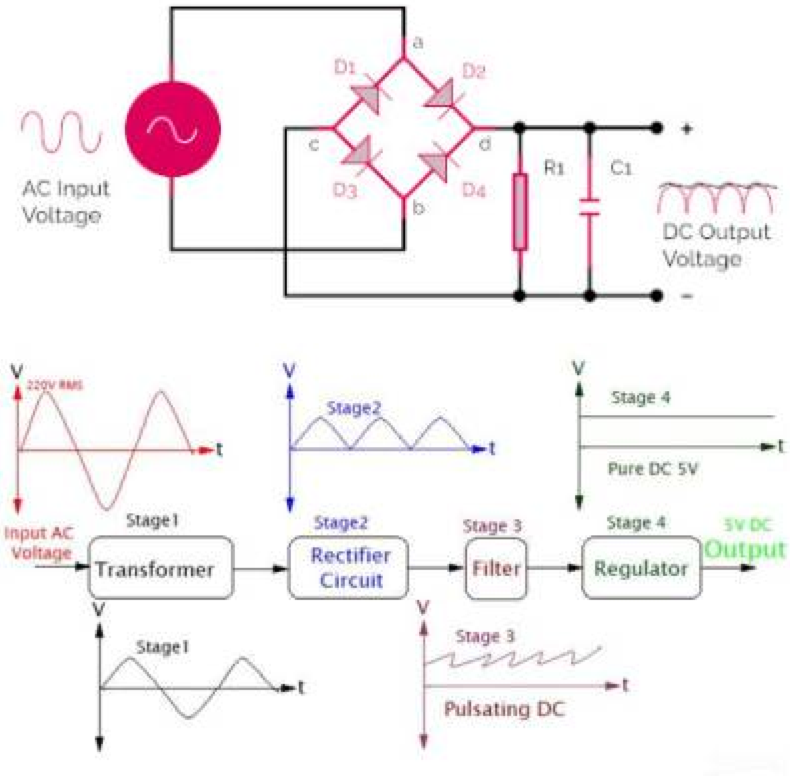
Rectifier Circuit

Overview

The bridge rectifier, or a full-wave bridge rectifier, is made up of four separate p-n junction diodes, an alternating supply, and a load resistor. Bridge rectifiers or diode bridge rectifiers have four diodes that create a closed loop, referred to as a bridge. The fundamental benefit of the bridge rectifier circuit is that it does not require a central tape transformer, which decreases its size.

The input of one side of the bridge is connected to the single winding. The load resistor is on the other side of the bridge, as shown in the bridge rectifier diagram below:

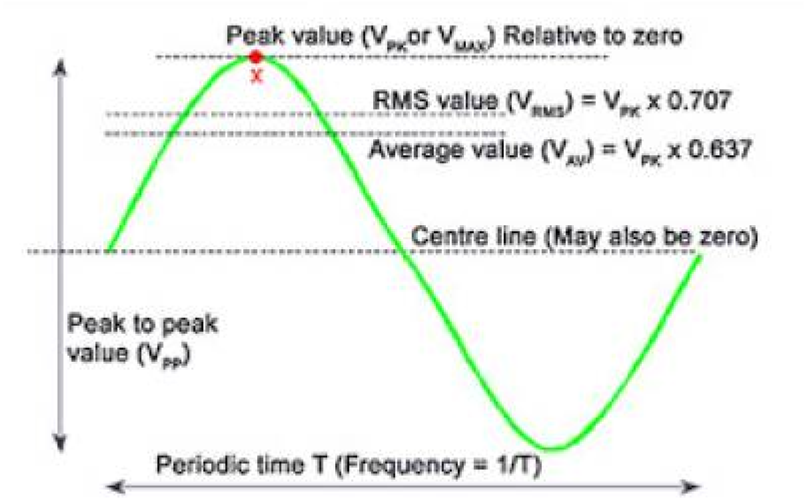


Basic Equations

The following different terminologies and units are used for the calculations around alternating voltages:

- **V*Peak* (V*p* or V*max*)**: The maximum instantaneous value of a function as measured from the zero-volt level. For the waveform shown above, the peak amplitude and peak value are the same, since the average value of the function is zero volts.
- **V*Peak−Peak* (Vpp)**:The full voltage between positive and negative peaks of the waveform; that is, the sum of the magnitude of the positive and negative peaks.
- **V*rms*** : The root-mean-square or effective value of a waveform.

- ***Vavg* or *VDC*** : The level of a waveform defined by the condition that the area enclosed by the curve above this level is exactly equal to the area enclosed by the curve below this level.



