CIRCUIT DESIGN FOR SEMICONDUCTOR POWER RECTIFIERS

Tables 3 and 4 show the theoretical values of direct and alternating voltages, current, and power for the basic rectifier and transformer elements of single-phase and polyphase conversion circuits, based on perfect rectifiers and transformers. The equations and the values of the constants K and I_{ac} are approximate, but they are sufficiently accurate for practical design of small rectifier circuits.

Symbols for Tables 3 and 4

I_{ac} = transformer secondary current in root-mean-square amperes

I_{dc} = average load direct current in amperes

K = circuit form factor

n = number of cells in series in each arm of rectifier

V_{ac} = alternating root-mean-square input voltage per secondary winding (see diagrams)

$V_{ac\Delta}$ = phase-to-phase alternating input voltage for 3-phase full-wave bridge

V_{dc} = average value of direct-current output voltage

V_p = reverse root-mean-square voltage per cell (rating of rectifier cell)

ΔV = root-mean-square voltage drop per cell at I_{dc}.

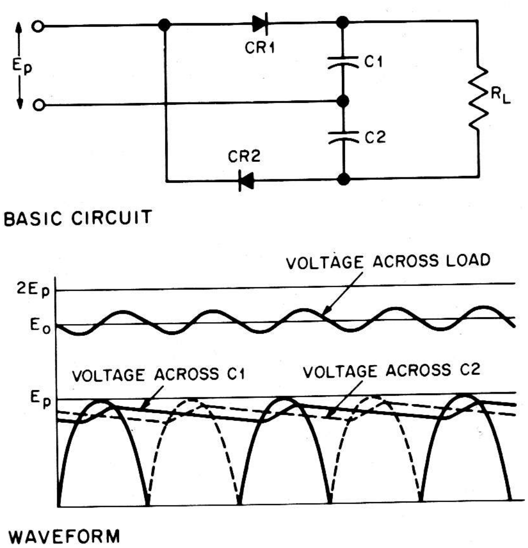


Fig. 1—Conventional voltage doubler.

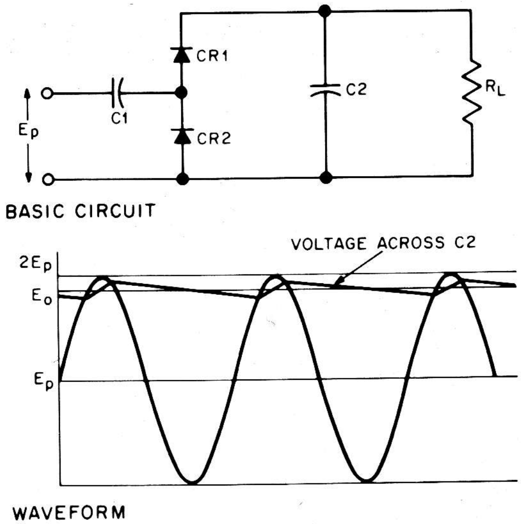


Fig. 2—Cascade voltage doubler.

More-rigorous equations, to be found in textbooks and technical papers, should be used in designing rectifiers with outputs in excess of about 10 kW and for accurate computations of regulation, efficiency, power factor, and overload characteristics of even small rectifiers.

VOLTAGE-MULTIPLIER RECTIFIER CIRCUITS

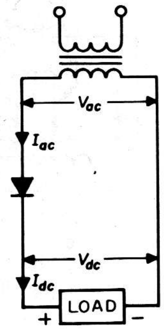
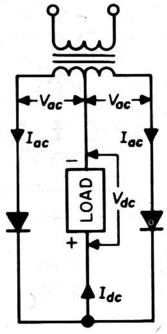
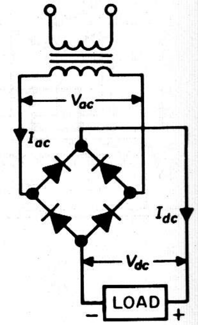
These circuits use the principle of charging capacitors in parallel from the ac input and adding the voltages across them in series to obtain dc voltages higher than the source voltage. Filtering must be of the capacitor-input type.

