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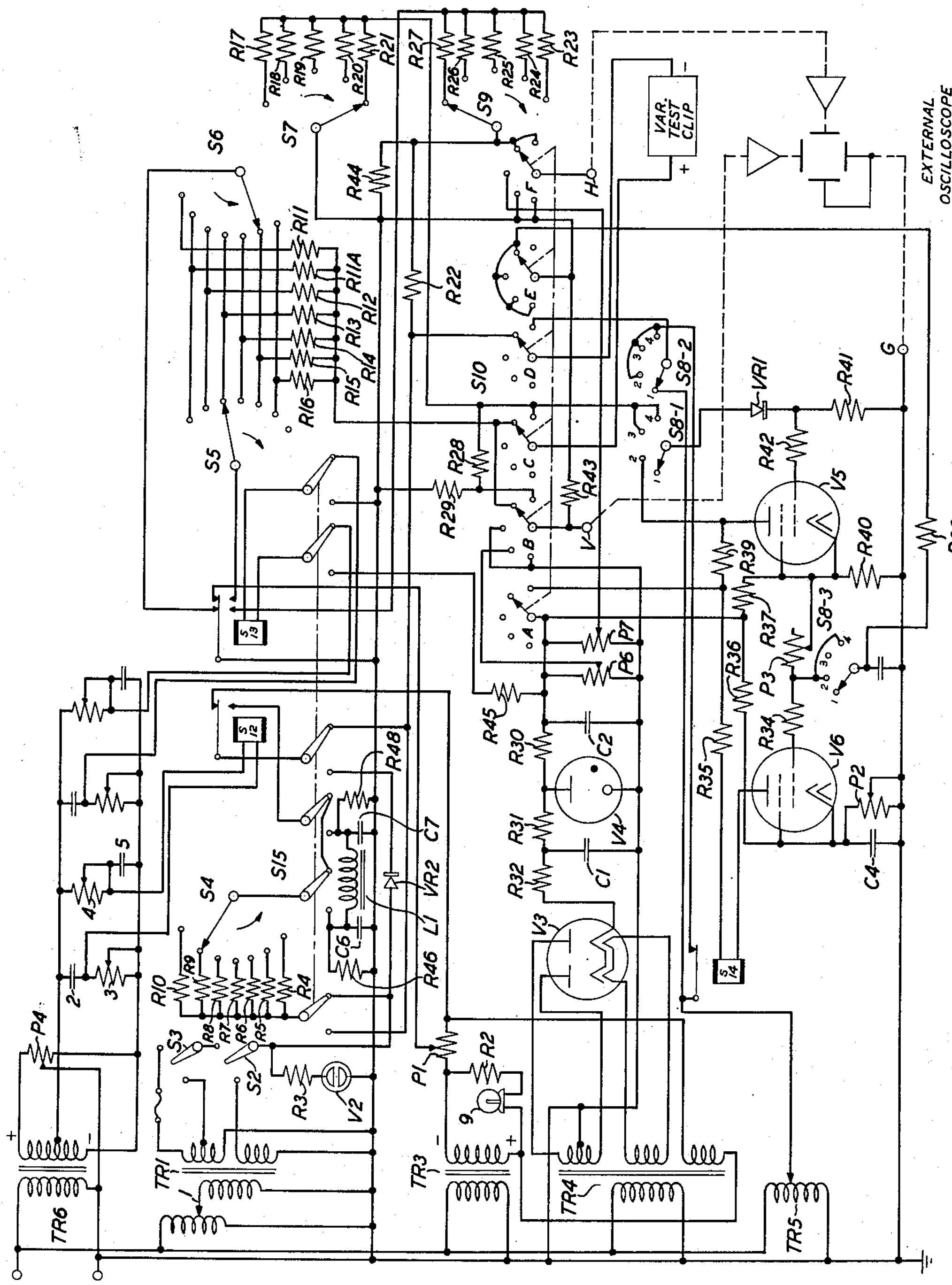

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VARISTOR CURVE TRACER

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This invention relates to apparatus for displaying the complete current-voltage characteristic of a varistor on a cathode-ray oscilloscope, and for applying electrical forming pulses to the varistor. A varistor may be defined as a two-pole semiconductor, such as a piece of germanium, silicon, etc., which may be mixed with a small proportion of some other substance.

