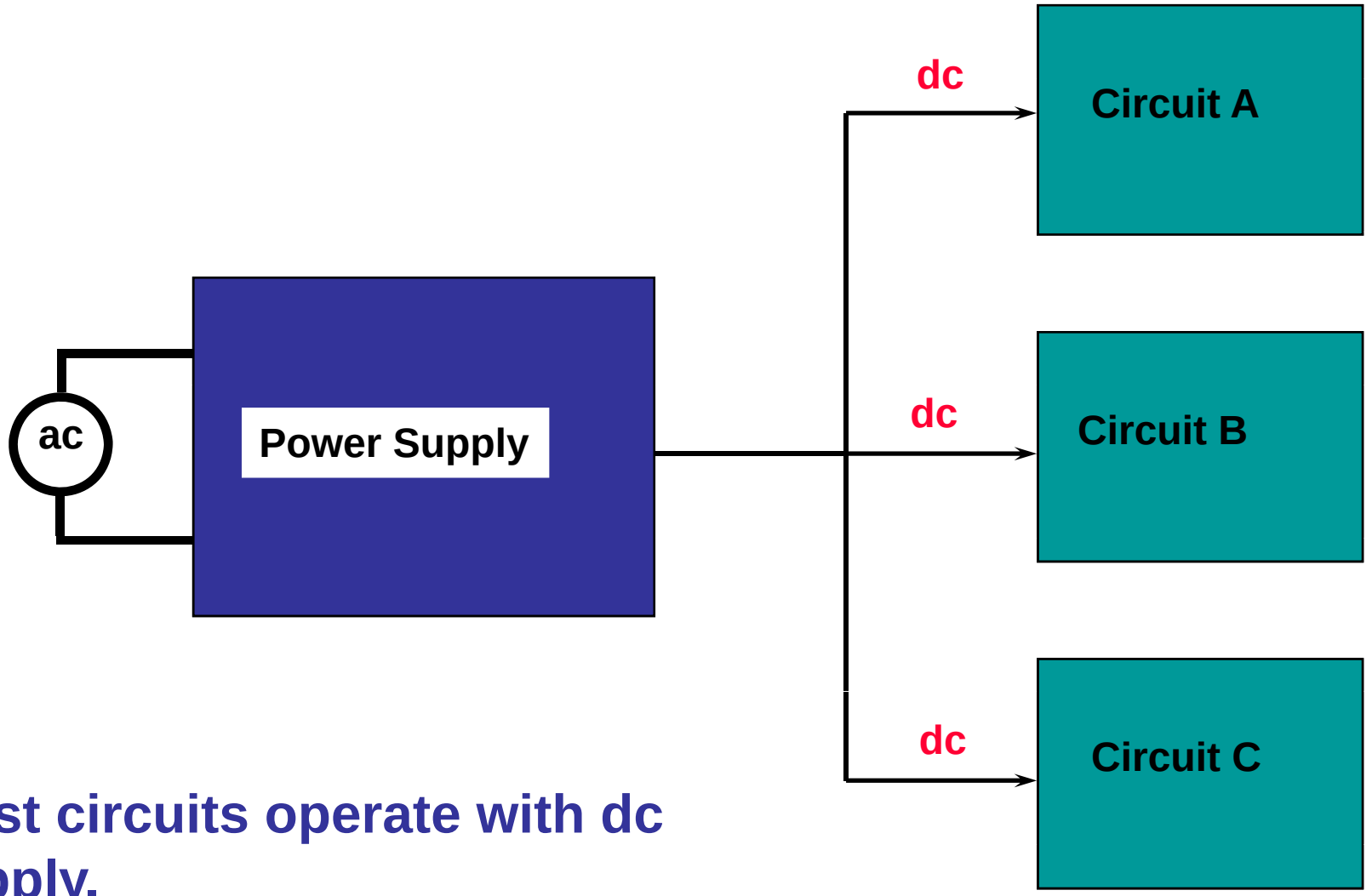
Diode Applications

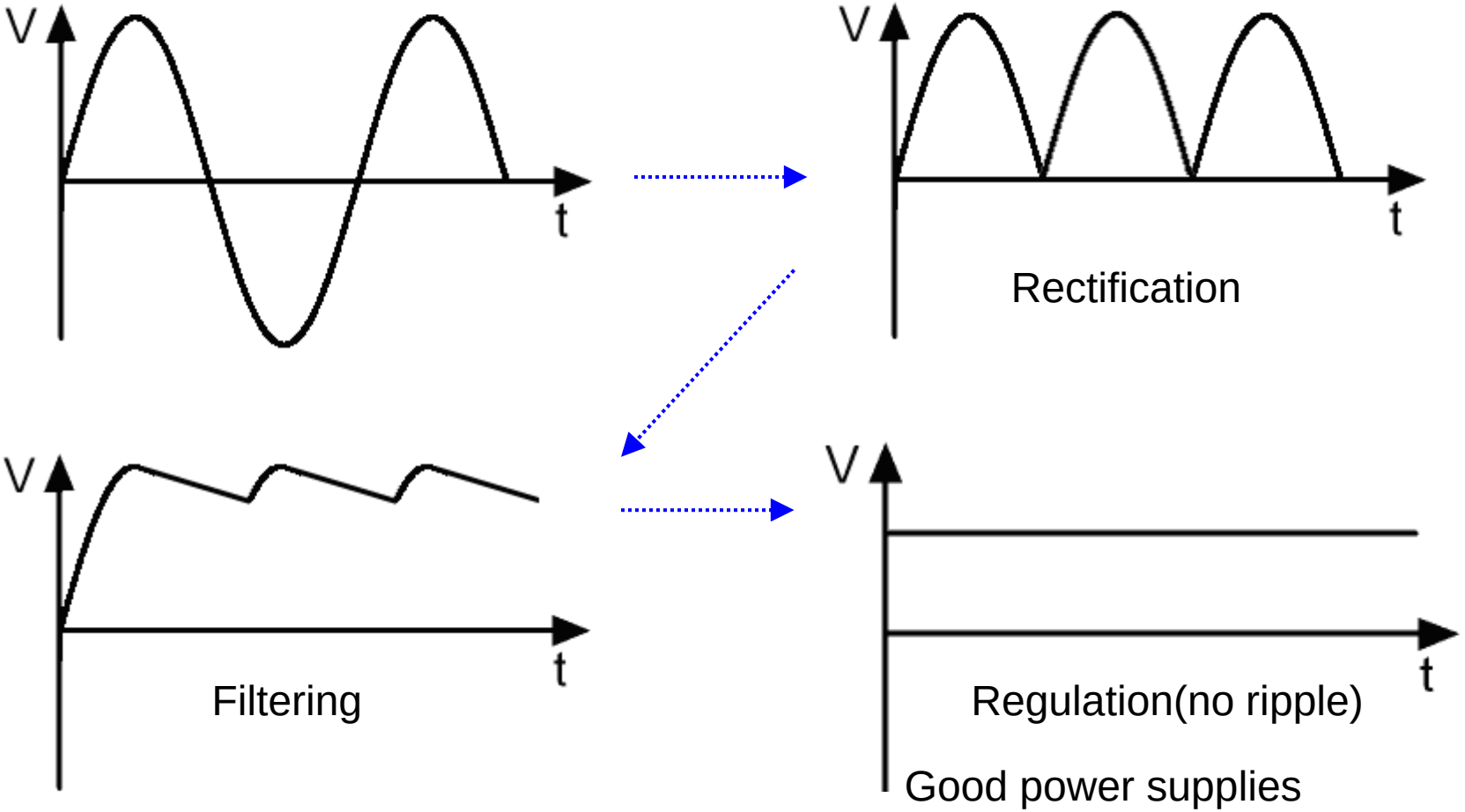
- Explain and analyze the operation of both half and full wave rectifiers
- Explain and analyze filters and regulators and their characteristics
- Explain and analyze the operation of diode limiting and clamping circuits
- Explain and analyze the operation of diode voltage multipliers.
- Interpret and use a diode data sheet
- Troubleshoot simple diode circuits

AC to DC



Most circuits operate with dc supply.

