SEMICONDUCTOR SWITCHING DEVICES

FOR POWER APPLICATION

by Wolfgang Prenosil August, 1958

63

SEMICONDUCTOR SWITCHING DEVICES

FOR POWER APPLICATION

Synopsis:

A recently announced solid-state device - the Hyperconductive Negative Resistance, Four Layer or Breakdown Diode - has been evaluated in respect to its applicability. The result of this investigation, first presented in concentrated form in an IDC in December, 1957, is contained in this report.

Introduction:

A wealth of opportunities awaits a new solid-state device: The Hyperconductive Negative Resistance, Four Layer or Breakdown Diode, and a similar device, the Silicon Controlled Rectifier. These components will become very versatile circuit elements, particularly in electronic controlled tools and machinery.

The Breakdown Diode can be considered an analog to the Thyratron, but with considerably superior properties. The device switches from an extremely high impedance, ranging from 10k ohms to 100 megohms to a low impedance in the order of 2 to 20 ohms.

The design objectives in development of these devices were: current ratings comparable to thyratrons, blocking voltages useful in industrial circuits, complete control of current turn-on and-off without complicated circuitry, switching speeds of the same order as small-signal transistors, efficiency equal to similarly rated rectifiers and construction conducive to high quality mass production at reasonable cost.

It seems to be appropriate to give some information as to the history of the device:

The p-n-p-n configuration emerged from Bell Laboratories. A device having three layers and a third junction formed by a metal contact has been published in a patent No. 2,655,608, issued to L. B. Valdes and assigned to Bell Telephone Lab. A combination of transistors and avalanche diode is covered by patent No. 2,655,609, issued to W. Shockley and also assigned to Bell Telephone Lab.

At the A.I.E.E. - I.R.E. Semiconductor Device Conference in Boulder, Colorado (July 15-17, 1957) three similar devices were introduced. One called the "Dynistor" was presented by John Phillips, Westinghouse, and the second called a "Three Terminal PNPN Switch" was presented by M. Mackintosh, Bell Telephone Lab. The third device called the "Thyristor", was a combined effort of C. W. Mueller and T. Hilibrand of Radio Corporation of America.

The Federal Telecommunication Lab. advertises a new device called "The Diffused Junction Silicon Switching Diode", and as mentioned, G.E. markets already a "Silicon Controlled Rectifier".

Production problems exist to a certain extent. Devices capable of handling high power have semiconductor crystals far greater than transistors or diodes. The crystal has to be doped with carefully controlled impurities to create the electronic barrier in its crystal structure. Instead of having two layers analogous to the common diode or three layers like the transistor, the new device has four layers arranged in p-n-p-n fashion. That is significantly harder to arrange.

This is apparently the reason for the rather high price asked for the new devices, at least in the very near future. (Prices range from $30.00 to $200.00.) Improved production processes and large-scale operation will doubtless contribute to more acceptable prices.

The switching devices, here discussed, differ somewhat in their switching mechanism, so to speak, and consequently in the associated circuitry. In the following all the presently known devices shall be discussed. Pertinent facts stem from investigations done by the author when with another company unless otherwise stated.

The attached annex demonstrates a small amount of application examples as discerned from manufacturers' publications and the author's patent disclosures assigned to his former employee.

THE SHOCKLEY 4-LAYER BISTABLE DIODE

(Beckman-Helipot Corporation)

Offering great versatility to the circuit designer, the new silicon four-layer switching diode is a 2-terminal device invented at Bell Telephone Laboratories. It operates in either of two states: An open or high-impedance state of 1 to 100 megohms, and a closed or low-impedance state of less than 20 ohms.

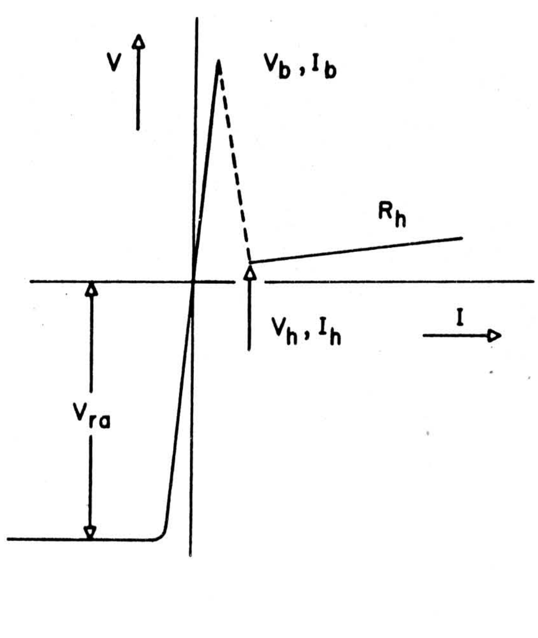
It is switched from one state to the other by voltage and current applied to the device. As the voltage is raised, the diode reaches a breakdown voltage and then changes to the low-impedance, high-conducting condition, thereby closing the circuit, which remains closed as long as the required holding current is maintained. If the current falls below this value, the device resumes its open or high-impedance condition. Rise times are usually less than 0.1 microsecond.

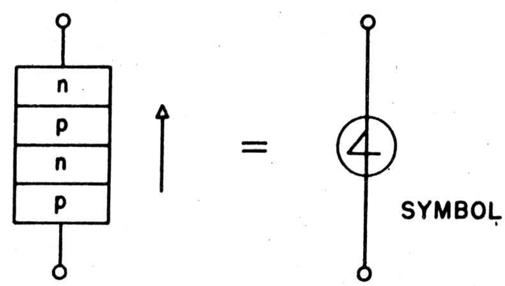
Characteristics

V_b (breakdown voltage)	- 10-100v
I_b (breakdown current)	- <500 μa
V_h (holding voltage)	- <2v
I_h (holding current)	- 1-50 ma
R_h ("on" resistance)	- <20 ohms
Dissipation	- ~100 mw
Time to close	- <0.1 μsec
Time to open	- <0.5 μsec

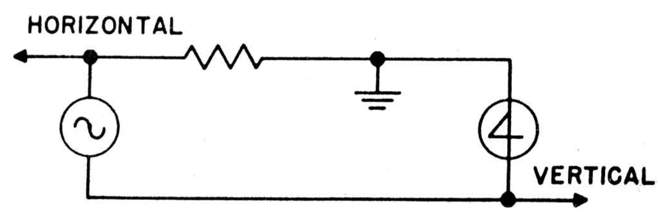
Standard Types

No.	V_b	I_b	V_h	I_h	R_h
	Volts	μa	Volts	ma	ohms
4N20D	20±5	<500	<2	<50	<20
4N30D	30±5	<500	<2	<50	<20
4N40D	40±5	<500	<2	<50	<20
4N50D	50±5	<500	<2	<50	<20





SLANTING LINE INDICATES FORWARD DIRECTION



DYNISTOR DIODE

for Switching and Control Uses

(Westinghouse Electric Corp.)

The Westinghouse-developed Dynistor Diode is a new germanium semiconductor switching device exhibiting bistable characteristics. It can exist in two states: a blocking or high resistance state; and a conducting or low resistance state. It is switched from the blocking to the conducting state by momentarily exceeding the breakdown voltage, and conversely it is switched from the conducting to the blocking state by momentarily reducing the voltage or current below some minimum sustaining value.