One object of the invention is apparatus for displaying both the forward, and the reverse, current-voltage characteristics of a varistor on the screen of a cathode-ray oscilloscope in such rapid alternations that, due to the persistency of vision, the two characteristics combine to form one complete characteristic.

Another object is apparatus for applying to a varistor electrical pulses for forming the varistor and for displaying a characteristic of the varistor during the forming process.

A feature of the invention is the provision of means for changing the voltage and current scales of the characteristics, so that both characteristics may be displayed at one time on the most advantageous scales.

Another feature of the invention is the provision of means for electronically timing the time interval of the application of the electrical forming pulses.

A further feature of the invention is the provision of means for detecting the sudden drop in the reverse resistance of the varistor, when the forming pulses have warmed the varistor sufficiently to reduce the peak reverse voltage below the forming voltage.

The drawing discloses a typical embodiment of the invention.

The circuit is switched for successive and alternate displays of the two characteristics by the relays S12, S13, which may conveniently be known types of mercury contact relays. Since the characteristics are displayed to small fractions of a volt, the switching device should have a very low passing resistance and no contact difference of potential, thus, mercury contact relays are preferred over other switching devices, such as electronic switches, varistor gates, etc. The winding of relay S12 is energized from the secondary winding of transformer TR6, through adjustable resistors 3, 4. Resistors 3, 4, with capacitors 2, 5, form a phase shifting bridge circuit, which may be adjusted to produce operation of the relay at a desired point, preferably zero, of the applied wave. The primary winding of transformer TR6, is connected to a source of commercial alternating power. The secondary winding of transformer TR6 is similarly connected to a similar phase shifting bridge circuit associated by the fifth and sixth sections of switch S15, with the winding of relay S13.

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In mercury relays S12, S13, there is a small stray capacitance between the relay coils and the relay contacts, which might result in the transmission of an alternating voltage to the relay contacts which would interfere with the accuracy of the test results. To avoid this result, the circuit supplying the windings of relays S12, S13, is connected to ground through the brush of potentiometer P4.

The alternating power supply is connected through an adjustable autotransformer 1, which may be of the type known commercially as a "Variac," to the primary winding of transformer TR1. One secondary winding of transformer TR1 is connected to the left contact of switch S2; the right contact of switch S2 being connected to the blade of switch S3. The other secondary winding of transformer TR1 is connected to the right contact of switch S2, while a tap from this winding is connected to the left contact of switch S3. With switch S2 on the left contact, a low voltage is selected; with switch S2 on the right contact and switch S3 on the left contact, a medium voltage is selected; with switch S2 on the left contact and switch S3 on the right contact, a high voltage is selected. Thus, by manipulation of switches S2, S3, and the Variac, a wide range of voltages may be selected. The resistor R3 and gas-filled glow lamp V2 connected in serial relationship across the output circuit indicates when voltages in excess of 50 volts are developed across the varistor, to warn the operator of the apparatus to exercise caution.

In the operated positions of relays S12, S13, current flows from ground through the selected secondary winding of transformer TR1, switch S2, the first section of switch S15, the resistor selected by switch S4, the second and third sections of switch S15, make contacts of relay S12, fourth section of switch S15, fourth contact and blade of switch S10-D, in the blocking direction through the varistor under test, blade and fourth contact of switch S10-C, resistor selected by switch S5, right make contact and swinger of relay S13 to ground. The vertical plates of the cathode-ray oscilloscope are connected through the fourth contact and blade of switch S10-B and terminal V across the resistor selected by switch S5, and are thus energized by a voltage proportional to the current flowing through the varistor.