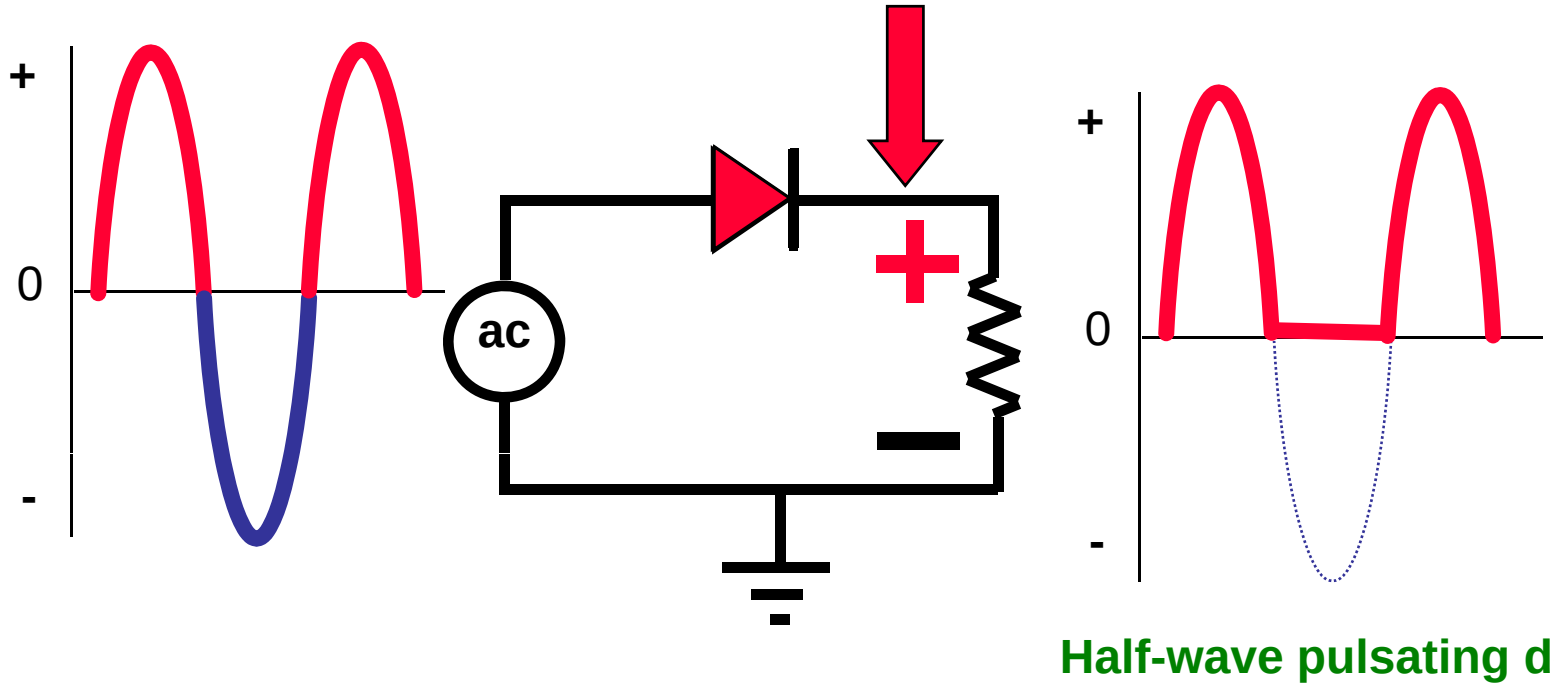
Basic Power Supply Principle



Good power supplies
(i.e. required switching techniques, zener regulation, etc)

Diode Rectify

The cathode makes this the positive end of the load.

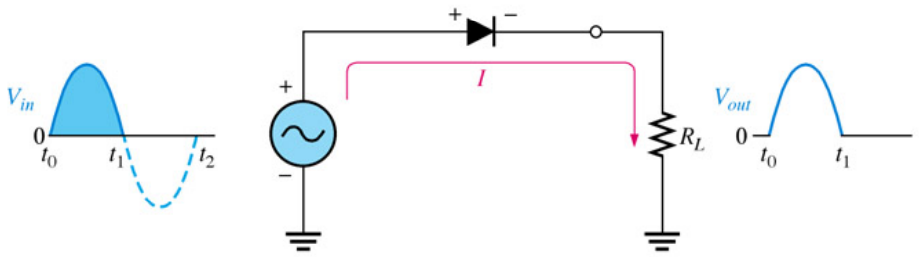


Half-wave pulsating dc

A series rectifier diode changes ac to dc.

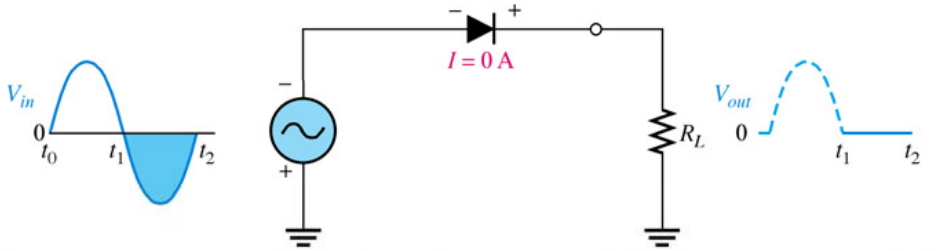
Half-wave Rectifier

A half wave rectifier(ideal) allows conduction for only 180◦ or half of a complete cycle.

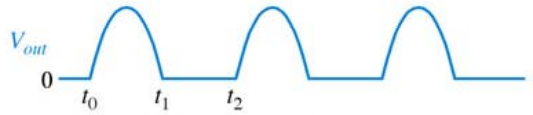


(a) During the positive alternation of the 60 Hz input voltage, the output voltage looks like the positive half of the input voltage. The current path is through ground back to the source.

The output frequency is the same as the input.



(b) During the negative alternation of the input voltage, the current is 0, so the output voltage is also 0.

