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Standard
for
**SEMICONDUCTOR RECTIFIER
COMPONENTS**

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CONTENTS

PART I

DEFINITIONS	Page
Definitions	5
1.000 Rectifier Cells	5
1.100 Fundamental Components	5
1.200 Electrical Characteristics	8
1.300 Circuits	9
1.400 Ratings	11

PART II

SEMICONDUCTOR RECTIFIER DIODE LETTER SYMBOLS

2.000 Abbreviations	13
2.100 Specific Letter Symbols.....	13

PART III

TEST PROCEDURES FOR SEMICONDUCTOR RECTIFIER CELLS, RECTIFIER DIODES AND RECTIFIER STACKS.....

3.000 GENERAL	15
3.001 Type Tests.....	15
3.002 Routine Tests	15
3.100 ELECTRICAL MEASUREMENTS	15
3.101 Choice of Meters.....	15
3.102 Input	15
3.103 Output	15
3.104 Ripple Voltage	15
3.200 THERMAL MEASUREMENTS	15
3.201 Ambient Temperature.....	16
3.202 Polycrystalline Semiconductor Rectifier Cell or Rectifier Stack Temperature Measurements (Copper Oxide, Selenium, etc.).....	16
3.203 Monocrystalline Semiconductor Rectifier Diode or Rectifier Stack Temperature Measurements (Germanium, Silicon, etc.).....	16
3.300 LETTER SYMBOLS AND RECTIFIER CIRCUITS.....	17
3.301 Letter Symbols	17
3.302 Fundamental Rectifier Circuits.....	18
3.400 TYPES OF TESTS.....	18
3.401 Direct-Current Tests (Static).....	18
3.402 Alternating-Current Tests (Dynamic).....	21
3.403 Pulse Tests (Instantaneous).....	22
3.404 Load Tests	23
3.405 Surge Current Tests.....	24
3.406 Life Tests	25
3.407 Thermal Resistance Tests.....	25
3.408 Junction Capacitance Tests.....	26
3.409 Reverse Recovery Time Tests.....	26
3.410 Environmental Tests	28
3.411 Mechanical Tests	31
3.412 Dielectric Tests	31

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STANDARD FOR SEMICONDUCTOR RECTIFIER COMPONENTS

PART I

DEFINITIONS

Definitions given herein apply specifically to semiconductor components used for rectification or control of electric power, or both. For the purpose of this standard, a semiconductor rectifier component is a semiconductor rectifier cell, rectifier diode, or rectifier stack. Note that the name of the actual semiconductor material (selenium, silicon, etc.) may be substituted in place of the word "semiconductor" in the name of the components.

Only those definitions likely to be needed by the user are included.

1.000 Rectifier Cells

1.001 Semiconductor—A semiconductor is an electronic conductor with resistivity usually in the range between metals and insulators in which the electric charge-carrier concentration increases with increasing temperature over some temperature range.

1.002 Extrinsic Semiconductor—An extrinsic semiconductor is a semiconductor whose charge-carrier concentration is dependent upon impurities.

1.003 Intrinsic Semiconductor—An intrinsic semiconductor is a semiconductor whose charge-carrier concentration is substantially the same as that of the ideal crystal.

1.004 N-type Semiconductor—An N-type semiconductor is an extrinsic semiconductor in which the conduction-electron concentration exceeds the mobile-hole concentration.

1.005 P-type Semiconductor—P-type semiconductor is an extrinsic semiconductor in which the mobile-hole concentration exceeds the conduction-electron concentration.

1.006 Charge Carrier (of a Semiconductor)—A charge carrier is a mobile conduction electron or mobile hole.

1.007 Hole—A hole is a vacancy in the electronic band structure of a semiconductor which acts like a positive electronic charge with a positive mass.

1.008 Conduction Electron—A conduction electron is an electron in the conduction band of a solid, which is free to move under the influence of an electric field.

1.009 Junction (of a Semiconductor Device)—A junction is a region of transition between semiconductor regions of different electrical properties (for example, n-n⁺, p-n, p-p⁺ semiconductors), or between a metal and a semiconductor.