The cathode-ray oscilloscope may be any suitable device, and should include the direct-current amplifiers, controls, and power supply usually furnished with such devices.

In a practical embodiment of the invention, with a widely used commercial oscilloscope, the resistors associated with switch S5 had graduated values from less than one ohm to over fifty thousand ohms.

Alternating currents also flow through resistor R22 and the resistor R23 to R27, associated with switch S9, through the left make contact of relay S13 to ground. The horizontal plates of the oscilloscope are connected through the fourth contact of switch S1–F and terminal H across the resistor selected by switch S9. As rather high voltages may be required to force a suitable current through the varistor in the blocking direction, resistor R22 and the resistor selected by switch S9 form a voltage divider to reduce this high voltage to a value suitable for application to the horizontal plates. Resistor R22 may have a resistance of 100,000 ohms, and the resistors associated with switch S9 may have graduated values from a few hundred ohms to several ten thousands of ohms.

The current from the grounded secondary winding of TR1 flows through the resistor selected by switch S4, the varistor under test, and the resistor selected by switch S5 to ground. The series resistors selected by the switch S4 which have graduated values from a few hundred ohms to a megohm are inserted in the circuit as a safety precaution to limit to a safe value the current that can flow when the applied voltage carries the varistor characteristic into the region where the resistance of the varistor falls to a low value. The vertical plates of the oscilloscope are connected across the resistor selected by the switch S5 and are responsive to the current flowing through the varistor. Resistor R22 and the resistor selected by the switch S9 are connected as a potential divider across both the varistor under test and the resistor selected by switch S5; and the horizontal plates of the oscilloscope are connected to this potential divider. The horizontal plates thus are responsive to the voltage drop across both the varistor and the resistor selected by switch S5; but, as the resistance of the resistor selected by switch S5 is much less than the resistance of the varistor, the error is slight. In prior units, the circuit was grounded at the junction of the varistor and the resistor; but, this connection, in effect, connected a portion of the distributed capacity of the transformer winding across the varistor resulting in phase shift which caused the trace on the oscilloscope to open out into a loop. The present connection eliminates this undesirable effect.

The secondary winding of transformer TR3, and one secondary winding of transformer TR4 are connected, in series aiding, through the winding of potentiometer P1. Resistor R2 and pilot lamp L2 are connected in series across the secondary winding of transformer TR3 to indicate that power is being supplied to the equipment.

In the unoperated positions of relays S12, S13, current will flow from the brush of potentiometer P1, through both break contacts of relay S13, switch S6 and the resistor associated therewith, fourth contact and blade of switch S10–C, through the varistor under test in the passing direction, blade and fourth contact of switch S10–D, fourth section of switch S15, break contact of relay S12, back to the winding of transformer TR4. The vertical plates of the oscilloscope are connected through the fourth contact and blade of switch S10–B, and the break contacts of relay S13 across the resistor selected by switch S6. Current will also flow from the brush of potentiometer P1, right break contact and swinger of relay S13, through ground and the horizontal plates of the oscilloscope, resistor R22, fourth section of switch 15 and break contacts of relay S12 to the winding of potentiometer P1, to produce the horizontal sweep of the oscilloscope. As the voltages applied to the varistor in the passing direction are usually fairly low, it is not essential to use a voltage divider ahead of the CRO for this supply, as the potentiometer P1 may be adjusted to supply a suitable voltage.

By adjustment of switches S4, S5, S6, S9, the most suitable scales may be chosen for the display of the characteristics on the screen of the oscilloscope, and different scales may be used for the forward, and the reverse characteristics. Relays S12, S13, are operated at the frequency of the power supply, thus, due to persistency of vision, the two characteristics appear simultaneously as one complete characteristic. The phase shifting networks may be adjusted to operate relays S12, S13, at the proper point on the alternating wave.