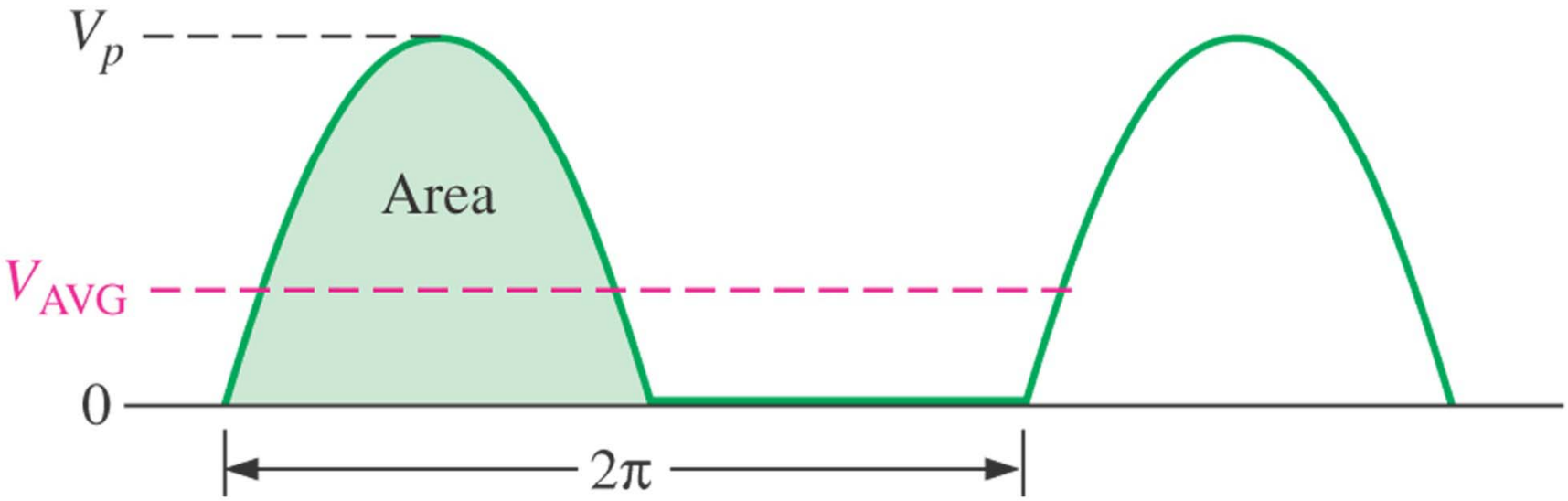


(c) 60 Hz half-wave output voltage for three input cycles

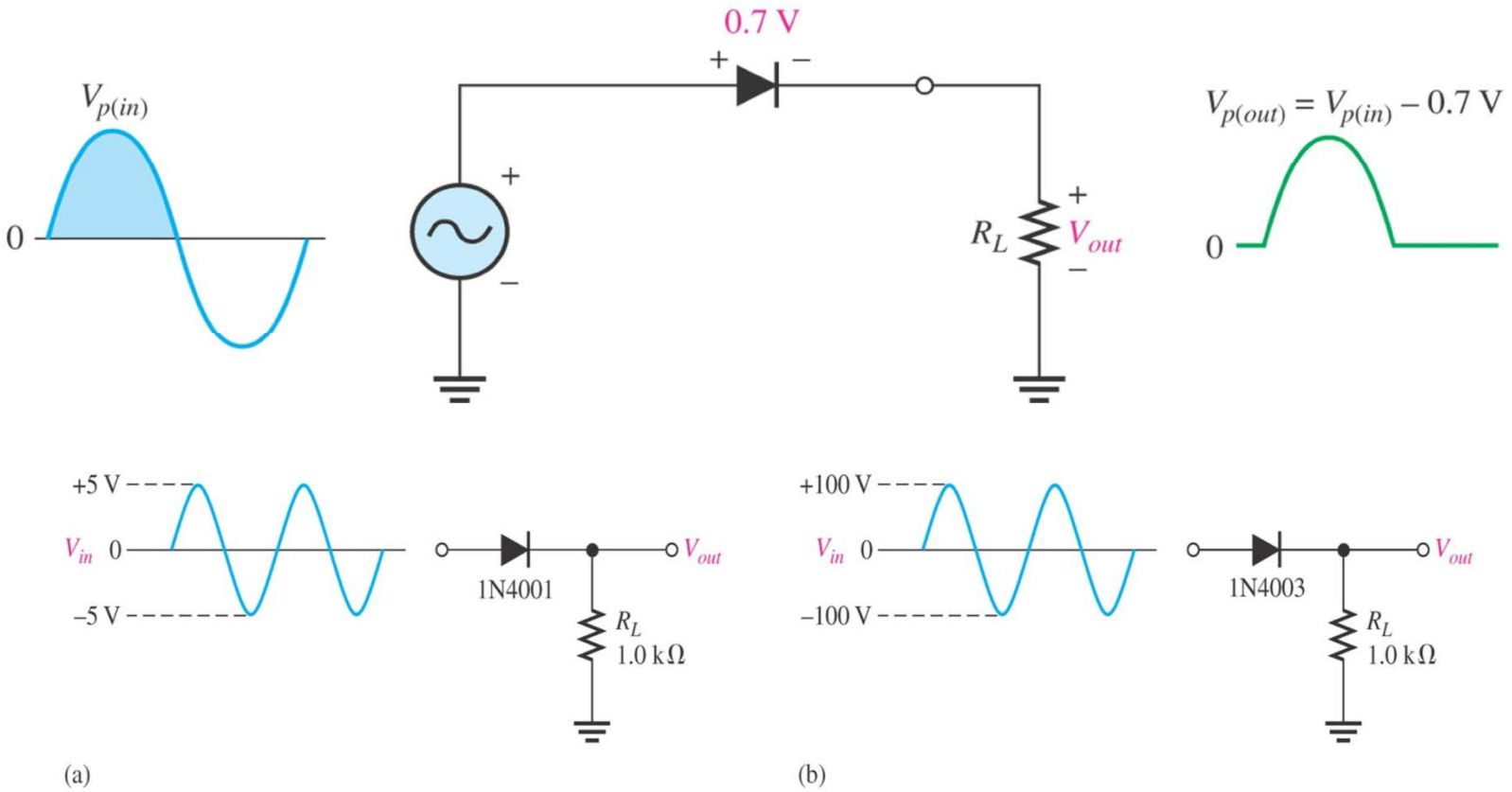
The average V_{DC} or $V_{AVG} = V_p/\pi$

Proof this!!!!

Average voltage of half-wave rectifier

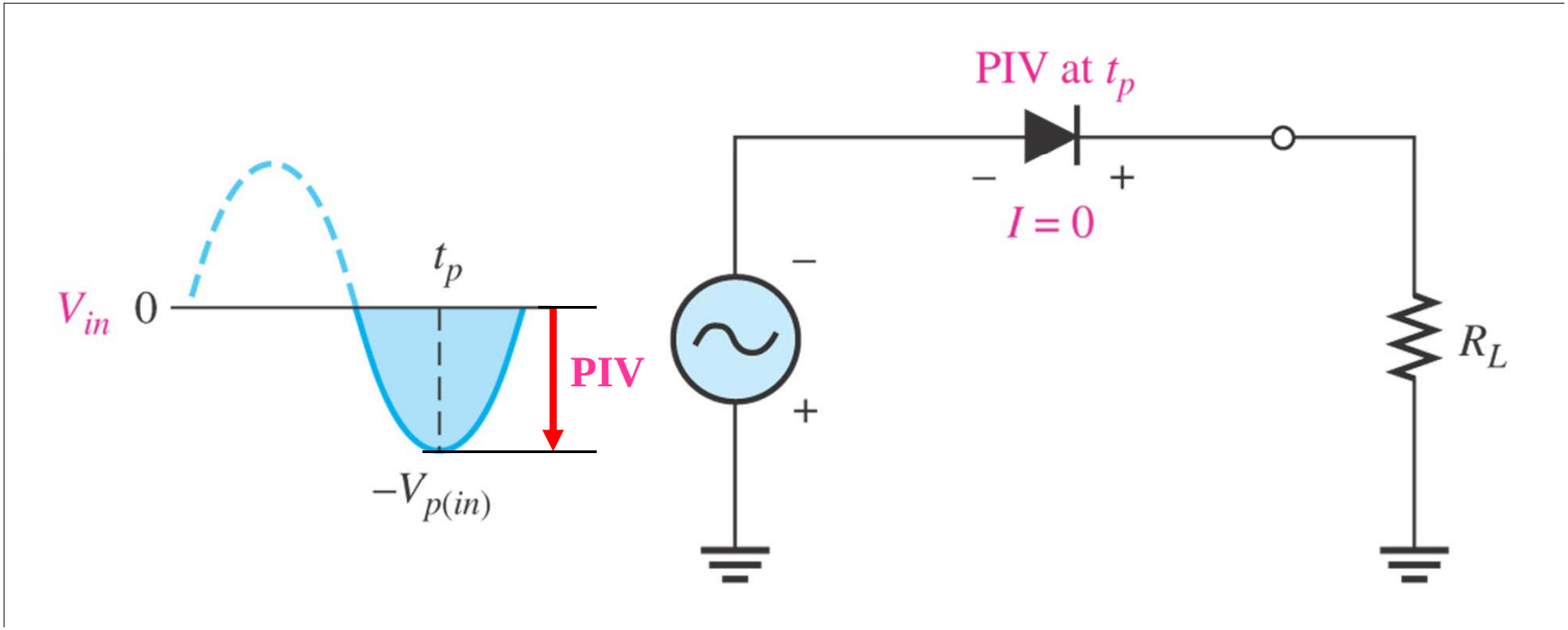


The effect of the barrier potential on the half-wave rectified output voltage is to reduce the peak value of the input by about 0.7 V.



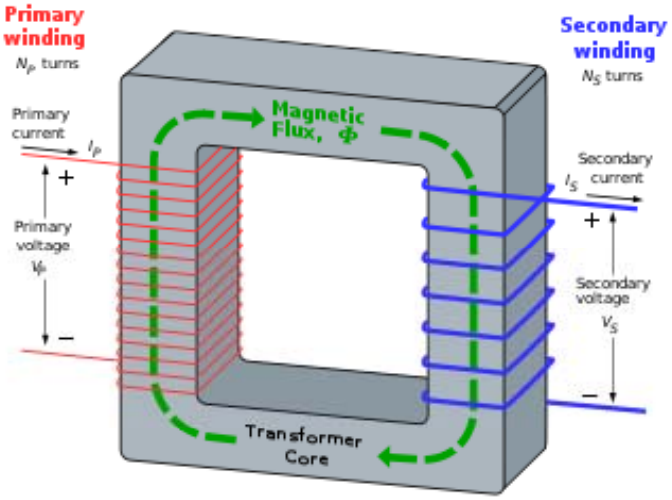
Reverse Operation

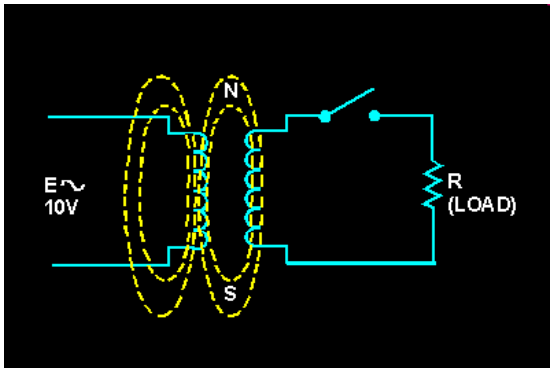
Peak inverse voltage(PIV) is the maximum voltage across the diode when it is in reverse bias.

