such that no peaks appear in the diode characteristic of said collector electrode, means for biasing said emitter electrode negative with respect to said base electrode, said emitter bias being so adjusted that the peak which is caused, by said emitter bias, to appear in said collector characteristic has passed through a maximum and decreases in magnitude with increased emitter bias, means for biasing said collector electrode positively to a predetermined magnitude with respect to said base electrode, said peak being only slightly greater in magnitude than the voltage between said collector and base electrodes, to establish an operating point of relatively low collector current, whereby a small increase of ambient temperature will lower the voltage of said peak to a magnitude less than the voltage between said collector and base electrodes, and an operating point of relatively high collector current will be substantially instantaneously established.

38. A thermostatic device, comprising a body of "P" type semi-conductive material containing an inclusion of "N" type semi-conductive material partially exposed on the external surface of said body, an emitter electrode placed on the "P" type material near said inclusion, a collector electrode placed on said inclusion, a base electrode placed on said "P" type material and spaced from said emitter electrode, said collector electrode being initially adjusted in location and contact pressure such that no peak appears in the diode characteristic of said collector electrode, means for biasing said emitter electrode positive with respect to said base electrode, said emitter bias being so adjusted that the peak which is caused, by said emitter bias, to appear in said collector characteristic has passed through a maximum and decreases in magnitude with increased emitter bias, means for biasing said collector electrode negatively to a predetermined magnitude with respect to said base electrode, said peak being only slightly greater in magnitude than the voltage between said collector and base electrodes, to establish an operating point of relatively low collector current, whereby a small increase of ambient temperature will lower the voltage of

21

said peak to a magnitude less than the voltage between said collector and base electrodes, and an operating point of relatively high collector current will be substantially instantaneously established.

39. A thermostatic device, comprising a body of "N" type semi-conductive material containing an inclusion of "P" type semi-conductive material partially exposed on the external surface of said body, an emitter electrode placed on the "N" type material near said inclusion, a collector electrode placed on said inclusion, a base electrode placed on said "N" type material and spaced from said emitter electrode, said collector electrode being initially adjusted in location and contact pressure such that no peak appears in the diode characteristic of said collector electrode, means for biasing said emitter electrode negative with respect to said base electrode, said emitter bias being so adjusted that a peak appears in said collector characteristic, means for biasing said collector electrode positively to a predetermined magnitude with respect to said base electrode, said peak being only slightly greater in magnitude than the voltage between said collector and base electrodes, to establish an operating point of relatively low collector current, whereby a small increase of ambient temperature will lower the voltage of said peak to a magnitude less than the voltage between the collector and base electrode, and an operating point of relatively high collector current will be substantially instantaneously established.

40. A relay device, comprising a body of "P" type semi-conductive material containing an inclusion of "N" type semi-conductive material partially exposed on the external surface of said body, an emitter electrode placed on the "P" type material near said inclusion, a collector electrode placed on said inclusion, said collector electrode being initially adjusted in location and contact pressure such that no peak appears in the diode characteristic of said collector electrode, a base electrode placed on said "P" type material and spaced from said emitter electrode, means for biasing said emitter electrode positive with respect to said base electrode, said emitter bias being so adjusted that a peak appears in said collector characteristic, means for biasing said collector negatively to a predetermined magnitude with respect to said base electrode, said peak being only slightly greater in magnitude than the voltage between said collector and base electrodes, to establish an operating point of relatively low collector current, whereby a small increase of ambient temperature will lower the voltage of said peak to a magnitude less than the voltage between said collector and base electrodes, and an operating point of relatively high collector current will be substantially instantaneously established.

41. A relay device, comprising a body of "N" type semi-conductive material containing an inclusion of "P" type semi-conductive material partially exposed on the external surface of said body, an emitter electrode placed on the "N" type material near said inclusion, a collector electrode placed on said inclusion, a base electrode placed on said "N" type material and spaced from said emitter electrode, the location and contact pressure of said collector electrode being initially so adjusted that no peak appears in its diode volt-ampere characteristic, and means for biasing said emitter electrode negatively with respect to said base electrode, a load impedance in circuit with said collector electrode,

22

said emitter negative bias being adjusted such that the collector characteristic peak is of maximum magnitude, means for biasing said collector electrode to a positive magnitude with respect to said base electrode such that the load line will intersect said collector characteristic at a point just below said maximum peak magnitude to establish an operating point of relatively low load impedance current, whereby a slight change in the emitter electrode contact temperature in either sense, will cause said collector characteristic peak to be reduced to a magnitude such that the load line will intersect said collector characteristic at only one point, whereby an operating point on relatively high load impedance current is substantially instantaneously established.