The vertical and horizontal input impedances of the cathode-ray oscilloscope should have proper values for use with the resistors associated with switches S5, S6, S9. With the vertical sensitivity of the oscilloscope adjusted to 0.05 volt per inch of deflection on the screen, the resistors associated with S5 and S6 are selected to produce current ranges of 1, 10, 100 microamperes and 1, 10, 100, 1000 milliamperes. With the horizontal sensitivity of the oscilloscope adjusted to 0.83 volt per inch of deflection, the scale for the forward voltage is one volt per inch; and the resistors associated with switch S9 may be selected to provide scales of 1, 5, 10, 50, 100 and 500 volts per inch for the reverse voltage.

Some semiconductor diodes have very small reverse currents, and, when this condition is associated with appreciable shunt capacitance, either in the diode itself, or in the wiring, the reverse trace on the oscilloscope tends to open into a loop due to phase shift. Entrapped moisture in point contact diodes may also produce a similar effect. To eliminate this effect, the varistor characteristic may be traced at slow speed, much slower than the normal tracing at sixty cycles. In such cases, to avoid heating of the diode due to forward current, the display of the forward characteristic is suspended.

The tapped secondary winding of transformer TR4 is connected to the anodes of the rectifying diodes V3; the other secondary winding being connected to the heaters. The cathodes of the diodes V3 are connected to the filter formed of resistors R32, R31, and capacitor C1, the voltage regulator V4, and the filter formed of resistor R30 and capacitor C2. Switch S15 is moved to the left-hand contacts, completing a circuit through resistor R45, left contact of fifth section of switch S15, winding of relay S13, left contact of sixth section of switch S15, locking up relay S13 in the operated condition.

Alternating current from the selected secondary winding of transformer TR1 flows through switches S2, S3, and is rectified by the rectifier VR2. The rectified current flows through the left contacts of the fourth section of switch S15, makes contacts of relay S12, left contacts of third section of switch S15, filter formed of resistor R48, capacitor C7, inductor L1, capacitor C6, resistor R46, left contacts of second section of switch S15, resistor selected by switch S4, left contacts of first section of switch S15, fourth contacts of switch S10–D, through the varistor under test in the reverse direction, fourth contacts of switch S10–C, resistor selected by switch S5, break contacts of relay S13, back to the secondary winding of transformer TR1. By using a capacitative input to the filter, the amplitude of the filtered voltage may be made equal to the peak value of the alternating voltage used in alternating-current tests, thus giving the same peak deflection on the oscilloscope for either position of switch S15.

The fourth contacts of switch S10–C are connected through the fourth contacts of switch S10–B and terminal V to the vertical plates of the oscilloscope; and the fourth contacts of switch S10–D are connected through resistor R22, fourth contacts of switch S10–F and terminal H to the horizontal plates of the oscilloscope. By manipulation of the variable transformer 1, the filtered current flowing through the varistor may be varied over the range of the characteristic of the varistor.

The brush of potentiometer P1 is left ungrounded by the break contacts of relay S13, thus the operation of relay S12 does not supply any alternating current in the forward direction to the varistor.

The switch S10 has five positions, first Zero, second Cal. V, third, Cal. H, fourth View, fifth Form. In the first position, switch S10–B grounds the V terminal, and switch S10–F grounds the H terminal, so that the oscilloscope may be adjusted to zero. In the second position, switch S10–B applies a standard voltage from the brush of potentiometer P6 to the V terminal, while switch S10–F continues to ground the H terminal, so that the sensitivity of the oscilloscope in the vertical direction may be calibrated. In the third position, switch S10–B grounds the V terminal, while switch S10–F applies a standard voltage from the brush of potentiometer P7 to the H terminal, so that the sensitivity of the oscilloscope in the horizontal direction may be calibrated. As described herein above, in the fourth position of switch S10, the varistor characteristic may be viewed. The switch S8 selects one of four forming processes, and is moved to the desired position before switch S10 is moved to the fifth position.