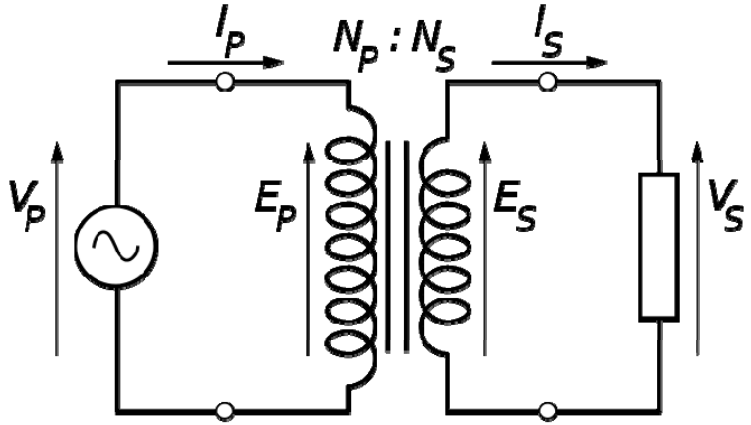


The diode must be capable of withstanding this amount of voltage.

TRANSFORMER Review







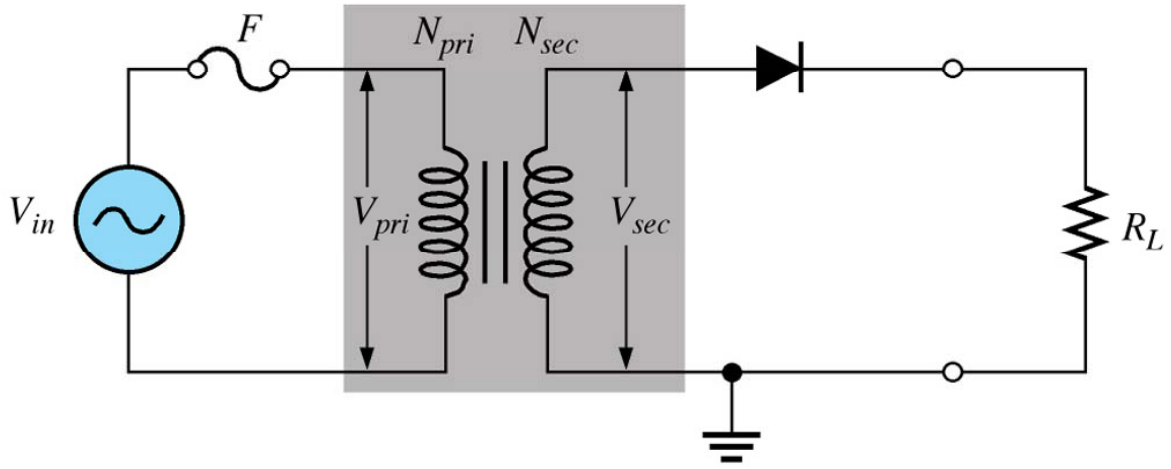
$$\frac{V_P}{V_S} = \frac{I_S}{I_P} = \frac{N_P}{N_S}$$

Transformer-Coupled Input

Transformers are often used for voltage change and isolation.

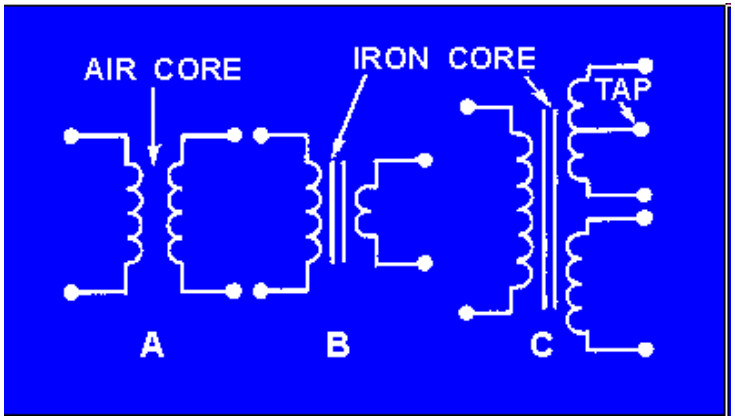
The turns ratio of the primary to secondary determines the output versus the input.

The fact that there is no direct connection between the primary and secondary windings prevents shock hazards in the secondary circuit.



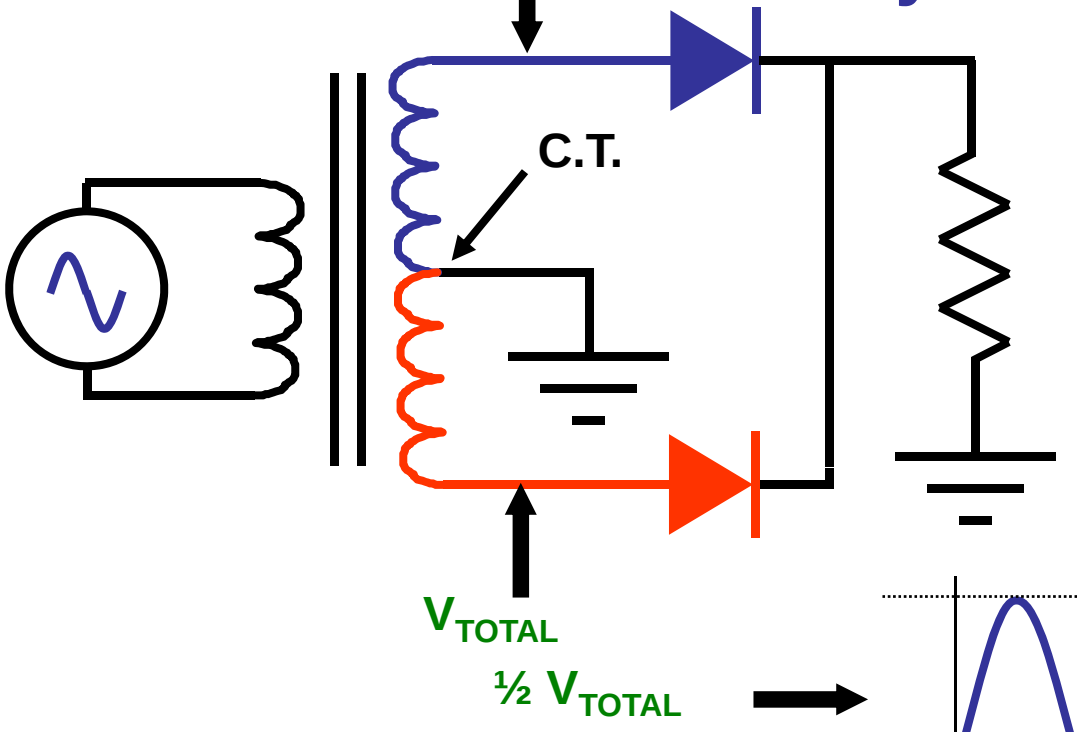
VCT

- Volts center tapped (VCT) describes the voltage output of a center tapped transformer. For example: A 24 VCT transformer will measure 24 VAC across the outer two taps (winding as a whole), and 12VAC from each outer tap to the center-tap (half winding). These two 12 VAC supplies are 180 degrees out of phase with each other, thus making it easy to derive positive and negative 12 volt DC power supplies from them.