42. A relay device, comprising a body of "P" type semi-conductive material containing an inclusion of "N" type semi-conductive material partially exposed on the external surface of said body, an emitter electrode placed on the "P" type material near said inclusion, a collector electrode placed on said inclusion, a base electrode placed on said "P" type material and spaced from said emitter electrode, the location and contact pressure of said collector electrode being initially so adjusted that no peak appears in its diode volt-ampere characteristic, means for biasing said emitter electrode positively with respect to said base electrode, a load impedance in circuit with said collector electrode, said emitter positive bias being adjusted such that the collector characteristic peak is of maximum magnitude, means for biasing said collector electrode to a negative magnitude with respect to said base electrode such that the load line will intersect said collector characteristic at a point just below the maximum peak magnitude to establish an operating point of relatively low load impedance current, whereby a slight change in emitter electrode contact temperature in either sense, will cause said collector characteristic peak to be reduced to a magnitude such that the load line will intersect said collector characteristic at only one point, whereby an operating point of relatively high load impedance current is substantially instantaneously established.

43. A relay device, comprising a body of "N" type semi-conductive material containing an inclusion of "P" type semi-conductive material partially exposed on the external surface of said body, an emitter electrode placed on the "N" type material near said inclusion, a collector electrode placed on said inclusion, a base electrode placed on said "N" type material and spaced from said emitter electrode, said collector electrode being initially adjusted in location and contact pressure such that a peak appears in its diode volt-ampere characteristic, means for biasing said collector electrode positively to a predetermined magnitude with respect to said base electrode, means for biasing said emitter electrode positively with respect to said base electrode, said emitter bias being so adjusted that the collector peak is of a magnitude such that a load line will intersect said collector characteristic at a point just below said peak to establish an operating point of relatively low collector current, whereby a slight increase in ambient temperature will lower said peak to a magnitude such that the load line will intersect said collector characteristic at only one point, and an operating point of relatively high collector

current will be substantially instantaneously established.

44. A relay device, comprising a body of "P" type semi-conductive material containing an inclusion of "N" type semi-conductive material partially exposed on the external surface of said body, an emitter electrode placed on the "P" type material near said inclusion, a collector electrode placed on said inclusion, a base electrode placed on said "P" type material and spaced from said emitter electrode, said collector electrode being initially adjusted in location and contact pressure such that a peak appears in its diode volt-ampere characteristic, means for biasing said collector electrode negatively to a predetermined magnitude with respect to said base electrode, means for biasing said emitter electrode negatively with respect to said base electrode, said emitter bias being so adjusted that the collector peak is of a magnitude such that a load line will intersect the collector characteristic at a point just below said peak to establish an operating point of relatively low collector current, whereby a slight rise in ambient temperature will lower said peak to a magnitude such that the load line will intersect said collector characteristic at only one point and an operating point of relatively high collector current will be substantially instantaneously established.

45. A relay device, comprising a body of "N" type semi-conductive material containing an inclusion of "P" type semi-conductive material partially exposed on the external surface of said body, a collector electrode in contact with said inclusion, a base electrode placed on the "N" type material, said collector electrode being adjusted in location and contact pressure such that no peak appears in the collector characteristic, an emitter electrode in contact with "N" type material on said body near said inclusion, means for biasing said emitter electrode negatively with respect to said base electrode, a load impedance in circuit with said collector electrode, said emitter negative bias being adjusted such that the collector characteristic peak is of maximum magnitude, means for biasing said collector electrode to a positive magnitude with respect to said base electrode such that the load line will intersect said collector characteristic at a point just below said maximum peak magnitude to establish an operating point of relatively low load impedance current, whereby a slight change in either sense, in the voltage between the emitter electrode and the base electrode, will cause said collector characteristic peak to be reduced to a magnitude such that the load line will intersect said collector characteristic at only one point, whereby an operating point of relatively high load impedance current is substantially instantaneously established.