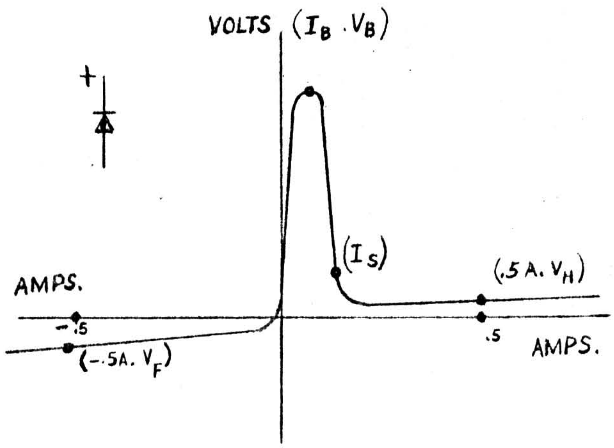
The series X800 has a resistance of an ohm or less in the conducting state and is capable of controlling several amperes of current. Switching times of the Dynistor Diode are of the order of a microsecond, making it much more useful than transistors of comparable power handling capacity in high speed switching circuits.

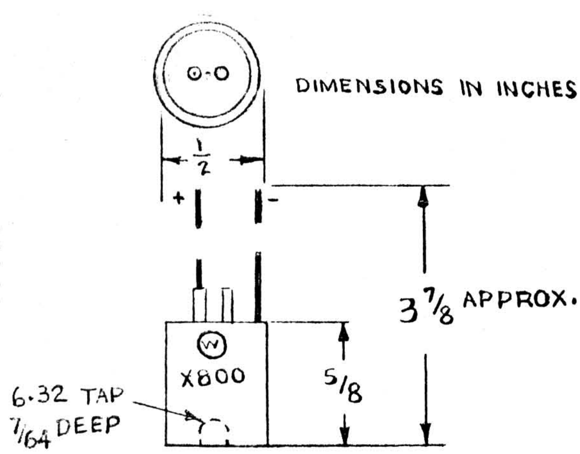
Applications of this device range from pulse generators, relaxation oscillators, and inverters to time delay circuits, overload protection and replacement of magnetic amplifiers and thyratrons in certain cases.

Tentative Ratings

(all values at 25° C.)

Type X800	10 - 49	volts breakdown (V_B)
Type X800-A	50 - 99	volts breakdown (V_B)
Type X800-B	100 - 149	volts breakdown (V_B)
Type X800-C	150 - 199	volts breakdown (V_B)
Type X800-D	200 - 250	volts breakdown (V_B)





Typical Values of Parameters

(at 25° C.)

V_B - Breakdown Voltage 10-250 volts
I_B - Breakdown Current 10 ma.
I_S - Minimum Sustaining Current 10-150 ma.
V_H - Hyperconductive Drop (at .5A) .5 volts
V_F - Forward Drop (at .5A) 2 volts

SILICON CONTROLLED RECTIFIER

(General Electric)

The ZJ39A Silicon Controlled Rectifier is a three junction semiconductor device for use in power control and power switching applications requiring blocking voltages up to 400 volts and load currents up to 16 amperes. Series and parallel circuits may be used for higher power applications.

The Controlled Rectifier reverse characteristic is similar to a normal silicon rectifier in that it represents essentially an open circuit with negative anode to cathode voltage. The forward characteristic is such that it will block positive anode to cathode voltage below a critical break-over voltage if no signal is applied to the gate terminal. However, by exceeding the forward break-over voltage or applying an appropriate gate signal the device will rapidly switch to a conducting state and present the characteristically low forward voltage drop of a single junction silicon rectifier.

Maximum Allowable Ratings

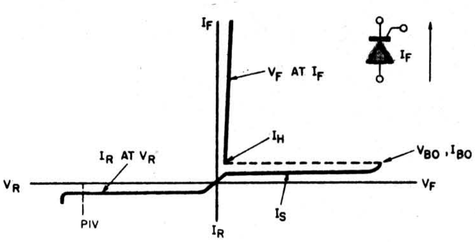
(Resistive or Inductive Load)

	ZJ39A 25	ZJ39A 40	ZJ39A 75	ZJ39A 100	ZJ39A 150	ZJ39A 200	ZJ39A 250	ZJ39A 300	ZJ39A 400
Cont. PIV	25	40	75	100	150	200	250	300	400 v
Trans. PIV (non-recurrent <5 milli-sec)	35	60	100	150	225	300	350	400	500 v
RMS Voltage (Vrms)	17.5	28	53	70	105	140	175	210	280 v
Average Forward Current (I_F)	Up to 16 amperes								
Peak One Cycle Surge Current (i surge)	150 amperes								
Peak Gate Current (i_g)	300 ma								
Peak Gate Voltage (e_g)	5 volts								
Storage Temp.	-65°C to +150°C								
Operating Temp.	-65°C to +125°C								
Stud Torque	30 Inch-pounds								

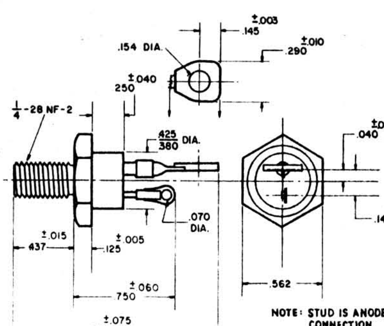
Characteristics

(At Maximum Ratings)

	ZJ39A 25	ZJ39A 40	ZJ39A 75	ZJ39A 100	ZJ39A 150	ZJ39A 200	ZJ39A 250	ZJ39A 300	ZJ39A 400
Min. Forward Breakover Voltage (V_{BO})	25	40	75	100	150	200	250	300	400
Max. Forward Voltage (V_F Ave.)	0.75 Volts (Full Cycle Average)								
Max. Reverse Current (I_R)	5 ma (Full Cycle Average)								
Maximum Gate Current to Fire (I_{GF})	25 ma								
Max. Gate Voltage to Fire (V_{GF})	3 Volts								
Max. Thermal Resistance	2°C/Watt (Junction to Stud)								
Typ. Holding Current (I_H)	10 ma								
Typ. Gate Cur. to Fire (I_{GF})	10 ma @ + 1.5 volts (Gate to Cathode Voltage)								
Typ. Reverse Current (I_R)	(See Chart)								
Typ. Forward Saturation Cur. (I_S)	10 ma								
Typ. Turn-on Time	1 microsec) Depends on Circuit.								
Typ. Turn-off Time	3 microsec)								