1.010 Alloy or Fused Junction—An alloy or fused junction is a junction formed by recrystallization on a base crystal from a liquid phase of one or more components and the semiconductor.

1.011 Grown Junction—A grown junction is a junction produced during growth of a crystal from a melt.

1.012 Diffused Junction—A diffused junction is a junction formed by the diffusion of an impurity within a semiconductor crystal.

1.013 Rectifier Junction (of a Semiconductor Rectifier Cell)—A rectifier junction is the junction in a semiconductor rectifier cell which exhibits asymmetrical conductivity.

1.014 Active Area (of a Semiconductor Rectifier Cell)—The active area of a semiconductor rectifier cell is that portion of the rectifier junction that effectively carries forward current.

1.015 Electrode (of a Semiconductor Device)—An electrode is an electric and mechanical contact to a region of a semiconductor device.

1.016 Cathode (of a Semiconductor Rectifier Cell)—The cathode of a semiconductor rectifier cell is the electrode to which the forward current flows within the cell.

1.017 Anode (of a Semiconductor Rectifier Cell)—The anode of a semiconductor rectifier cell is the electrode from which the forward current flows within the cell.

1.018 Forward Direction (of a Semiconductor Rectifier Cell)—The forward direction of a semiconductor rectifier cell is the direction of lesser resistance to steady direct-current flow through the cell; for example, from the anode to the cathode.

1.019 Reverse Direction (of a Semiconductor Rectifier Cell)—The reverse direction of a semiconductor rectifier cell is the direction of greater resistance to steady direct-current flow through the cell; for example, from the cathode to the anode.

1.100 Fundamental Components

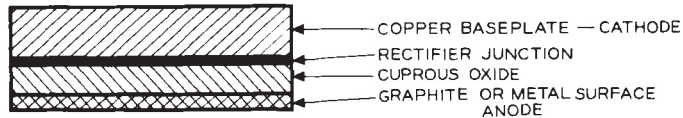
1.101 Semiconductor Device—A semiconductor device is a device whose essential characteristics are due to the flow of charge carriers within a semiconductor.

1.102 Semiconductor Rectifier Cell—A semiconductor rectifier cell is a semiconductor device consisting of one cathode, one anode, and one rectifier junction.

CROSS-SECTIONS OF TYPICAL COPPER-OXIDE, SELENIUM, GERMANIUM AND SILICON RECTIFIER CELLS

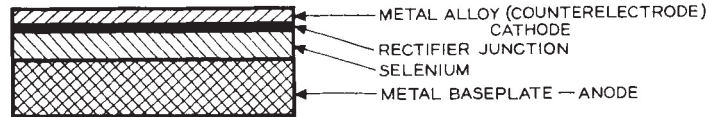
1. COPPER-OXIDE RECTIFIER CELL

FORWARD DIRECTION AND DIRECTION OF EASY CURRENT FLOW. NOTE THAT THIS IS OPPOSITE TO THE DIRECTION OF ELECTRON FLOW



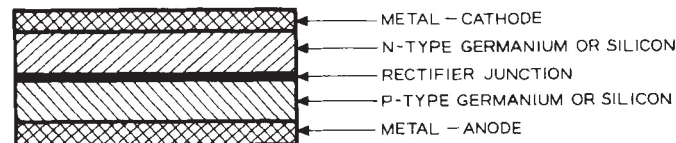
2. SELENIUM RECTIFIER CELL

FORWARD DIRECTION AND DIRECTION OF EASY CURRENT FLOW. NOTE THAT THIS IS OPPOSITE TO THE DIRECTION OF ELECTRON FLOW



3. GERMANIUM OR SILICON RECTIFIER CELL

FORWARD DIRECTION AND DIRECTION OF EASY CURRENT FLOW. NOTE THAT THIS IS OPPOSITE TO THE DIRECTION OF ELECTRON FLOW

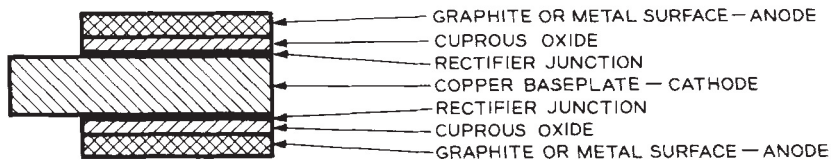


1.103 Multiple Semiconductor Rectifier Cell—A multiple semiconductor rectifier cell is a semiconductor device consisting of one common electrode and two