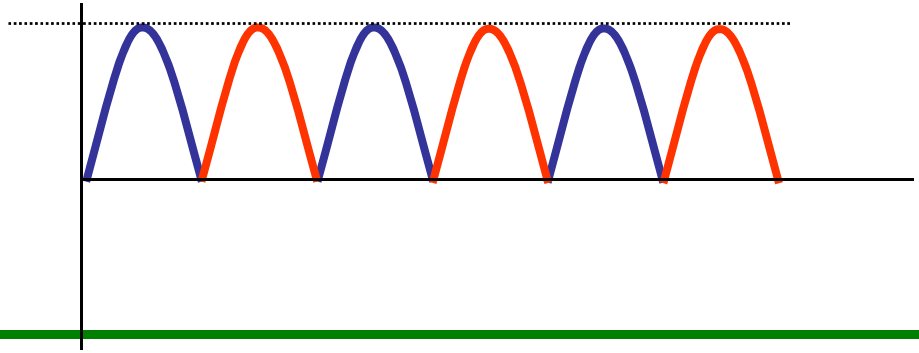


Center-tapped transformer

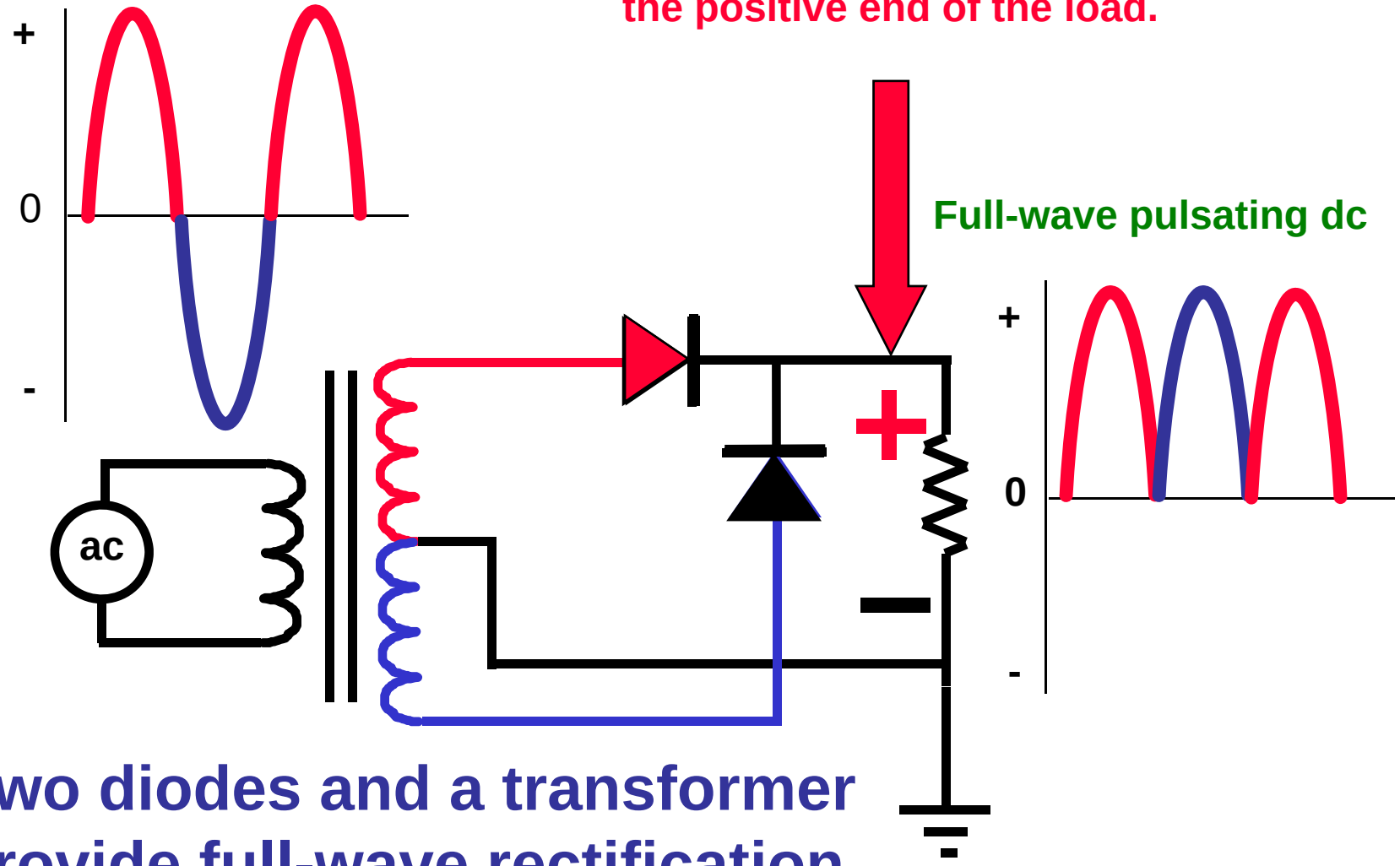
Only half of the transformer secondary conducts at a time.



V_{LOAD} is equal to one-half the total secondary voltage.



The cathodes make this the positive end of the load.

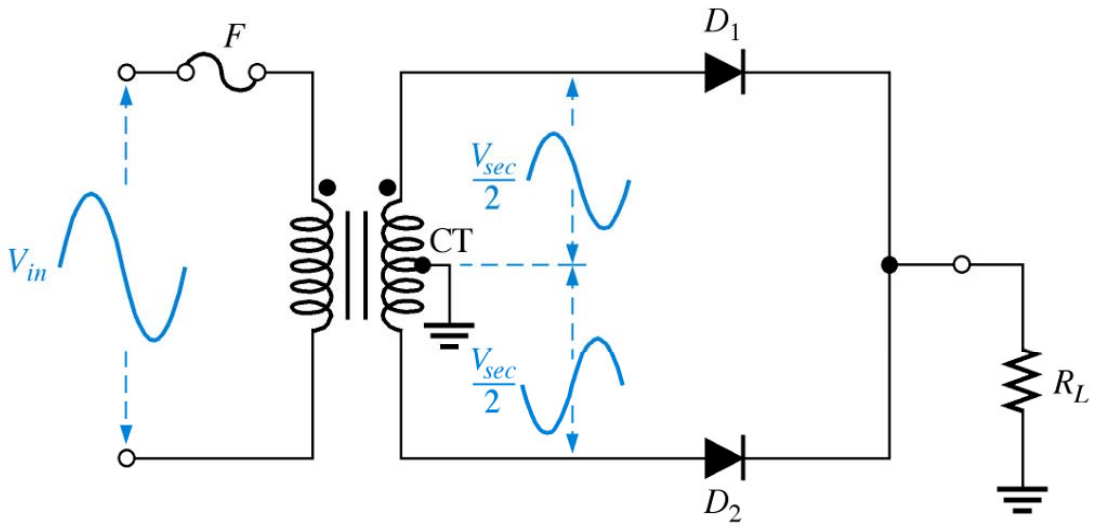


Two diodes and a transformer provide full-wave rectification.

Full-wave Rectifier(VCT)

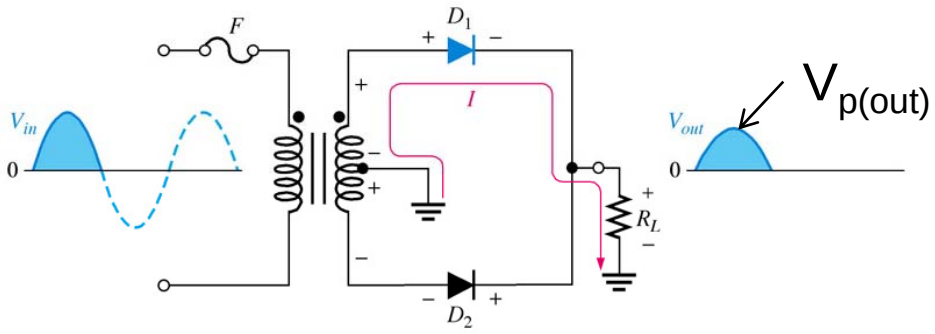
This method of rectification employs two diodes connected to a center-tapped transformer.

The peak output is only half of the transformer's peak secondary voltage.



Full-wave Rectifier(VCT)

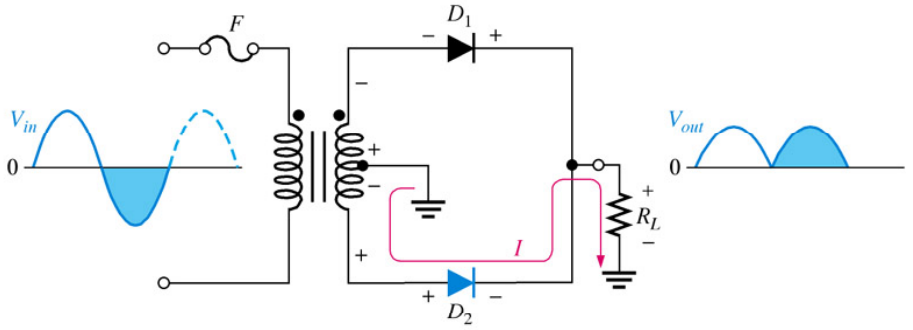
Note the current flow direction during both alternations. Being that it is center tapped, the peak output is about half of the secondary windings total voltage.