TYPICAL E-1
CHARACTERISTICS



OUTLINE DRAWING

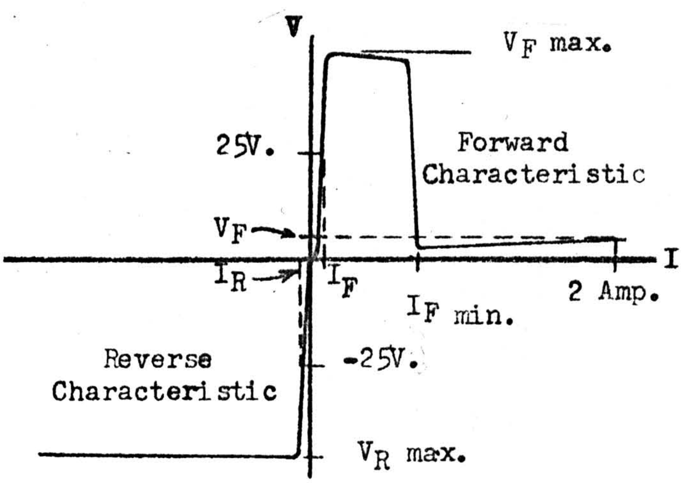
DIFFUSED JUNCTION SILICON SWITCHING DIODE - TYPE CP-624

(Federal Telecommunication Laboratories)

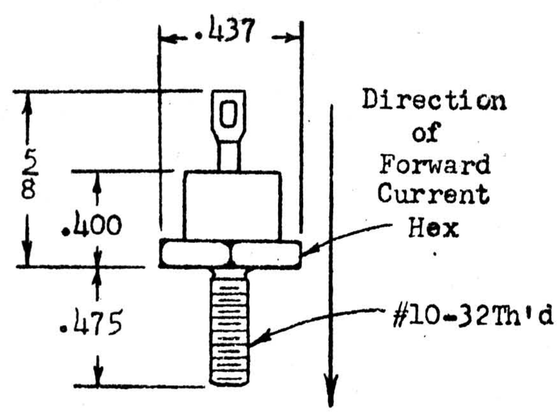
The FTL Type CP-624 switching diode is a medium-power diffused junction silicon npnp device. Its voltage-current characteristic contains a negative resistance region separating two positive resistance regions, as shown in the figure below. When operated as a switch, this diode in the "off" condition exhibits a d-c resistance of approximately one megohm and a dynamic a-c resistance of approximately 10 megohms. In the "on" condition the d-c resistance is 0.5 ohm at 2 amperes and the dynamic resistance is 0.1 ohm. Triggering from the "off" condition to the "on" condition is accomplished by applying a voltage pulse, either in series with the supply voltage, or directly across the diode, which momentarily exceeds the breakdown voltage, V_F max. The circuit resistance must be sufficient to limit the current to the maximum value listed below. A pulse of opposite polarity will trigger the diode from the "on" to the "off" condition.

Electrical Data

Maximum continuous power dissipation (25°C)	2.5	watts
Maximum continuous forward current (25°C)	2	amp.
Breakdown voltage, V_F max., nominal	50	volts
Minimum sustaining current, I_F min., nominal	0.1	amp.
Saturation voltage, V_F (at +2 amp.), nominal	1.3	volts
Reverse breakdown voltage, V_R max., nominal	50	volts
Forward leakage current, I_F (at + 25 V.), nominal	25	µamp.
Reverse leakage current, I_R (at -25V.), nominal	25	µamp.
Maximum operating frequency (as relaxation oscillator)	200	kc.



Volt-Ampere Characteristic



Dimensions & Polarity

THE THYRISTOR

(Radio Corporation of America)

The TA1693 Thyristor is a new high speed switching transistor with regenerative characteristics. The regeneration is accomplished through electron injection at the collector contact.

The TA1693 functions as a conventional high speed transistor until the collector current reaches a critical value, at which time the device "breaks over" into a high conductance mode of operation. In the high conductance mode, the device can conduct currents of the order of 100 ma with a collector-emitter voltage drop of the order of 0.5 volts.

When operated in the regenerative mode the device is bi-stable and is similar to a thyratron in operation. A marked difference from the thyratron is the fact that TA1693 may be turned off by applying a reverse voltage to the control element without removing the collector voltage.

If no connection is made to the base, the TA1693 operates in a manner similar to a PNPN negative resistance diode.

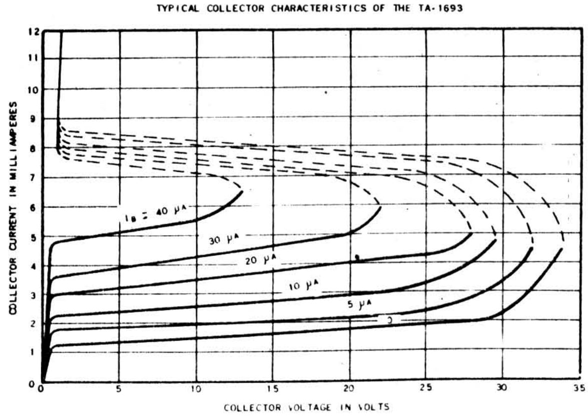
The thyristor will find wide application because of its high power handling capabilities, low power loss, high switching speed and the circuit simplication which results from its bi-stable nature.

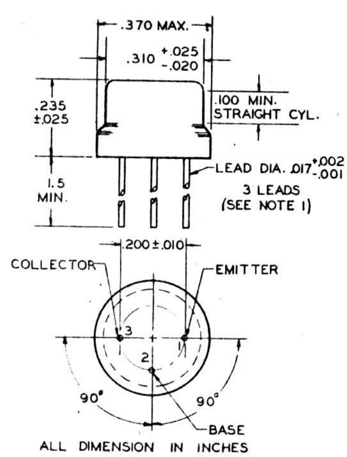
Maximum Ratings

Voltage values are given with respect to the base unless otherwise spec.

V_C	V_E	I_C	V_{CE} (V_{be} = + .3 volts)	P_C (25°C)
-25 v	-5 v	-100 ma	25 v	100 mw

TYPICAL COLLECTOR CHARACTERISTICS OF THE TA-1693





Electrical Characteristics

(at 25°C)

		Min.	Typ.	Max.	
Collector breakdown voltage(I_C=-20µamp. I_E=0)	V_{CO}	-25	-70		volts
Emitter breakdown voltage (I_E=-20 µamp. I_E=0)	V_{EO}	- 5	- 3		volts
Breakover Current*	I_0		3	10	ma
Regenerative switching time				100	m µsec.

*The breakover current is the emitter current at which the TA1693 regeneratively shifts from a low conductance to a high conductance state.

STATIC D.C.-A.C. CONVERTER OF HIGH EFFICIENCY

Description:

The circuit as shown in Figure 1 is a push-pull arrangement. The d.c voltage is applied at the transformer center-tap and the minus-line, indicated as points C and D.

To the two primary terminals of the transformer T_r, components D_1, Di_1, D_3, D_4, Di_2, D_2 are symmetrically connected. The breakdown voltage of the Dynistors is higher than twice the supply voltage. Only with a control signal added to the supply voltage, switching of the Dynistors takes place.

We suppose that the polarity of the control signal at the moment of application is positive at point A and negative at point B. The supply voltage and the applied control signal now appear across Dynistor Di_1, causing it to break down. Current flows from point D to point C through L_1, D_1, Di_1, and D_3.

If the polarity of the control signal is reversed, Di_2 will break down. When Di_2 conducts, it will shunt Di_1. The current in Di_1 will be decreased to a value which is below the requirements for sustained conduction. Di_1 will "snap back" to the nonconductive state.

The symmetrical arrangement of the circuit provides repetition of the cycle. Feed back makes the circuit self-oscillatory.