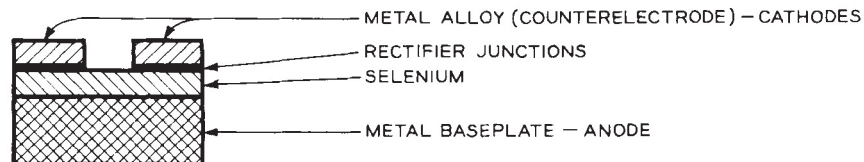
or more separate electrodes of the opposite polarity, each associated with a rectifier junction.

CROSS SECTIONS OF TYPICAL COPPER-OXIDE AND SELENIUM MULTIPLE RECTIFIER CELLS

1. COPPER-OXIDE MULTIPLE RECTIFIER CELL



2. SELENIUM MULTIPLE RECTIFIER CELL

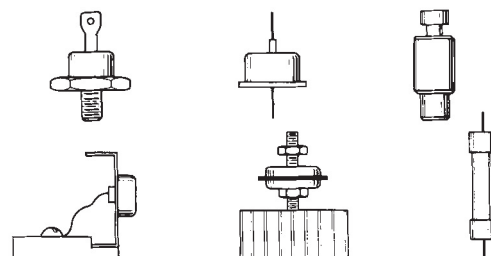


1.104 Semiconductor Diode—A semiconductor diode is a semiconductor device having two terminals and exhibiting a nonlinear voltage-current characteristic.

1.105 Semiconductor Rectifier Diode—A semiconductor rectifier diode is a semiconductor diode having an asymmetrical voltage-current characteristic, used for the purpose of rectification, and including its associated housing, mounting, and cooling attachments if integral with it.

Note: It may comprise one or more semiconductor rectifier cells.

TYPICAL SEMICONDUCTOR RECTIFIER DIODES

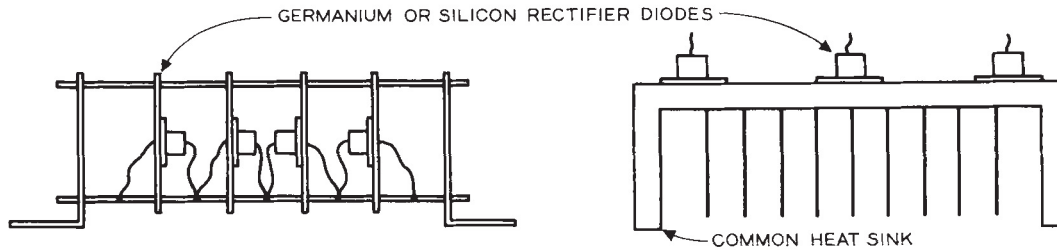


1.106 Semiconductor Rectifier Stack—A semiconductor rectifier stack is an integral assembly, with terminal connections, of one or more semiconductor rectifier

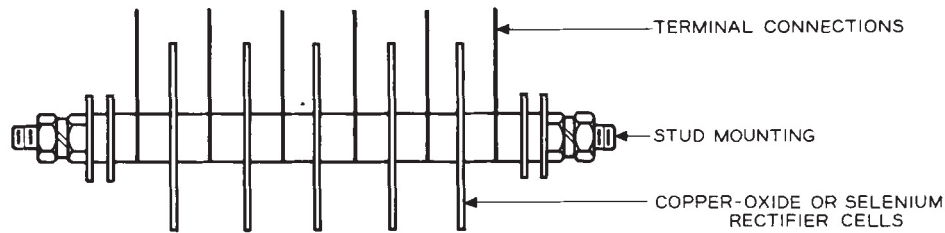
cells or semiconductor rectifier diodes and includes its associated mounting and cooling attachments if integral with it.