46. A relay device, comprising a body of "P" type semi-conductive material containing an inclusion of "N" type semi-conductive material partially exposed on the external surface of said body, a collector electrode in contact with said inclusion, a base electrode placed on the "P" type material, said collector electrode being adjusted in location and contact pressure such that no peak appears in the collector characteristic, an emitter electrode in contact with "P" type material on said body near said inclusion, means for biasing said emitter electrode positively with respect to said base electrode, a load impedance in circuit with said collector electrode, said emitter

positive bias being adjusted such that the collector characteristic peak is of maximum magnitude, means for biasing said collector electrode to a negative magnitude with respect to said base electrode such that the load line will intersect said collector characteristic at a point just below said maximum peak magnitude to establish an operating point of relatively low load impedance current, whereby a slight change in either sense, in the voltage between the emitter electrode and the base electrode, will cause said collector characteristic peak to be reduced in magnitude such that the load line will intersect said collector characteristic at only one point, whereby an operating point of relatively high load impedance current is substantially instantaneously established.

47. A relay device, comprising a body of "N" type semi-conductive material containing an inclusion of "P" type semi-conductive material partially exposed on the external surface of said body, an emitter electrode placed on the "N" type material near said inclusion, a collector electrode placed on said inclusion, a base electrode placed on said "N" type material and spaced from said emitter electrode, said collector electrode being initially adjusted in location and contact pressure such that a peak appears in its diode volt-ampere characteristic, means for biasing said collector electrode positively to a predetermined magnitude with respect to said base electrode, means for biasing said emitter electrode positively with respect to said base electrode, said emitter bias being so adjusted that the collector peak is of a magnitude such that a load line will intersect said collector characteristic at a point just below said peak to establish an operating point of relatively low collector current, whereby a slight increase in temperature in the vicinity of the emitter electrode will lower said peak to a magnitude such that the load line will intersect said collector characteristic at only one point, and an operating point of relatively high collector current will be substantially instantaneously established.

48. A relay device, comprising a body of "P" type semi-conductive material containing an inclusion of "N" type semi-conductive material partially exposed on the external surface of said body, an emitter electrode placed on the "P" type material near said inclusion, a collector electrode placed on said inclusion, said collector electrode being initially adjusted in location and contact pressure such that no peak appears in the diode characteristic of said collector electrode, a base electrode placed on said "P" type material and spaced from said emitter electrode, means for biasing said emitter electrode positive with respect to said base electrode, said emitter bias being so adjusted that a peak appears in said collector characteristic, means for biasing said collector negatively to a predetermined magnitude with respect to said base electrode, said peak being only slightly greater in magnitude than the voltage between said collector and base electrodes, to establish an operating point of relatively low collector current, whereby a small decrease of temperature in the vicinity of the emitter electrode will lower the voltage of said peak to a magnitude less than the voltage between said collector and base electrodes, and an operating point of relatively high collector current will be substantially instantaneously established.

49. A relay device, comprising a body of "P" type semi-conductive material containing an inclusion of "N" type semi-conductive material par-

25

tially exposed on the external surface of said body, an emitter electrode placed on the "P" type material near said inclusion, a collector electrode placed on said inclusion, a base electrode placed on said "P" type material and spaced from said emitter electrode, said collector electrode being initially adjusted in location and contact pressure such that a peak appears in its diode volt-ampere characteristic, means for biasing said collector electrode negatively to a predetermined magnitude with respect to said base electrode, means for biasing said emitter electrode negatively with respect to said base electrode, said emitter bias being so adjusted that the collector peak is of a magnitude such that a load line will intersect the collector characteristic at a point just below said peak to establish an operating point of relatively low collector current, whereby a slight rise in the temperature in the vicinity of the emitter electrode will lower said peak to a magnitude such that the load line will intersect said collector characteristic at only one point and an operating point of relatively high collector current will be substantially instantaneously established.

50. A relay device, comprising a body of semiconductive material, a base electrode, a collector electrode, and an emitter electrode, in contact with said body, a load impedance connected in

26

circuit with said collector electrode, means for applying biasing voltages to said collector and emitter electrodes, said biasing voltages being so adjusted that the collector characteristic intersects the load line at at least two points, and means for affecting the emitter bias to cause the collector characteristic to intersect the load line at one point only, whereby the collector current instantaneously jumps from one magnitude to a substantially different magnitude.

51. A device as claimed in claim 50, wherein said means for affecting the emitter bias comprises an input impedance connected in series with a source of emitter bias potential between the emitter and base electrode, and means for applying an input potential across said input impedance.

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