(a) During positive half-cycles, D_1 is forward-biased and D_2 is reverse-biased.

Each diode is subjected to a PIV of the full secondary winding output minus one diode voltage drop.

$$PIV = 2V_{p(out)} - 0.7V$$



(b) During negative half-cycles, D_2 is forward-biased and D_1 is reverse-biased.

NOTE. The diode must be able to withstand this “Reverse” or “Inverse” voltage without breaking down. The diode 1N4001 has a PIV or PRV (Peak Inverse Voltage or Peak Reverse Voltage) rating of 50 V. (Note that this is a peak value.)

1N4001 - 1N4007

1.0A RECTIFIER

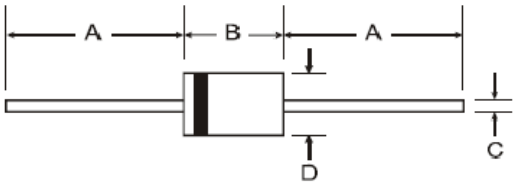
Please click here to visit our online spice models database.

Features

- Diffused Junction
- High Current Capability and Low Forward Voltage Drop
- Surge Overload Rating to 30A Peak
- Low Reverse Leakage Current
- **Lead Free Finish, RoHS Compliant (Note 3)**

Mechanical Data

- Case: DO-41
- Case Material: Molded Plastic. UL Flammability Classification Rating 94V-0
- Moisture Sensitivity: Level 1 per J-STD-020D
- Terminals: Finish - Bright Tin. Plated Leads Solderable per MIL-STD-202, Method 208
- Polarity: Cathode Band
- Mounting Position: Any
- Ordering Information: See Page 2
- Marking: Type Number
- Weight: 0.30 grams (approximate)



Dim	DO-41 Plastic Min	Max
A	25.40	—
B	4.06	5.21
C	0.71	0.864
D	2.00	2.72

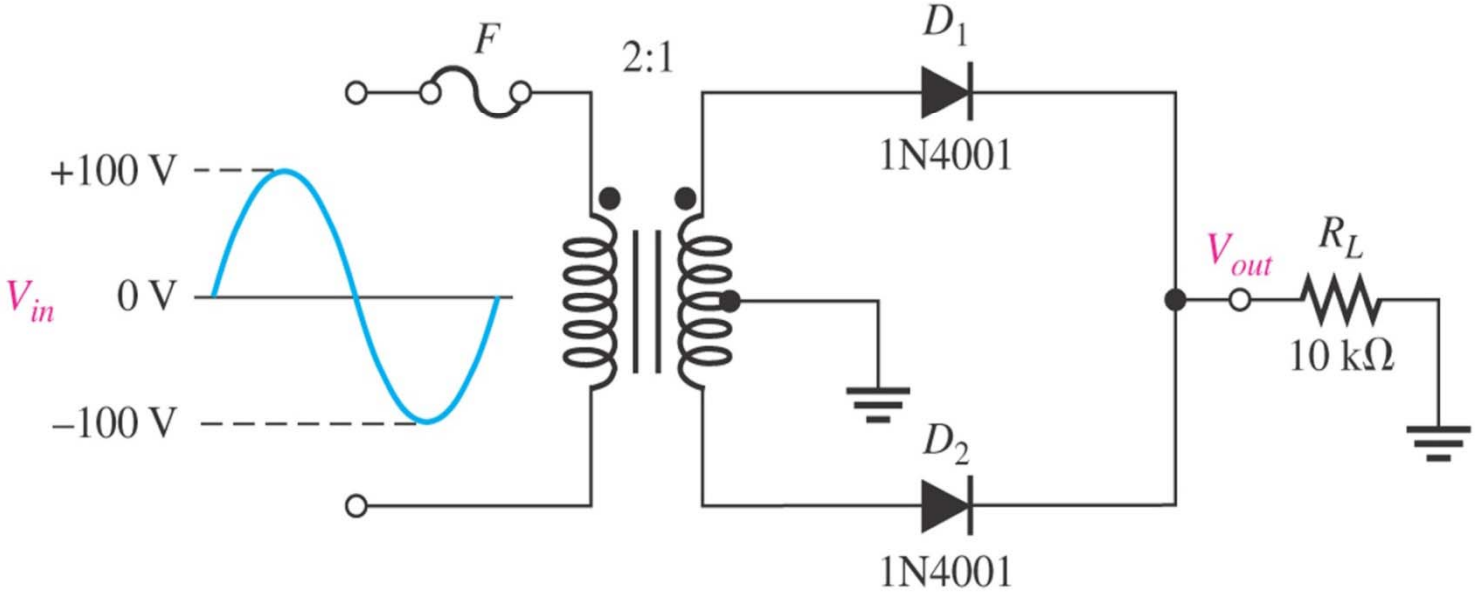
All Dimensions in mm

Maximum Ratings and Electrical Characteristics @T_A = 25°C unless otherwise specified

Single phase, half wave, 60Hz, resistive or inductive load.
For capacitive load, derate current by 20%.

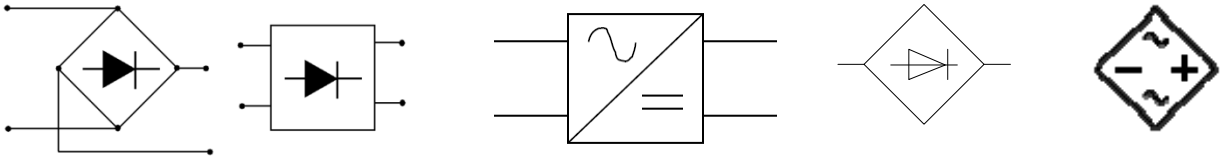
Characteristic	Symbol	1N4001	1N4002	1N4003	1N4004	1N4005	1N4006	1N4007	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	V_{RRM} V_{RWM} V_R	50	100	200	400	600	800	1000	V
RMS Reverse Voltage	$V_{R(RMS)}$	35	70	140	280	420	560	700	V
Average Rectified Output Current (Note 1) @ T_A = 75°C	I_O	1.0							A
Non-Repetitive Peak Forward Surge Current 8.3ms single half sine-wave superimposed on rated load	I_{FSM}	30							A
Forward Voltage @ I_F = 1.0A	V_{FM}	1.0							V
Peak Reverse Current @T_A = 25°C at Rated DC Blocking Voltage @ T_A = 100°C	I_{RM}	5.0 50							μA
Typical Junction Capacitance (Note 2)	C_j	15				8			pF
Typical Thermal Resistance Junction to Ambient	$R_{\theta JA}$	100							K/W
Maximum DC Blocking Voltage Temperature	T_A	+150							°C
Operating and Storage Temperature Range	T_J, T_{STG}	-65 to +150							°C

Homework



Classification

- Rectification is a process used to convert alternating current(ac) signal to direct current(dc) signal. Rectifiers are widely used as a first stage interfacing circuit in electrical and electronics devices particularly when the dc signal is required i.e. power supplies, battery charger, dc motor drive inverters, etc.
- 2 types: uncontrolled rectifier(diode) and controlled rectifier(phase control device, i.e. thyristors)
- Considering at the output: 2 types are half-wave and full-wave rectifiers
- Basic Symbol:

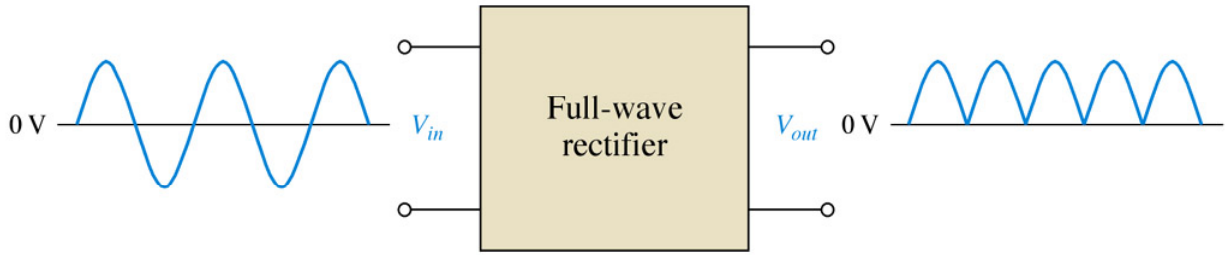


Note. Replace diode with SCRs symbol for controlled rectifier

Full-wave Rectifier

A full-wave rectifier allows current to flow during both the positive and negative half cycles or the full 360º. Note that the output frequency is twice the input frequency.