SKETCHES OF TYPICAL SEMICONDUCTOR RECTIFIER STACKS

A. GERMANIUM OR SILICON RECTIFIER STACKS



B. COPPER-OXIDE OR SELENIUM RECTIFIER STACK



C. COPPER-OXIDE, SELENIUM, GERMANIUM OR SILICON RECTIFIER STACKS



1.107 Terminal (of a Semiconductor Device)—A terminal is the externally available point of connection to one or more electrodes.

1.108 Cathode Terminal—The cathode terminal of a semiconductor rectifier diode or rectifier stack is the terminal from which forward current flows to the external circuit.

Note: In the semiconductor rectifier components field, the cathode terminal is normally marked positive.

1.109 Anode Terminal—The anode terminal of a semiconductor rectifier diode or rectifier stack is the terminal to which forward current flows from the external circuit.

Note: In the semiconductor rectifier components field, the anode terminal is normally marked negative.

1.110 Semiconductor Rectifier Cell Combination—The semiconductor rectifier cell combination is the arrangement of semiconductor rectifier cells in one rectifier circuit, rectifier diode, or rectifier stack. The semiconductor rectifier cell combination is described by a sequence of four symbols written in the order a-b-c-d with the following significances:

(a) Number of rectifier circuit elements.

(b) Number of semiconductor rectifier cells in series in each rectifier circuit element.

(c) Number of semiconductor rectifier cells in parallel in each rectifier circuit element.

(d) Symbol designating circuit.

The following symbols apply:

H—half wave	—1-1-1-H
C—center tap	—2-1-1-C
B—bridge	—4-1-1-B or 6-1-1-B
Y—wye	—3-1-1-Y or 6-1-1-Y
S—star	—6-1-1-S
D—voltage doubler	—2-1-1-D

If a semiconductor rectifier stack consists of sections of semiconductor rectifier cells insulated from each other, the total semiconductor rectifier cell combination becomes the sum of the semiconductor rectifier cell combinations of the individual insulated sections. If the insulated sections have the same semiconductor rectifier cell combination, the total semiconductor rectifier cell combination may be indicated by the semiconductor rectifier cell combination of one section preceded by a figure showing the number of insulated

sections. Example: 4(4-1-1-B) indicates 4 single-phase full-wave bridges insulated from each other assembled as one semiconductor rectifier stack.

Notes:

(1) The total number of semiconductor rectifier cells in each semiconductor rectifier cell combination is the product of the numbers in the combination.

(2) This arrangement can also be applied by analogy to give a semiconductor rectifier diode combination.

1.200 Electrical Characteristics

1.201 Rectification—Rectification is the term used to designate the process by which electric energy is transferred from an alternating-current circuit to a direct-current circuit.

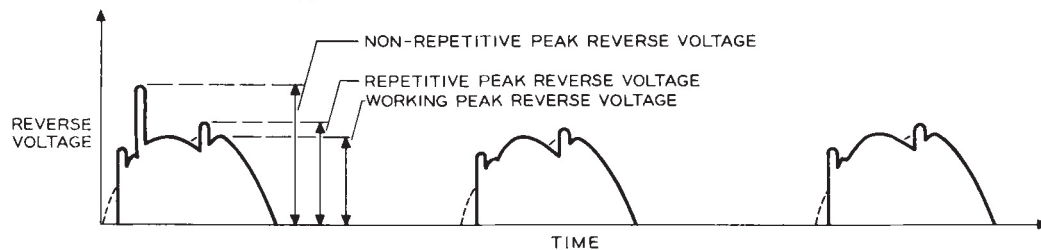
1.202 Average Current—The average current is the value of the current averaged over a full cycle unless otherwise specified.

1.203 Average Voltage—The average voltage is the value of the voltage averaged over a full cycle unless otherwise specified.

1.204 Forward Current—The forward current is the current that flows through a semiconductor rectifier cell in the forward direction.