Conventional and Cascade Voltage Doublers: In the conventional circuit (Fig. 1), capacitors C1 and C2 are each charged, during alternate half-cycles, to the peak value of the alternating input voltage. The capacitors are discharged in series into load R_L, thus producing an output across the load of approximately twice the ac peak voltage.

In the cascade circuit (Fig. 2), C1 is charged to the peak value of the ac input voltage through rectifier CR2 during one half-cycle, and during the other half-cycle it discharges in series with the ac source through CR1 to charge C2 to twice the ac peak voltage.

The "conventional" circuit has slightly better regulation and, since the ripple frequency is twice the supply frequency, the output is easier to filter, the percentage ripple being approximately the same in both circuits. In addition, both capacitors are rated at the ac peak voltage, whereas C2 in the cascade circuit must be rated at twice this value. With both circuits, the peak inverse voltage across each rectifier is twice the ac peak. The cascade

TABLE 3—SINGLE-PHASE-RECTIFIER CIRCUITS, EQUATIONS, AND DESIGN CONSTANTS.

Constant	Half-Wave	Full-Wave Center Tap	Full-Wave Bridge
Circuit			
V_{ac}	$KV_{dc}+n\Delta V$	$KV_{dc}+n\Delta V$	$KV_{dc}+2n\Delta V$
Resistive and inductive loads:			
n	$KV_{dc}/(V_p-\Delta V)$	$2KV_{dc}/(V_p-2\Delta V)$	$KV_{dc}/(V_p-2\Delta V)$
V_p	V_{ac}/n	$2V_{ac}/n$	V_{ac}/n
K	2.26	1.13	1.13
$I_{ac,rms}$	$1.57I_{dc,Av}$	$0.785I_{dc,Av}$	$1.11I_{dc,Av}$
Battery and capacitive loads:			
n	$2KV_{dc}/(V_p-2\Delta V)$	$2KV_{dc}/(V_p-2\Delta V)$	$KV_{dc}/(V_p-2\Delta V)$
V_p	$2V_{ac}/n$	$2V_{ac}/n$	V_{ac}/n
K	1.0	0.85	0.85
$I_{ac,rms}$	$2.3I_{dc,Av}$	$1.15I_{dc,Av}$	$1.65I_{dc,Av}$

circuit, however, has the advantage of a common input and output terminal and, therefore, permits the combination of units to give higher-order voltage multiplications. The regulation of both circuits is poor, so that only small load currents can be drawn.

Bridge Voltage Doubler: This circuit (Fig. 3) is a combination of the conventional voltage doubler and the bridge rectifier circuit. If CR3 and CR4 are removed, the circuit becomes a "conventional" voltage doubler. If the two capacitors and the connection from their midpoint to the junction of CR3 and CR4 are removed, the circuit becomes a standard bridge rectifier.

Further Voltage Multiplication: The cascade voltage doubler shown in Fig. 2 can be combined several times to obtain higher dc voltages, as shown in Fig. 4. The voltage ratings of all the capacitors and rectifiers are twice the ac peak voltage, but the capacitors must have the values shown. The value of C will be the same as that for the cascade voltage doubler (Fig. 2), which is the basic unit for the circuit in Fig. 4. The load current must be small. The increasing size of capacitors and the deterioration in regulation limit the voltages that can be obtained from this type of circuit.

SILICON RECTIFIERS

Ratings

Silicon-rectifier ratings* are generally expressed in terms of reverse-voltage ratings and of mean-

* For a complete list of silicon-rectifier ratings, refer to the EIA–NEMA Standards on Letter Symbols and Abbreviations for Semiconductor Device Data Sheets and Specifications, published by Electronics Industries Association, 2001 Eye Street, N.W., Washington, D.C. 20006.