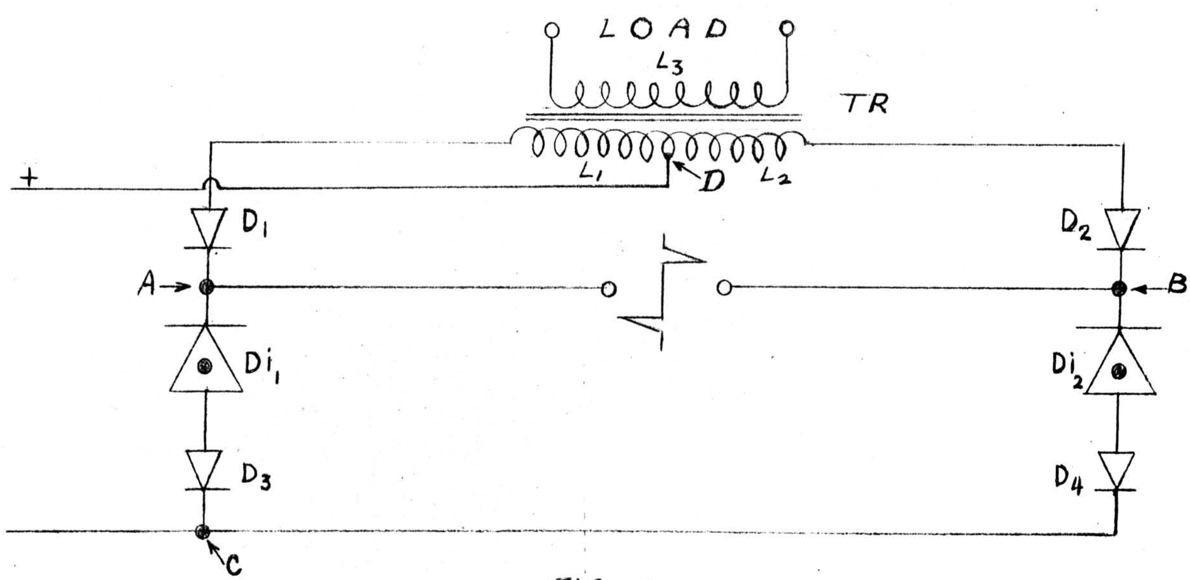


FIG. 1

Note: Disclosed by W. Prenosil to Westinghouse Electric Corp., Pittsburgh.

SQUARE-WAVE TO PULSE CONVERTER OF HIGH EFFICIENCY

Description:

A square-wave voltage is often used to produce pulses of alternate polarity and uniform spacing by differentiation. The differentiating circuits used in general for this purpose are only practical at a low power level, because they depend on the internal impedance of the source and the rise-time of the square wave. The circuit described herein performs very well at high power levels.

As seen in Figure 2, the capacitor C is charged toward the supply voltage through resistor R. When the charge voltage reaches the breakdown voltage of one of the Dynistors, Dy_1 or Dy_2, it breaks down according to the polarity. The other Dynistor is then conducting in the forward direction. When the forward voltage drop of this Dynistor is too high, a common diode can be connected in parallel as indicated by the dotted lines in Figure 1. The discharge current of C flows through the load producing sharp pulses of voltage. The shape and duration time of pulses can be well determined by the proper selection of the Dynistor, capacitor, and load.

Tests in the laboratory indicated many applications. This circuit, for example, makes the d.c.-a.c. converter, Fig. 1, self-oscillating.

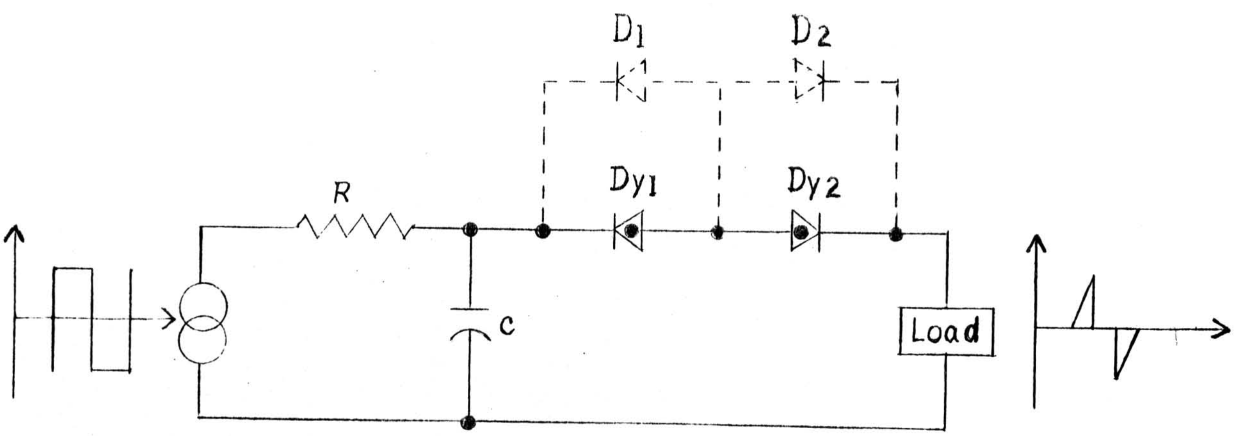


Fig.2

Note: Disclosed by W. Prenosil to Westinghouse Electric Corp., Pittsburgh.

A STATIC A.C. SWITCH FOR POWER APPLICATION

Description:

The circuit is shown in Fig. 3. The Dynistors Dy_1 and Dy_2 have a breakdown voltage higher or lower than the supply voltage or equal to it.

Breakdown is not activated by the supply voltage, it is accomplished by trigger-pulses produced in a separate circuit.

We assume that at the moment of investigation the supply voltage V_o is at zero and is to rise positive. By applying a positive pulse at Dy_1, this Dynistor conducts and current will flow through Dy_1.

The forward impedance of a Dynistor is rather high and it is good practice to bypass with a diode although this is not indispensable.

Current then flows through D_2 or Dy_2 and the load and back to the power supply.

At the other half-cycle, the same operation takes place for Dy_2 and the current flows in the opposite direction.

With a resistive or capacitive load no further components are needed. However, with an inductive load the situation is somewhat more difficult since the inductance will prohibit the flow of the pulse current and also offer a certain resistance to the immediate flow of the main current.

This of course would bring the just triggered Dynistor right back in the non-conductive state. This problem can be solved by shunting the inductive load in both directions by a component allowing the flow of a minimum current over a finite time, (the sustaining current of the Dynistors therefore has to be low), without affecting the main current-flow appreciably. A small condenser or adequate resistor would do the job.

In cases where the amount of current shunted is of great importance two diodes back-to-back connected across the load will work most effectively, since a pulse current can flow in the reverse direction of a diode until the rectifier characteristic takes place.

For different inductive loads the trigger pulses probably have to be applied at different times because of the phase-shift between voltage and current.