1.205 Forward Voltage Drop—The forward voltage drop is the voltage drop in a semiconductor rectifier cell.

EXAMPLE:



1.212 Initial Reverse Voltage—The initial reverse voltage is the instantaneous value of the reverse voltage which occurs across a rectifier circuit element immediately following the conducting period and including the first peak of oscillation.

1.213 Peak Reverse Voltage—The peak reverse voltage is the maximum instantaneous value of the reverse voltage which occurs across a semiconductor rectifier cell, rectifier diode, or rectifier stack.

1.214 Working Peak Reverse Voltage—The working peak reverse voltage is the maximum instantaneous value of the reverse voltage, excluding all repetitive and non-repetitive transient voltages, which occurs across a semiconductor rectifier cell, rectifier diode, or rectifier stack.

1.215 Repetitive Peak Reverse Voltage—The repetitive peak reverse voltage is the maximum instantaneous value of the reverse voltage, including all repetitive transient voltages but excluding all non-repetitive transient voltages, which occurs across a semiconductor rectifier cell, rectifier diode, or rectifier stack.

1.216 Non-Repetitive Peak Reverse Voltage—The non-repetitive peak reverse voltage is the maximum in-

stantaneous value of the reverse voltage, including all non-repetitive transient voltages but excluding all repetitive transient voltages, which occurs across a semiconductor rectifier cell, rectifier diode, or rectifier stack.

1.206 Reverse Current—The reverse current is the total current that flows through a semiconductor rectifier cell in the reverse direction.

1.207 Reverse Current, Resistive—The resistive reverse current is the in-phase current that flows through a semiconductor rectifier cell during the blocking period exclusive of the reverse recovery current.

1.208 Reverse Current, Capacitive—The capacitive reverse current is the current that flows through a semiconductor rectifier cell during the blocking period due to the capacitance of the cell.

1.209 Capacitance (of a Semiconductor Diode)—The capacitance of a semiconductor diode is the small-signal capacitance measured between the terminals of the diode under stated conditions of bias and frequency.

1.210 Reverse Recovery Current—The reverse recovery current of a semiconductor rectifier cell is the transient component of reverse current associated with a change from forward conduction to reverse voltage.

1.211 Reverse Voltage—The reverse voltage is the voltage which is applied to a semiconductor rectifier cell, rectifier diode, or rectifier stack in the reverse direction.

stantaneous value of the reverse voltage, including all non-repetitive transient voltages but excluding all repetitive transient voltages, which occurs across a semiconductor rectifier cell, rectifier diode, or rectifier stack.

1.217 Forward Power Loss—The forward power loss is the power loss resulting from the flow of forward current.

1.218 Reverse Power Loss—The reverse power loss is the power loss resulting from the flow of reverse current.

1.219 Total Power Loss—The total power loss is the sum of the forward and reverse power losses.

1.220 Small-Signal Resistance—The small-signal resistance is the resistive part of the quotient of incremental voltage by incremental current under stated operating conditions.

1.221 Static Resistance (Forward or Reverse)—The static resistance of a semiconductor rectifier cell is the quotient of the voltage by the current at a stated point on the static characteristic curve.

1.222 Breakdown Region (of a Semiconductor Diode

Characteristic)—The breakdown region is the entire region of the volt-ampere characteristic beyond the initiation of breakdown for increasing magnitude of reverse current.