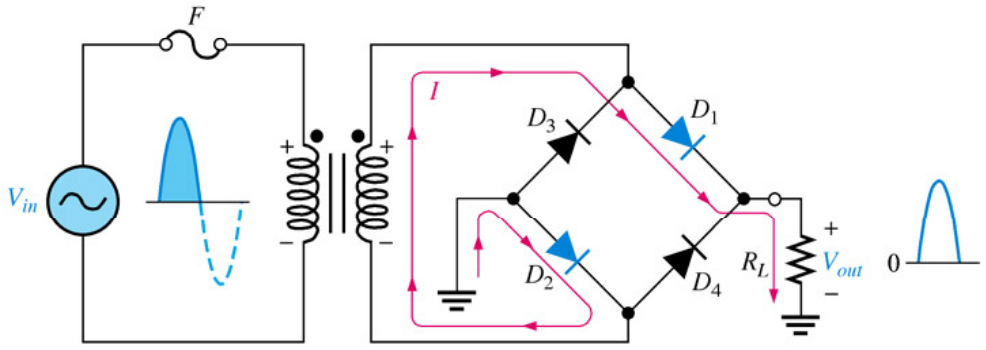
The average V_{DC} or $V_{AVG} = 2V_p/\pi$.



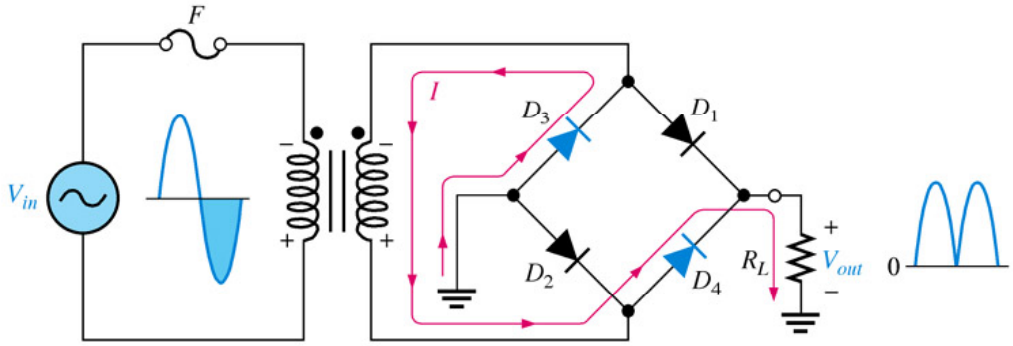
The Full-Wave Bridge Rectifier

The full-wave bridge rectifier takes advantage of the full output of the secondary winding.

It employs four diodes arranged such that current flows in the same direction through the load during each half of the cycle.

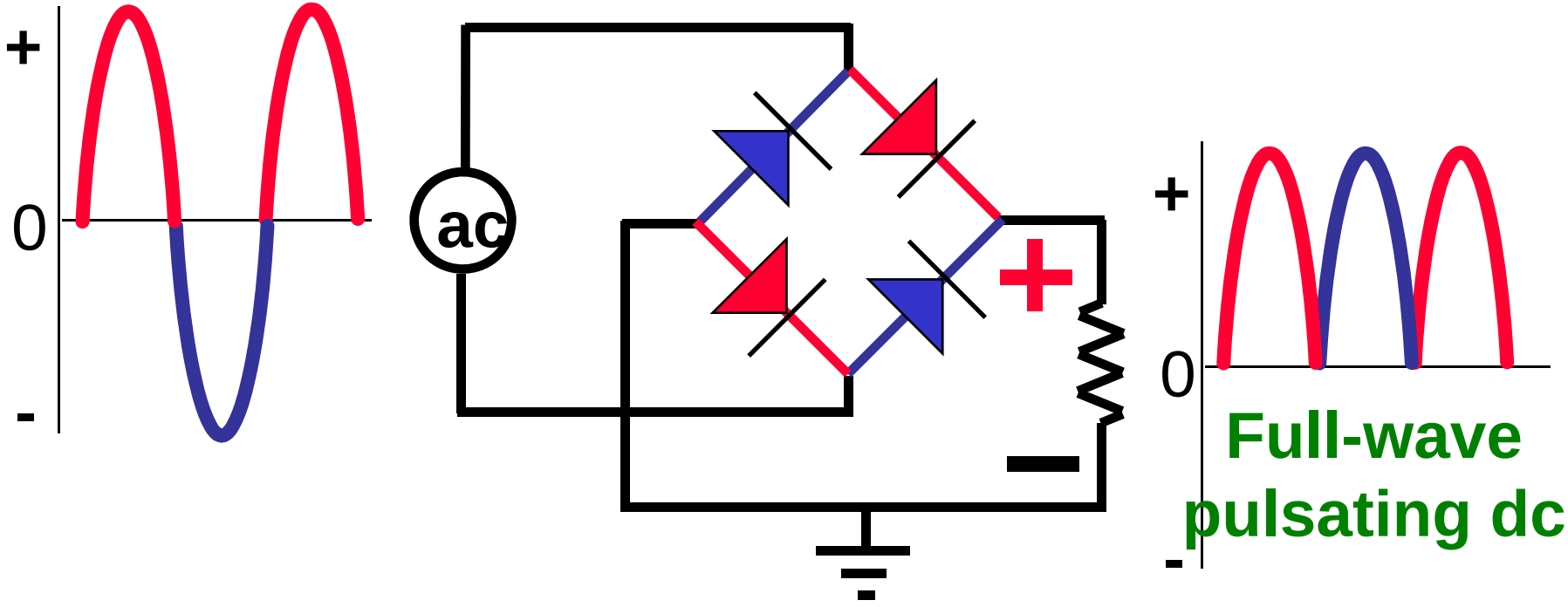


(a) During positive half-cycle of the input, D_1 and D_2 are forward-biased and conduct current. D_3 and D_4 are reverse-biased.

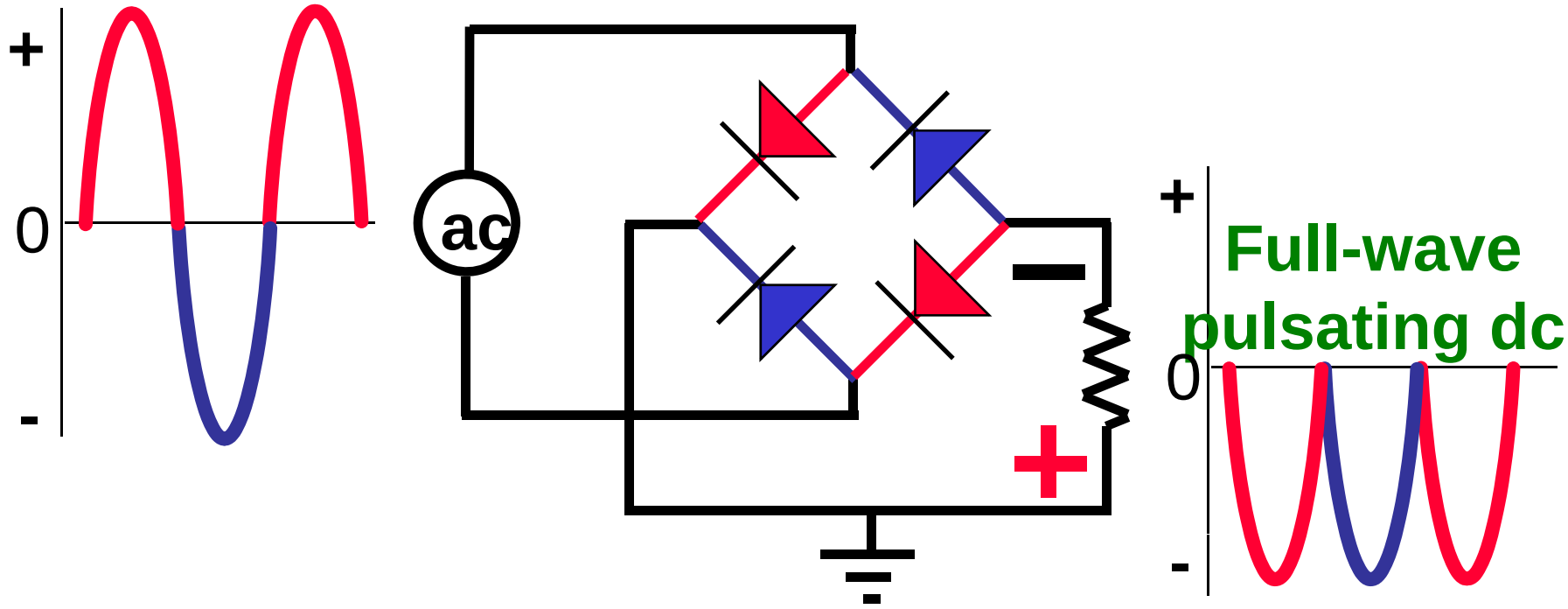


(b) During negative half-cycle of the input, D_3 and D_4 are forward-biased and conduct current. D_1 and D_2 are reverse-biased.