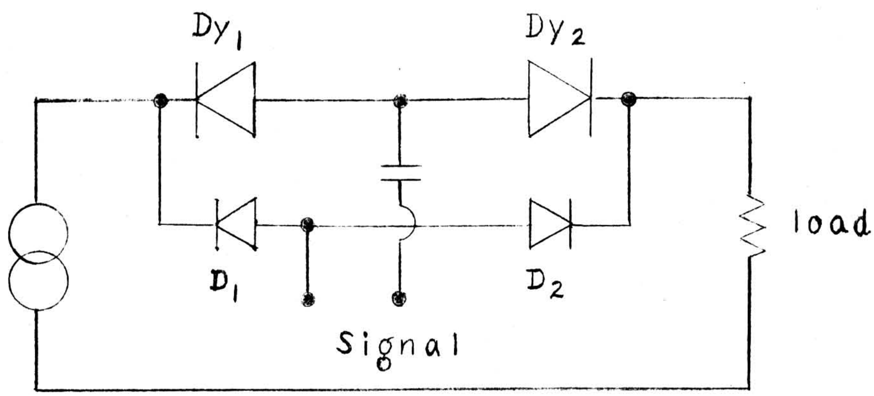


Fig. 3

Note: Disclosed by W. Prenosil to Westinghouse Electric Corp., Pittsburgh

HIGH VOLTAGE POWER SUPPLY FOR CATHODE-RAY TUBE ALSO PROVIDING CONSTANT FOCUS

Description:

The accelerating voltage in common T.V. receivers is developed from the retrace voltage pulses of the horizontal deflection. This is economical, but has several disadvantages. For instance, regulation is poor. Interaction with the horizontal deflection system is unavoidable. Proper focusing in the middle range produces defocusing of the high-light portions. The circuit shown in Fig. 4 will overcome these disadvantages.

Through resistor R, the capacitor C is charged. Reaching the breakdown voltage of Dynistor D, the Dynistor conducts through primary of transformer T.

By means of the damping circuit, consisting of R_1 and C_1 and the diode D_1, parasitic oscillation caused by the inductance of transformer and the back E.M.F. are cancelled. Greater efficiency is therefore achieved. At the present, damping in the primary of the transformer is recommended due to the high price of diodes withstanding the high voltage in the inverse direction. Damping in the secondary would be more efficient.

Since the operating frequency in this circuit is not important and the maximum current to be drawn should not exceed 100 µa, smallest size transformers can be used.

The filter capacitor can also be smaller when a higher frequency is used.

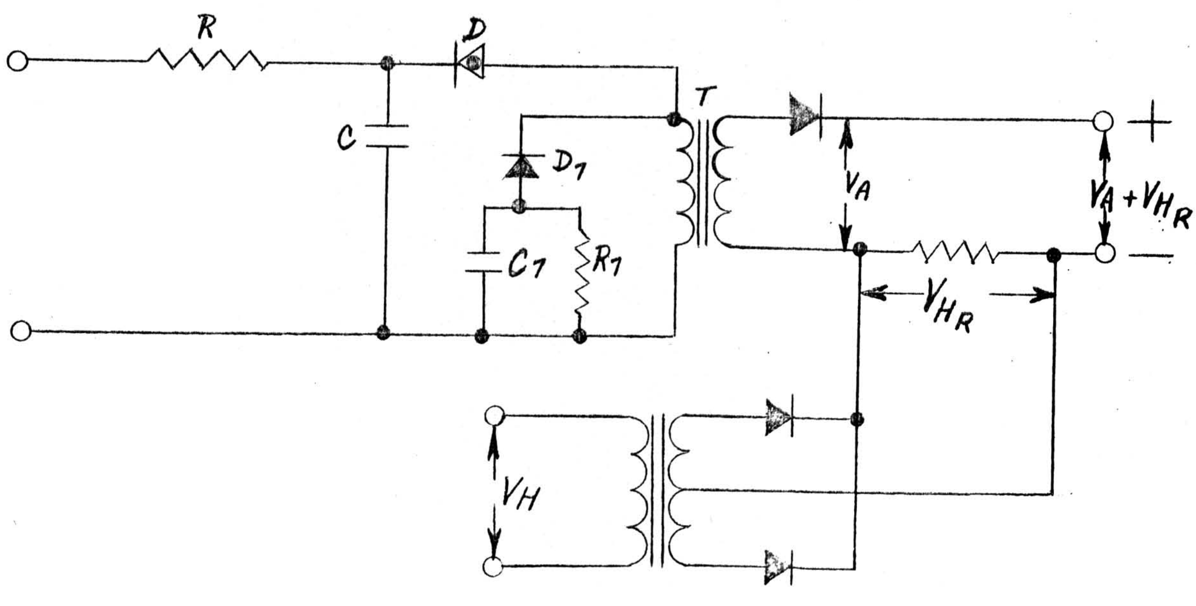


Fig. 4

The separation of the high voltage supply from the horizontal sweep circuits leads to another useful adaptation of this circuit. A part of the horizontal sweep voltage, V_H, can be added to the accelerating voltage, V_A, after full wave rectification in order to increase acceleration of the electron beam in synchronism with the deflection. This would provide good focusing over the entire screen of the cathode ray tube.

Note: Disclosed by W. Prenosil to Westinghouse Electric Corp., Pittsburgh

PULSE GENERATOR FOR ALTERNATE POLARITY PULSES INDEPENDENT OF REPETITION RATE AND PULSE DURATION

Description:

The circuit consists of a push-pull arrangement of RC-networks with HNR diodes as shown in Figure 5.

Capacitor C_1 is charged toward the d-c supply voltage through resistor R_1. The Dynistors have a breakdown voltage higher than the d-c supply voltage. An additional triggering signal has to be fed into the circuit to switch the Dynistor to the conductive state. The waveform of the triggering signal is not critical.

The charging time of the capacitor is determined by R_1 and C_1. This phase is shown in Figure 6a.

As a result of the triggering signal applied through the transformer Tr_1, a voltage appears across diode D_1 and is added to the voltage of C_1. The sum of these voltages is sufficient to break the Dynistor Dy_1 down, as seen in Figure 6b where a square wave triggering signal has been used for simplicity.

As Dynistor Dy_1 breaks down, a heavy current flows through winding L_1 of transformer Tr_3. Consequently, a voltage is induced in L_3 as shown in Figure 6c.

The load is connected in series with windings L_3 of Tr_3 and L_4 of Tr_4. The voltage induced in winding L_4 by the current flowing through L_4 is shortened by diode D_4, and therefore is of no consequence to the operation of the circuits.

The diode D_3 also has the dual purpose to bypass the induced voltage in L_1 caused by the back-EMF when Dynistor Dy_1 "snaps back" to the nonconductive state and to shorten the voltage induced by current in L_3 when the other half of the circuit is operative.

The other half of the circuit is symmetrical and the same action takes place if the alternate half of the trigger signal is applied. The output of the circuit is a series of pulses of equal shape and alternate polarity. The repetition rate of the pulses is determined by the a-c trigger signal.