- 1.223 Breakdown** (of a Semiconductor Diode)—Breakdown is a phenomenon occurring in a reverse-biased semiconductor diode, the initiation of which is observed as a transition from a region of high small-signal resistance to a region of substantially lower small-signal resistance for increasing magnitude of reverse current.
- 1.224 Current Density**—The current density of a semiconductor rectifier cell is the current per unit active area.
- 1.225 Aging** (of a Semiconductor Rectifier Cell)—Aging of a semiconductor rectifier cell is any persisting change (except failure) which takes place for any reason in either the forward or reverse resistance characteristic.
- 1.226 Forming**—Forming is the electrical or thermal treatment, or both, of a semiconductor rectifier cell for the purpose of increasing the effectiveness of the rectifier junction.
- 1.227 Loss of Forming**—Loss of forming is a partial loss in the effectiveness of the rectifier junction.
- 1.228 Reforming**—Reforming is the operation of restoring by an electrical or thermal treatment, or both, the effectiveness of the rectifier junction after loss of forming.
- 1.229 Reverse Recovery Time** (of a Semiconductor Diode)—The reverse recovery time of a semiconductor diode is the time required for the current or voltage to recover to a specified value after instantaneous switching from a stated forward current condition to a stated reverse voltage or current condition in a given circuit.
- 1.230 Forward Recovery Time** (of a Semiconductor Diode)—The forward recovery time of a semiconductor diode is the time required for the current or voltage to recover to a specified value after instantaneous switching from a stated reverse voltage condition to a stated forward current or voltage condition in a given circuit.
- 1.231 Blocking**—Blocking is the action of a semiconductor rectifier cell which essentially prevents the flow of current.
- 1.232 Positive Creep Effect**—The positive creep effect is the gradual increase in reverse current with time, which may occur when a d-c reverse voltage is applied to a semiconductor rectifier cell.
- 1.233 Thermal Resistance, Effective** (of a Semiconductor Device)—The effective thermal resistance of a semiconductor device is the effective temperature rise per unit power dissipation of a designated junction above the temperature of a stated external reference point under conditions of thermal equilibrium.

1.234 Ripple Voltage or Current—A ripple voltage or current is the alternating component whose instantaneous values are the difference between the average and instantaneous values of a pulsating unidirectional voltage or current.

1.235 Percent Ripple Voltage or Current—The percent ripple voltage or current is the ratio, in percent, of the effective (root-mean-square) value of the ripple voltage or current to the average value of a pulsating unidirectional voltage or current.

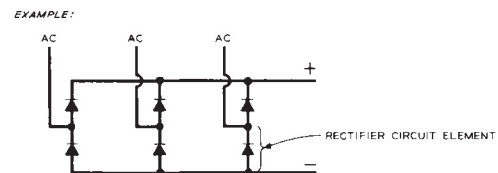
1.236 Harmonic Content—The harmonic content of a non-sinusoidal periodic wave is the order and magnitude of its harmonic components.

1.237 Form Factor—The form factor of a wave form is the ratio of the root-mean-square value of the wave to the average value.

1.300 Circuits

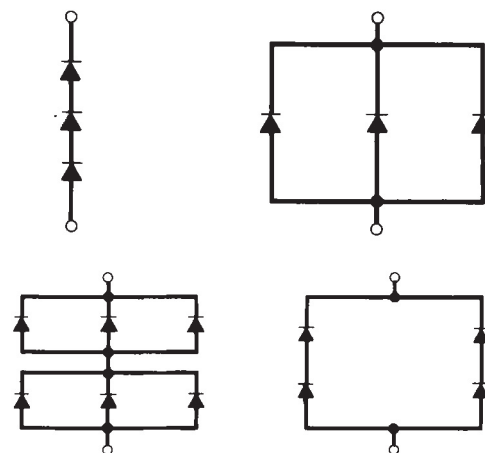
1.301 Rectifier Circuit Element—A rectifier circuit element is a circuit element bounded by two circuit terminals which has the characteristic of conducting current substantially in one direction only.

Note: The graphical symbol for a rectifier circuit element is:



The rectifier circuit element may consist of more than one semiconductor rectifier cell, rectifier diode, or rectifier stack connected in series or parallel or both, to operate as a unit.

EXAMPLES:



1.302 Half-Wave Rectifier Circuit—A half-wave rectifier circuit is a circuit which changes single-phase alternating current into pulsating unidirectional current, utilizing only one-half of each cycle.

1.303 Full-Wave Rectifier Circuit—A full-wave rectifier circuit is a circuit which changes single-phase alternating current into pulsating unidirectional current, utilizing both halves of each cycle.

1.304 Single-Way Rectifier Circuit—A single-way rectifier circuit is a circuit in which the current between each terminal of the alternating-voltage circuit and the rectifier circuit element conductively connected to it flows only in one direction. (See Note under 1.305).