The transformer TR5 may conveniently be a known type of adjustable voltage device. With switch S8 in the first position, alternating currents will flow from ground through TR5, first contact and blade of switch S8–2, fifth contact and blade of switch S10–D, through the varistor being formed, blade and fifth contact of switch S10–C, and one of the resistors selected by switch S7 to ground. The resistors selected by switch S7 may be graduated in resistance from say five ohms to one hundred ohms, so that by adjustment of transformer TR5 and switch S7, a desired value of current will flow in the varistor. A potential divider, formed by resistors R28, R29, is connected across the resistor selected by switch S7, and the junction of these resistors is connected through the fifth contact and blade of switch S10–B to the vertical plates of the oscilloscope. At the same time an alternating voltage from one of the secondaries on TR1 is applied to the horizontal plates through S15 (right-hand position), a resistor selected by S4, make contact of S12 and R22 to obtain a horizontal sweep. Thus a trace is obtained on the oscilloscope which plots varistor current vs. the voltage obtained from TR1. While not a true EI trace, it is useful for observing varistor current during forming.

With switch S8 on the second contact, the forming process may be automatically timed. The alternating currents then flow from transformer TR5 through the break contacts of relay S14, and the second contact of switch S8–2.

Tubes V5, V6, are gas-filled tetrodes, of known type, having the second grid connected to the cathode, and the cathodes energized by the usual heater supply (not shown). The first grid of tube V5 is connected to ground through resistor R41; the anode may be connected to the anode supply through resistor R39, and the fifth contact and blade of switch S10–A; and the second grid and cathode are connected to the potential divider formed of resistor R37, R40, connected across the anode supply. The cathode of tube V5 is connected through adjustable resistor P3 to the first grid of tube V6. The anode of tube V6 may be connected to the anode supply through the winding of relay S14, resistor R35, and the fifth contact and blade of switch S10–A; the second grid and cathode are connected to the potential divider formed of resistor R36 and adjustable resistor P2, connected across the anode supply, and are connected through capacitor C4 to ground.

When switch S8 is on the second contact, and switch S10 is moved to the fifth position positive voltage from the anode supply is applied through the blade and fifth contact of switch S10–A, resistor R39, second contact and blade of switch S8–1, rectifier VR1, to the first grid of tube V5, firing the tube, and causing the potential of the cathode to rise. Capacitor C3 is connected from ground through the blade and second contact of switch S8–3 to the junction of resistors P3, R34, and thus to the first grid of tube V6. Current will then flow from the cathode of tube V5 through resistor P3 to charge capacitor C3, and, eventually, will raise the potential of the first grid of tube V6 to the critical value firing tube V6, and operating relay S14 to cut off the forming current. The circuit is restored by operating switch S10 to remove the anode supply from tubes V5, V6, and to discharge capacitor C3 through resistor R33 and switch S10–E.

Resistor P3 may have a maximum resistance of, say one megohm, and capacitor C3 a capacitance of several microfarads, thus the forming period may be from a small fraction of a second to several seconds.

As a varistor warms up during the forming process, the peak back voltage tends to decrease, and, if the peak back voltage becomes less than the forming voltage, the varistor is then operating in a negative resistance region in which the current rapidly increases, causing an abrupt increase in the internal temperature of the varistor, and a sudden drop in the originally high reverse resistance to a low value of the order of the forward resistance. The present apparatus provides means for producing and observing this change in the characteristic of the varistor.

When switch S8 is on the third contact, and switch S10 is moved to the fifth position current is supplied to the varistor, as before, through the contacts of relay S14 and switch S8–2. The normal current through the varistor in the reverse, or blocking, direction, is small, thus the positive voltage drop across the resistor selected by switch S7 is also small. When the reverse resistance suddenly snaps to a low value, the positive voltage drop across the resistor selected by switch S7 suddenly rises. This positive voltage is applied through the third contact and blade of switch S8-1, and rectifier VR1, to the first grid of tube V5, which fires, applying a positive voltage to the first grid of tube V6, which also fires, operating relay S14 to cut off the forming voltage from the varistor.