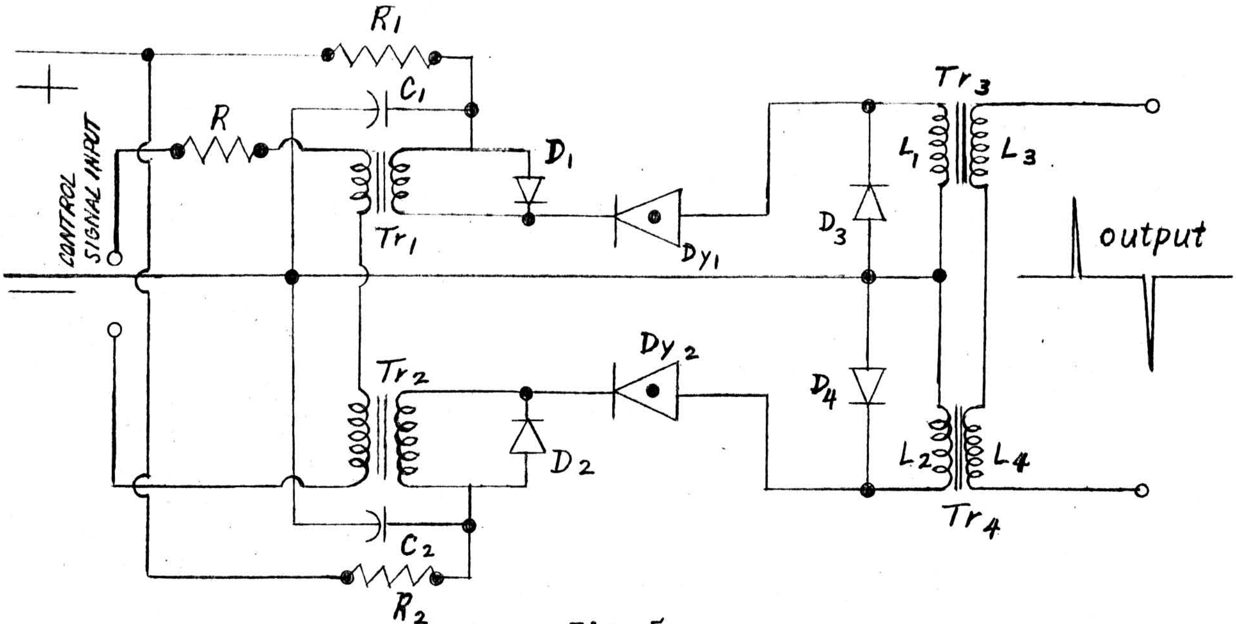


Fig. 5

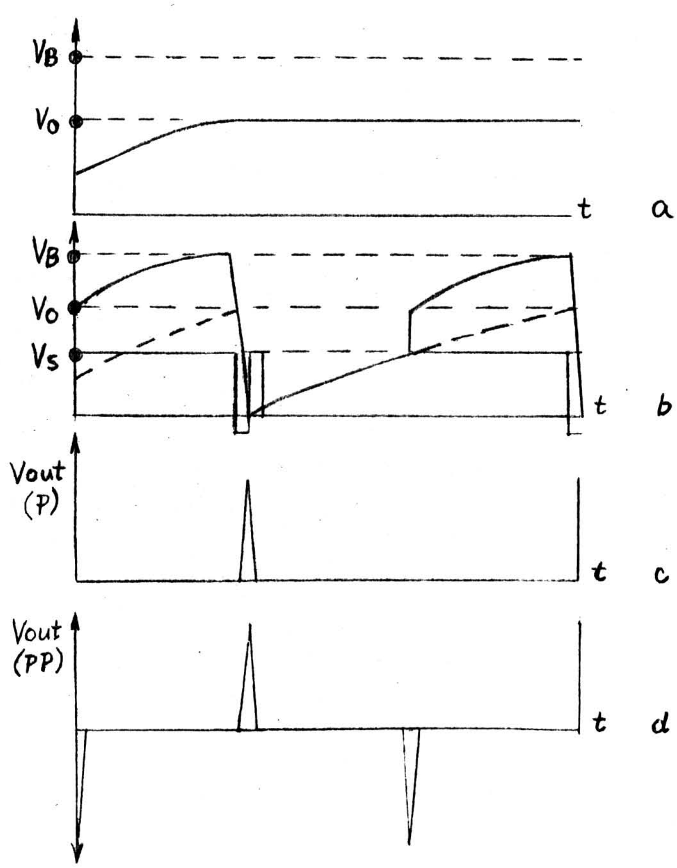


Fig. 6

Note: Disclosed by W. Prenosil to Westinghouse Electric Corp., Pittsburgh

PULSE GENERATOR

Description:

Short, high energy pulses for applications such as radar modulation are usually generated by quickly discharging an energy storage device such as a pulse network or a coaxial cable. The switch used to initiate the discharge of the network has long been a problem since it must close in a very short time and be capable of carrying a high peak current. Among the switches which have been used are spark gaps, thyratrons and vacuum tubes. Each of these devices, although useable, has certain disadvantages. Spark gaps wear out quickly and are not reliable. Thyratrons have jitter and are fragile. Vacuum tubes cannot pass high peak currents.

The circuit described in this disclosure uses a Dynistor as a switch. Among the advantages of using the Dynistor as a switch are ruggedness, no maintenance, high reliability, very little jitter and high peak current. A method is also provided whereby the repetition rate can be controlled by either an external sync signal or a self-contained oscillator.

The basic pulse circuit is shown in Figure 7. The energy storage element may be a coaxial cable for short pulses or a pulse network for longer pulses. When the network has been charged to the voltage of the source (V_1), switch SW_1 is closed. The energy stored in the network is discharged into the load resistor R_L. When R_L is chosen to be equal to the internal impedance of the network or cable, a good square pulse is obtained across R_L.

The circuit using the Dynistor as a switch is shown in Figure 8. Dynistor Dy_1 acts as the switch and diodes D_1 and D_2 are necessary for the control of Dy_1. The Dynistor is turned on by applying a pulse at V_p with the polarity shown. This pulse adds to the voltage of V_1 to increase the inverse voltage across Dy_1. When the pulse is high enough the sum of V_1 and the pulse voltage exceeds the breakdown voltage of Dy_1 and causes it to switch to its hyperconductive region. When the control pulse is derived from a condenser discharge, the peak pulse current will be very high. This high current causes a carrier storage effect in the Dynistor allowing it to remain in its hyperconductive stage for several microseconds after the control pulse. During this time, it is almost a complete short circuit so that the pulse network is discharged into the load resistance. Resistor R_1 is large enough to limit the Dynistor current to a value below the sustaining current. Then after the network has discharged and the carriers in the Dynistors have decayed, the Dynistor will turn off and the pulse network will charge again in preparation for the next pulse.

Diode D_1 acts as an open circuit for the control pulse and as a short circuit for the discharge of the network. Diode D_2 limits the amount of control pulse which appears at the load resistance R_L. The diode will conduct if the voltage across R_L becomes greater than half the charge voltage of the network (if R_L is matched to the network) and therefore prevent any unwanted spikes of voltage from appearing at the load.

The output pulse which appears across R_L will then be determined completely by the characteristics of the pulse network. The rise time of such a pulse can be very fast because the turn on time of the Dynistor is in the order of 20 to 100 millimicroseconds.