1.305 Double-Way Rectifier Circuit—A double-way rectifier circuit is a circuit in which the current between each terminal of the alternating-voltage circuit and the rectifier circuit elements conductively connected to it flows in both directions.

Note: The terms single-way and double-way provide a means for describing the effect of the rectifier circuit on current flow in transformer windings connected to rectifier circuits. Most rectifier circuits may be classified into these two general types. Double-way circuits are also referred to as bridge circuits.

1.306 Conducting Period—The conducting period of a rectifier circuit element is that part of an alternating-voltage cycle during which the current flows in the forward direction. (See Note under 1.308).

1.307 Reverse Period—The reverse period of a rectifier circuit element is that part of an alternating-voltage cycle during which the current flows in the reverse direction. (See Note under 1.309).

1.308 Forward Period—The forward period of a rectifier circuit element is that part of an alternating-voltage cycle during which forward voltage appears across the rectifier circuit element.

Note: The forward period is not necessarily the same as the conducting period because of the effect of circuit parameters and semiconductor rectifier cell characteristics.

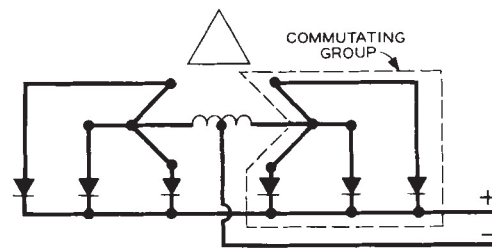
1.309 Blocking Period—The blocking period of a rectifier circuit element is that part of an alternating-voltage cycle during which reverse voltage appears across the rectifier circuit element.

Note: The blocking period is not necessarily the same as the reverse period because of the effect of circuit parameters and semiconductor rectifier cell characteristics.

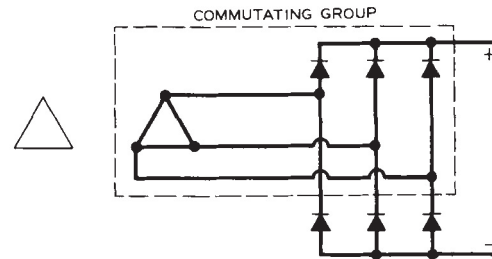
1.310 Commutation—Commutation is the transfer of unidirectional current between rectifier circuit elements which conduct in succession.

1.311 Commutating Group—A commutating group is a group of rectifier circuit elements and the alternating-voltage supply elements conductively connected to them in which the direct current of the group is commutated between individual elements which conduct in succession.

EXAMPLES:



COMMUTATING GROUP IN A SINGLE-WAY RECTIFIER CIRCUIT



COMMUTATING GROUP IN A DOUBLE-WAY RECTIFIER CIRCUIT

1.312 Set of Commutating Groups—A set of commutating groups consists of two or more commutating groups which have simultaneous commutations.

1.313 Commutating Voltage—The commutating voltage is the phase-to-phase a-c voltage of a commutating group.

1.314 Commutating Angle—The commutating angle is the angle during which the current is commutated between two rectifier circuit elements.

1.315 Phase Control—Phase control is the process of varying the point within the cycle at which forward conduction is permitted to begin.

Note: The amount of phase control may be expressed in two ways:

- (1) the reduction in d-c voltage obtained by phase control or,
- (2) the angle of retard, or advance.

1.316 Commutating Reactance—Commutating reactance is the reactance which effectively opposes the transfer of current between rectifier circuit elements of a commutating group, or set of commutating groups.

Note: For convenience, the reactance from phase to neutral, or one half the total reactance in the commutating circuit, is the value usually employed on computations, and is the value designated as the commutating reactance.

1.317 Commutation Factor—The commutation factor for a rectifier circuit is the product of the rate of current decay at the end of conduction, in amperes per microsecond, and the initial reverse voltage, in kilovolts.

1.318 Commutating Reactance Factor—The commutating reactance factor is the line-to-neutral commutating reactance in ohms multiplied by the direct cur-