If desired, switch S8 may be moved to the fourth contact, connecting capacitor C3, through resistor R34, to the first grid of tube V6. Under these conditions, the forming voltage is supplied to the varistor for a measured time interval after the reverse resistor has snapped to a low value.

A current characteristic of the varistor is displayed on the screen, as described above, during all of the forming processes, and switch S10 is usually restored to the fourth position after any of the forming processes.

What is claimed is:

1. Apparatus for alternately displaying on the screen of a cathode-ray oscilloscope the forward and reverse voltage-current characteristics of a two-pole asymmetrically conductive device comprising first and second conductive elements contacting said device, first and second series resistors connected to said second element and to one of the vertical plates of said oscilloscope, a third resistor connected from said first element to one of the horizontal plates of said oscilloscope, an adjustable resistor connected in series with said third resistor, sources of positive and negative voltage, and switching means for alternately and recurrently connecting the source of said positive voltage from said first element to said first series resistor, said adjustable resistor and the other plates of said oscilloscope, and the source of said negative voltage from said first element to said series resistor and the other plates of said oscilloscope, said series resistors and said adjustable resistor being selected to produce advantageous scale factors for both characteristics of said device.

2. The combination in claim 1 with a fifth resistor, a source of alternating voltage, second switching means for disconnecting said first and second resistors from said second element and for connecting said fifth resistor to said element, and third switching means for disconnecting the sources of said positive and negative voltages from said first element and for connecting said source of alternating voltage to said first element and said fifth resistor.

3. The combination in claim 1 with a fifth resistor, a source of alternating voltage, second switching means for disconnecting said first and second resistors from said second element and for connecting said fifth resistor to said element, third switching means for disconnecting the sources of said positive and negative voltages from said first element and for connecting said source of alternating voltage to said first element and said fifth resistor, a relay having a pair of break contacts connected in series with the connection from said source of alternating current and a winding, and thermionic timing means connected to be activated by said third switching means to energize said relay winding after a predetermined time interval.

4. A varistor curve tracer including a cathode-ray oscilloscope having vertical and horizontal deflection plates, first and second sources of alternating voltage of opposite polarity, first and second resistors, switching means synchronized with said alternating voltages for recurrently connecting a first combination of the varistor to be tested in series with the first resistor across the first source, and alternately connecting a second combination of said varistor in series with the second resistor across the second source and alternately connecting said vertical plates across said resistors, and means for connecting said horizontal plate alternately across said first and second combinations.

5. A varistor curve tracer including a cathode-ray oscilloscope having vertical and horizontal deflection plates, a first grounded resistor connected to the vertical deflection plates and in series with the varistor to be tested, a relay having a pair of break contacts and a winding, a grounded source of alternating voltage connected in series with said contacts across the varistor and first resistor, a second resistor connected in series with the horizontal plates across said source, two gas-filled tubes, each having a cathode, an anode, and a control electrode, a third resistor, a grounded source of direct voltage connected through said third resistor to the anode of the first tube and through said winding to the anode of the second tube, first and second potential dividers connected across said source of direct voltage and respectively to the cathodes of said tubes, an adjustable resistor connected from the cathode of the first tube to the control grid of the second tube, a fourth grounded resistor connected to the signal grid of the first tube, and a rectifier connected from the junction of the varistor and first resistor to the control grid of the first tube, whereby when the heat produced in the varistor produces a sudden diminution in the reverse resistance of the varistor, the tubes are fired to operate the relay and disconnect the source of alternating voltage from the varistor.

6. The combination in claim 5 with a grounded capacitor connected to the control grid of the second tube to delay the firing of the second tube for a predetermined time.

7. The combination in claim 4 with a source of direct current, a switch connecting said source to said switching means to hold said switching means operated, a variable transformer connected to said first source of alternating voltage, a rectifier and filter connected from said transformer to the combination of said varistor and said first resistor, whereby slowly varying direct current may be supplied to said varistor.

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