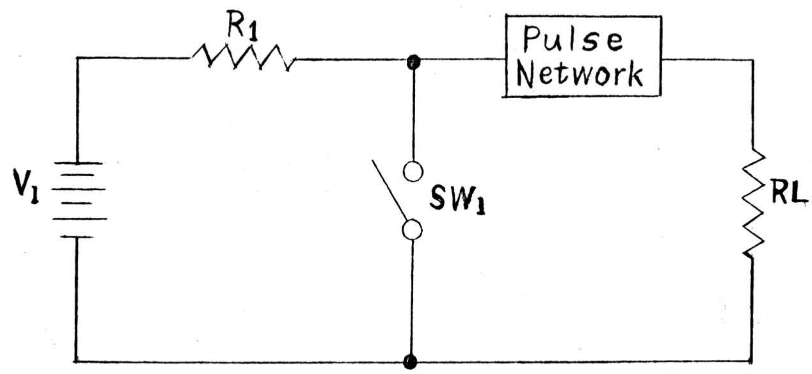


Fig. 7

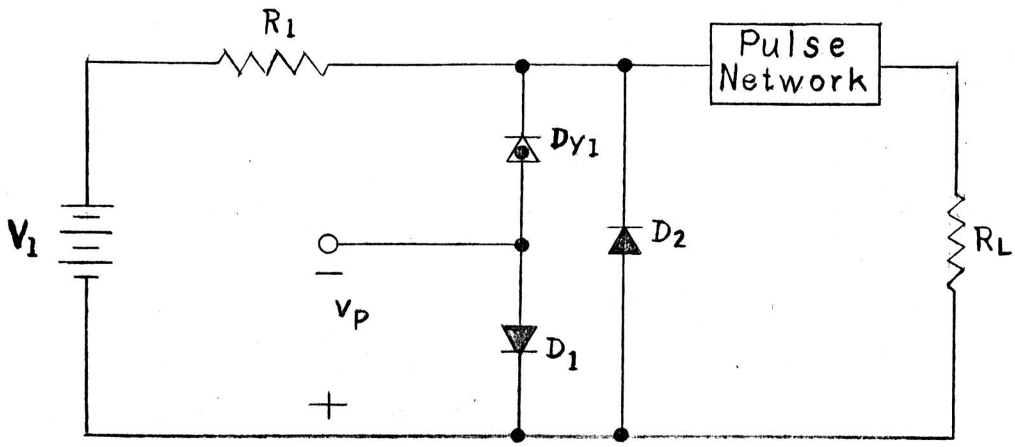


Fig. 8

Note: Disclosed by W. Prenosil to Westinghouse Electric Corp., Pittsburgh

LINE SYNCHRONIZED TRINISTOR
SQUARE WAVE GENERATOR

Description:

In many systems, it is necessary to generate square waves or pulses which are synchronized with the zero crossovers of the line voltage. The circuit described in this disclosure uses a Trinistor and a minimum number of associated components to generate good square waves.

The Trinistor is a breakdown diode with a third terminal connected to the base.

Since the Trinistor can be turned on or off in about 1 microsecond, the rise and fall times of the square waves are quite good. The efficiency of this generator is quite high because the dissipation of the Trinistor is very low in both its "off" and "on" regions and its switching time is very short.

A schematic diagram of the circuit is shown in Figure 9. The Trinistor is supplied from the d-c source V_2 through resistor R_L. The a-c from source V_1 serves as a control signal for the base of the Trinistor. Inductance L_1 is wound on a saturable core in such a way that it saturates at a low voltage compared with V_1. The voltage across L_1 in relation to the line voltage will then be as shown in Figure 10. The low voltage pulses from L_1 are fed to the base of Tr_1 through resistor R_2. The base is then pulsed alternately positive and negative. The positive pulses turn the Trinistor "off" and the negative pulses turn it "on", causing the voltage across Tr_1 to be as shown in Figure 10. The output across P_L is then a square wave which switches at the line voltage zeros.

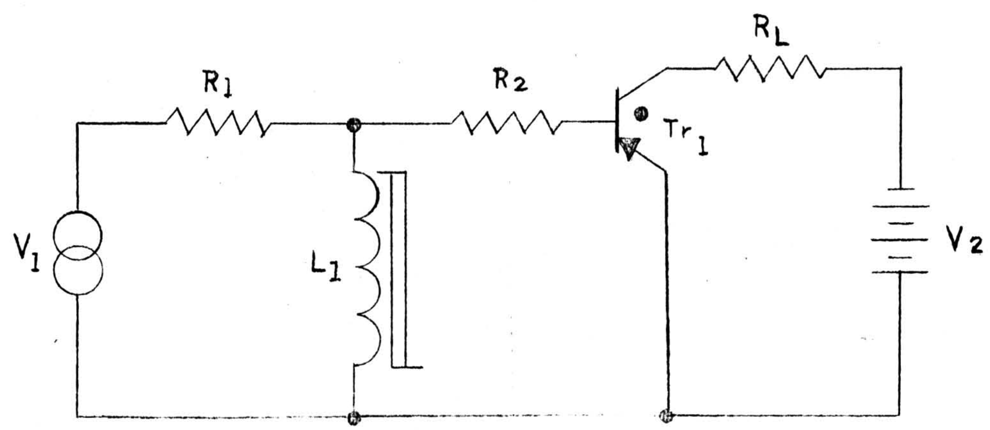


Fig. 9

The d-c for source V_2 can be obtained directly from the line as shown in Figure 11. The generator would then be self-contained and would operate directly from the a-c.

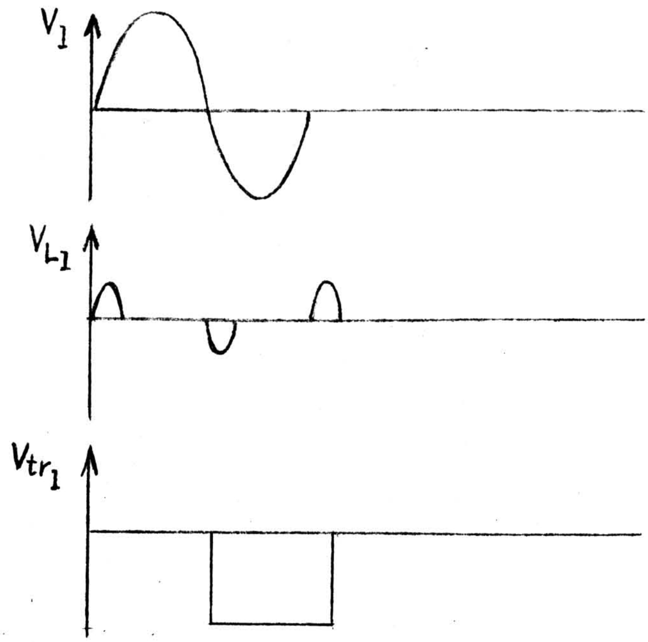


Fig. 10

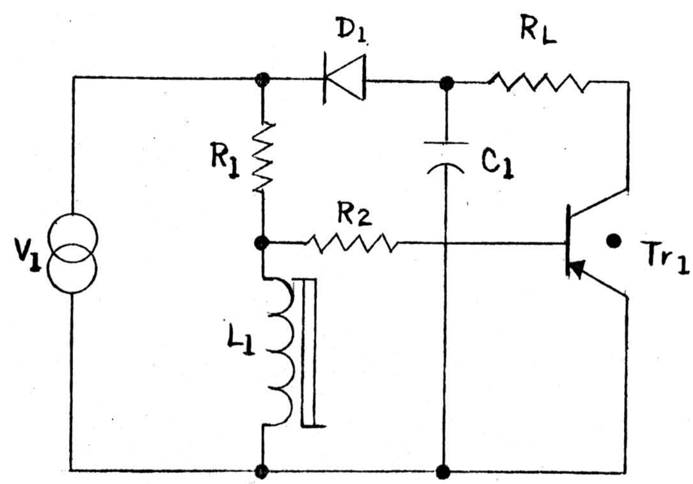


Fig. 11

Note: Disclosed by W. Prenosil to Westinghouse Electric Corp., Pittsburgh

RECOVERY TIME TESTER

Description:

Figure 12 shows the circuit diagram of the recovery time tester using fast switching semiconductor devices. The breakdown voltage of Br_2 is chosen to be higher than the power supply voltage V_o. Only with an additional voltage applied (in form of a pulse for example) can the diode conduct. This pulse can be provided by the relaxation-oscillator, consisting of L_1, C_1, B_r and Tr_1. The oscillator can be easily incorporated in the test circuit. As long as Br_2 is not conducting a current flows through the diode under test, determined by V_o, R_2, R_3 and partly by V_1.

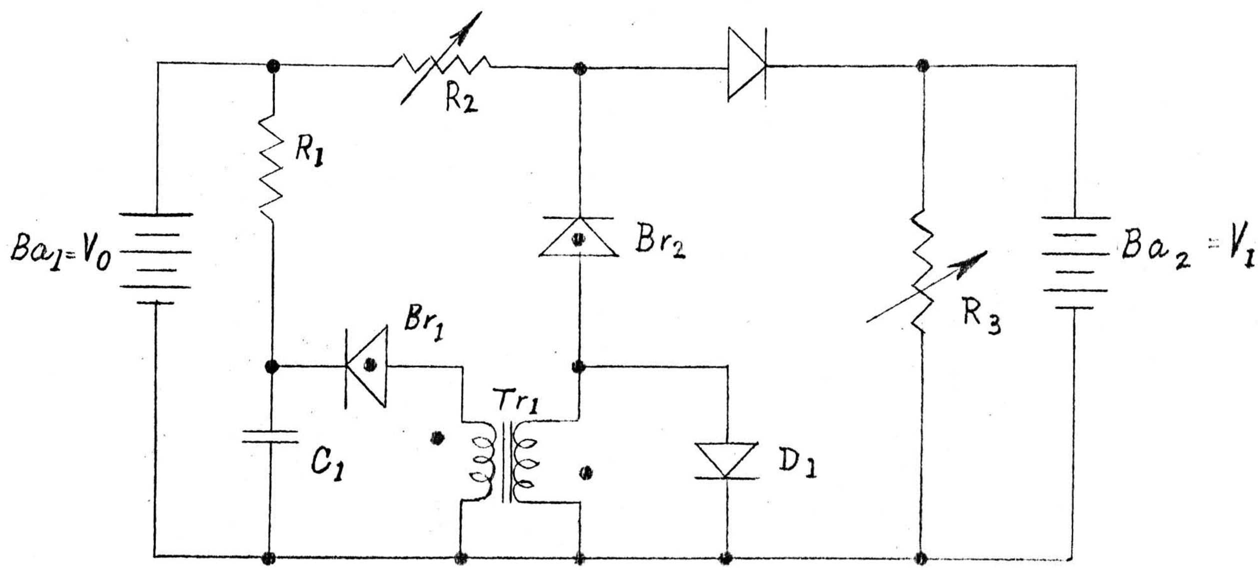


Fig. 12

Note: Disclosed by W. Prenosil to Hughes Products, Semiconductor Div.

D.-C. STATIC SWITCH CIRCUIT

Description:

Figure 13 illustrates one way in which the silicon controlled rectifier can be used to switch D.C. loads. To close the switch, the gate circuit is energized momentarily from the main D.C. supply through some kind of signal device.

This device is represented in Figure 13 as a start push-button. As soon as the start-button is released, capacitor C changes to essentially the D.C. supply voltage through resistor R.

When the stop button is depressed momentarily, the positive terminal of C is connected to ground. This action impresses a negative voltage across the controlled rectifier for the few µsec. necessary to return it to the blocking state.

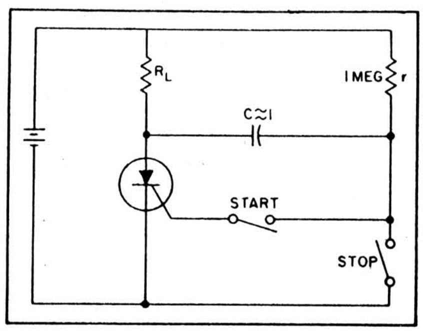


Fig. 13

Note: General Electric Publication.

HALF-WAVE PHASE CONTROLLED D.C. POWER SUPPLY PROVIDES UNIFORM OUTPUT

Description:

The circuit shown in Figure 14 uses a potentiometer control scheme that permits shifting the a-c gate current signal between 0 and 180° with respect to the anode supply voltage.

This phase shift regulates the point at which the rectifier fires during each cycle. Average output voltage can be varied uniformly from zero to about 0.45 of the RMS supply voltage.

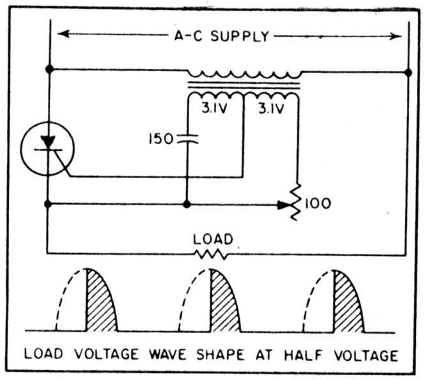


Fig. 14

Note: General Electric Publication.

SURGE VOLTAGE SUPPRESSION CIRCUIT

(Capacitor prevents overshoot.)

Description:

The type of circuit shown in Figure 15 is useful in protecting transistor and semiconductor-rectifier circuits from harmful line-voltage surges. When line voltage exceeds a predetermined value, one of the controlled rectifiers conducts. It draws enough line current to drop the voltage across the line impedance.

Value of resistor R should be selected to limit anode current to the rating of the rectifier. For surge durations of less than one cycle, R should be selected to limit peak anode current to 150 amp. when using this device. Voltage level at which suppression starts is determined by breakdown voltage of the regulator diode.

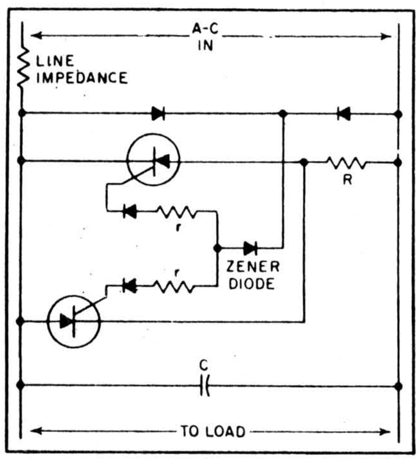


Fig. 15

Note: General Electric Publication.