These values can be easily converted to each other. The way formulas for these conversions differ upon the the waveform that applies (sinus, triangle, square). The relevant basic conversions are:

Sinus

- **V*p* = V*pp* / 2**
- **V*dc* = V*avg* = (2 * V*p*) / π**
- **V*rms* = V*p* / √(2)**
- **V*rms* = V*pp* / (2 * √(2))**
- **V*pp* = 2*√(2) * V*rms***

Triangle

- **V*dc* = V*avg* = V*p* / 2**
- **V*rms* = V*p* / √(3)**

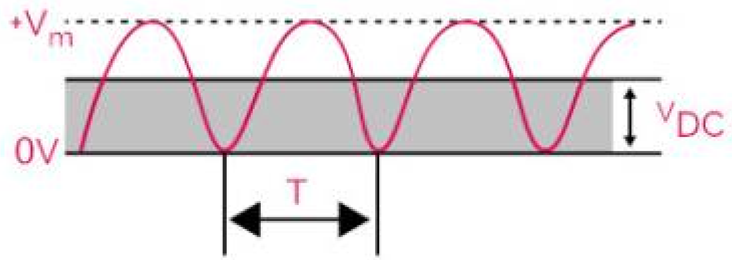
Square

- **V*p* = V*pp* / 2**
- **V*dc* = V*avg* = V*p***
- **V*rms* = V*p***

Transformer

Rectifier

After the rectifier the output voltage is a positive pulsed DC as shown in the picture below.



Resultant Output Waveform

The output voltage of the rectifier is lower +/- 1.4V lower then the input voltage. This is due to the forward-biased (conducting) voltage over two diodes. Due to voltage over the diodes the maximum peak value is:

- **V*p*_out = V*p*_in - 2 * 0,7V**

The term V*in* defines the voltage coming from the secondary windings of the transformer (or input voltage). The average Vdc value can be calculated with the formula below:

- **V*dc*_out = V*avg*_out = 2 * V*p* / π**

Current

Using Ohm's law to derive the current, we should note that two types of resistance will limit the current, the load resistance (RL), and the forward resistance of the diode (Rf). Note: We can find the forward resistance using the diode's I-V characteristic. The maximum current can be calculated with:

- **I*max* = V*max* / (2 * R*f* + R*l*)**

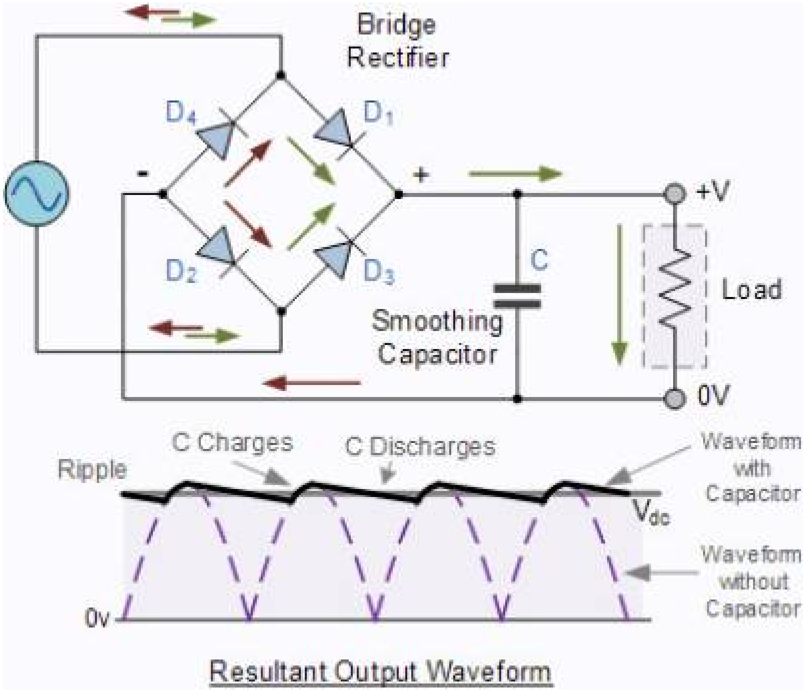
Where R*l* is the load resistance, R*f* is the forward resistance of the diodes. V*max* is the maximum AC voltage.

Filter / Capacitor

Calculation of ripple voltage

The value of the ripple voltage will depend on a number of factors:

- the value of the smoothing capacitor – the higher the value of the capacitor the smaller the ripple voltage for a given load
- the size of the load – the smaller the load resistance the larger the load current and so the larger the ripple voltage.



We can improve the average DC output of the rectifier while at the same time reducing the AC variation of the rectified output by using smoothing capacitors to filter the output waveform. Smoothing or reservoir capacitors connected in parallel with the load across the output of the full wave bridge rectifier circuit increases the average DC output level even higher as the capacitor acts like a storage device.

For a full wave rectifier the ripple voltage can be calculated with the following formulas:

- **V*r* = V*p* / (f*r* * R*load* * C)**
- **V*r* = I*load* / (f*r* * C)**

Where:

- V*r* is the peak-to-peak ripple voltage
- I*load* is the load current
- f*r* is the frequency of the ripple. Due to the rectifier this value is twice the frequency of the transformer. 50 Hz for half-wave rectification and 100 Hz for full-wave rectification.
- C is the capacitance of the smoothing capacitor

Calculation of ripple Factor

For a full wave rectifier with filter the ripple factor can be calculated with the following formula:

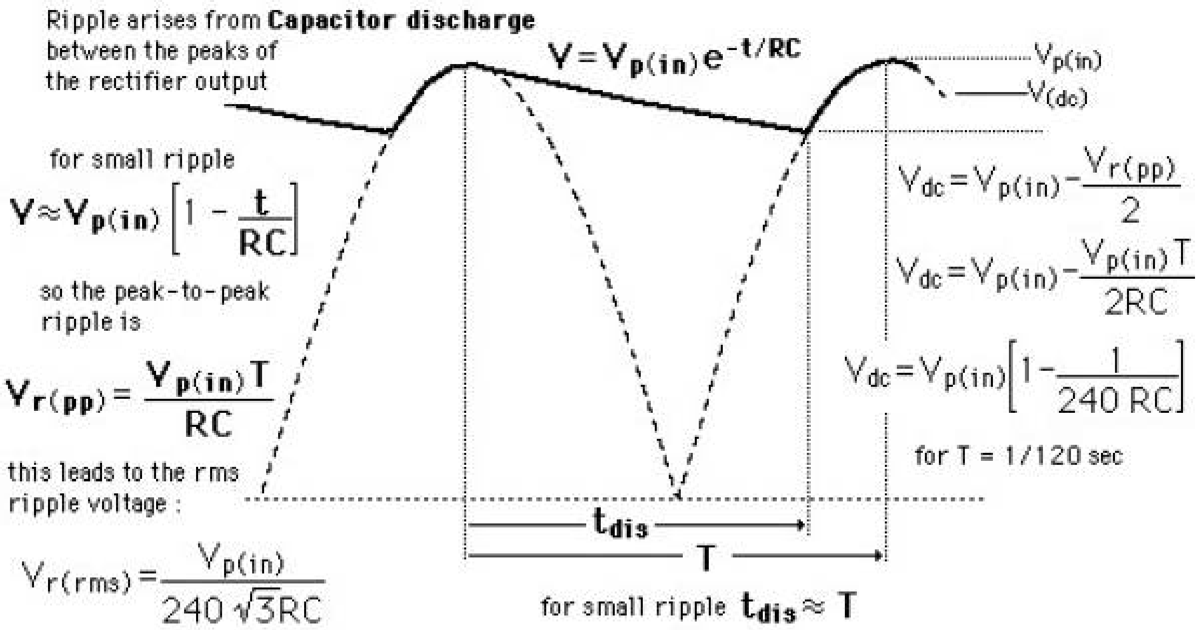
- **Ripple factor = 1 / (4√3fCR)**

Calculate the ripple factor of the output waveform as the ratio of the ripple voltage or current (also known as the RMS voltage) to the DC voltage.

- **Ripple factor = √ ((V*rms* / V*dc*)^2 - 1)**
- **Ripple factor = √ ((I*rms* / I*dc*)^2 - 1)**

DC output Voltage

Please note: the calculations below only work if the RC time is » (x10) then the period T. E.g. in case of 100 hz (T=10ms) the RC should be in the range of 0,1 (100 ms) = 100 Ohm * 1000uF.



For a full wave rectifier with filter the output voltage can be calculated with the following formula:

- **V*dc* = V*p* - (I*dc* / 4fC)**

Substituting I*dc* with V*dc* / R this becomes:

- **V*dc* = V*p* * 4fRC) / (1 + 4fRC)**

Transformer Selection

Based on the above formulas, the table below calculates the required tranformer voltage to achieve a specific DC voltage.

Preferred Vdc	Stabilizer drop (V)	Vp	Rectifier Drop (V)	Trafo Vpp	Trafo RMS
	-3		-1,4		
5	8	8,0	9,4	18,9	6,7
9	12	12,1	13,5	26,9	9,5
12	15	15,1	16,5	33,0	11,7
15	18	18,1	19,5	39,0	13,8
16	19	19,1	20,5	41,0	14,5
18	21	21,1	22,5	45,0	15,9
20	23	23,1	24,5	49,0	17,3
24	27	27,1	28,5	57,1	20,2

Links

- https://en.wikipedia.org/wiki/Rectifier
- https://www.powerelectronicsnews.com/power-supply-design-notes-rectifier-circuits/
- https://www.omnicalculator.com/physics/bridge-rectifier
- https://youtu.be/NeMLVTqDluo?si=LJtCGiPQxSv8blqs
- https://www.studocu.com/en-za/document/central-university-of-technology/electronic-fundamentals-i/unit5-power-supply-design-3/14924637
- https://gtuttle.net/circuits/topics/rectifiers.pdf
- https://www.physicsforums.com/threads/calculating-the-dc-value-of-the-output-voltage-for-a-full-wave-rectifier.1003323/
- https://www.electronics-tutorials.ws/diode/diode_6.html
- https://resource.download.wjec.co.uk/vtc/2016-17/16-17_1-9/gce-electronics-book-chapter-7.pdf
- https://www.pcbway.com/blog/PCB_Design_Tutorial/A_Comprehensive_Guide_for_5V_DC_Power_Supply_Design_1c983d89.html
- https://mcitransformer.com/about-mci/power-supply-design-notes/
- https://www.researchgate.net/publication/360727172_Designing_a_DC_power_supply_circuit_with_transformer_rectifier_filter_and_regulator_that_can_be_used_to_turn_on_number_8_of_the_7-segment_display