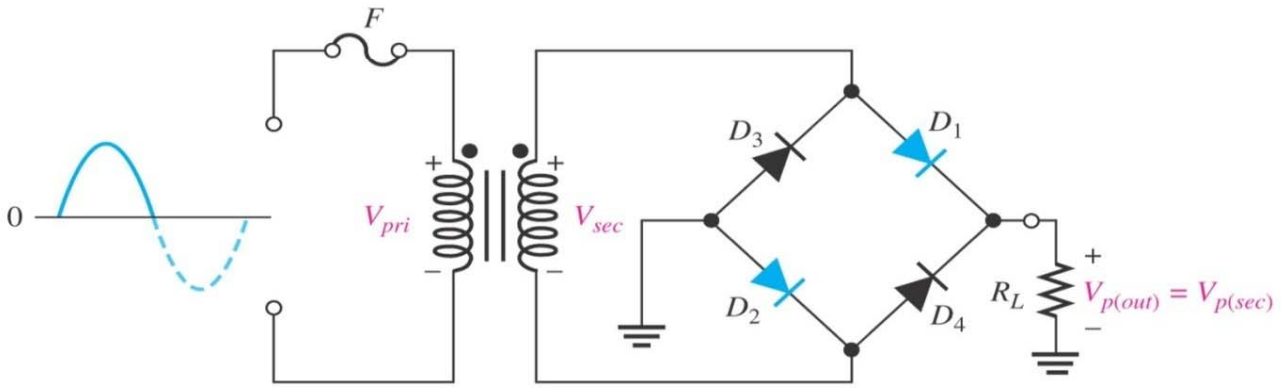
Positive Vout



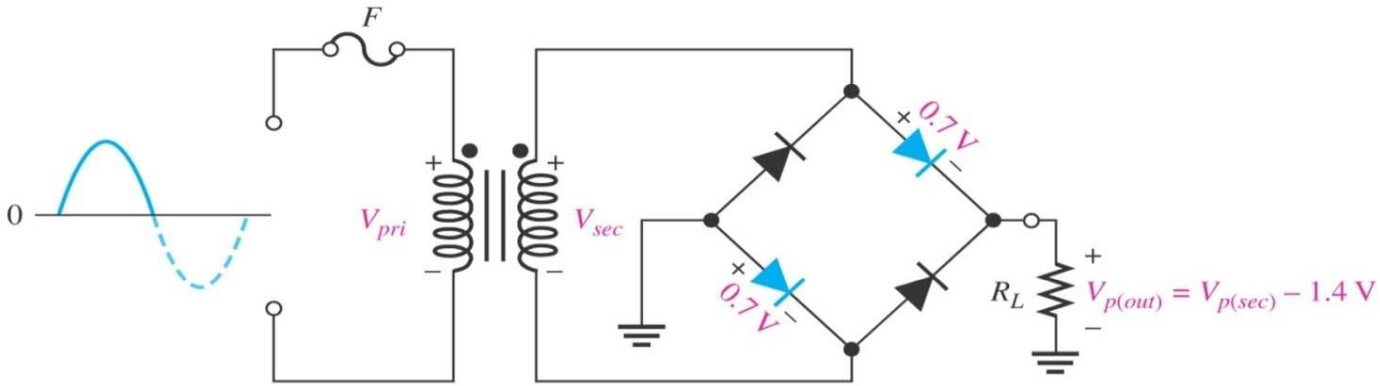
Negative Vout



Reversing the diodes produces a negative power supply.

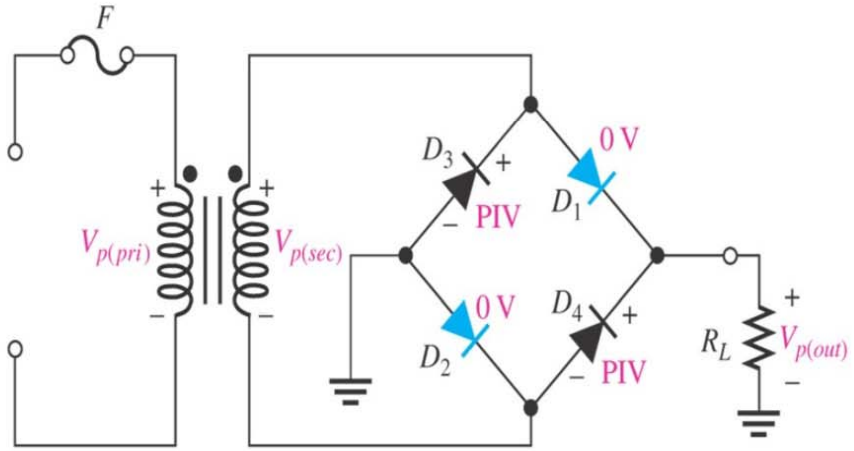


(a) Ideal diodes

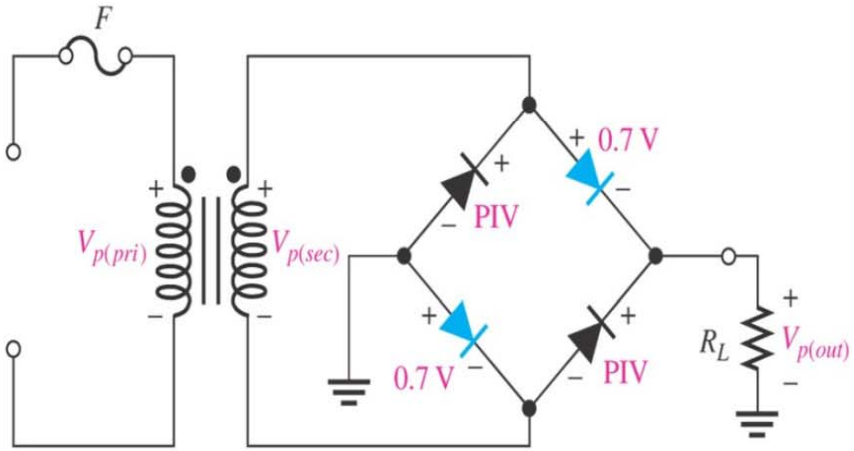


(b) Practical diodes (Diode drops included)

PIV for full-wave rectifier



(a) For the ideal diode model (forward-biased diodes D_1 and D_2 are shown in blue), PIV = $V_{p(out)}$.

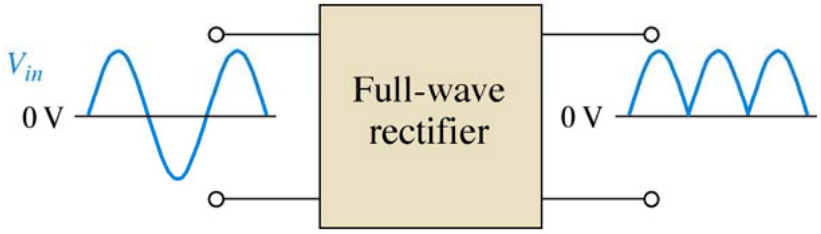


(b) For the practical diode model (forward-biased diodes D_1 and D_2 are shown in blue), PIV = $V_{p(out)}$ + 0.7 V.

KVL here

Power Supply Filters And Regulators

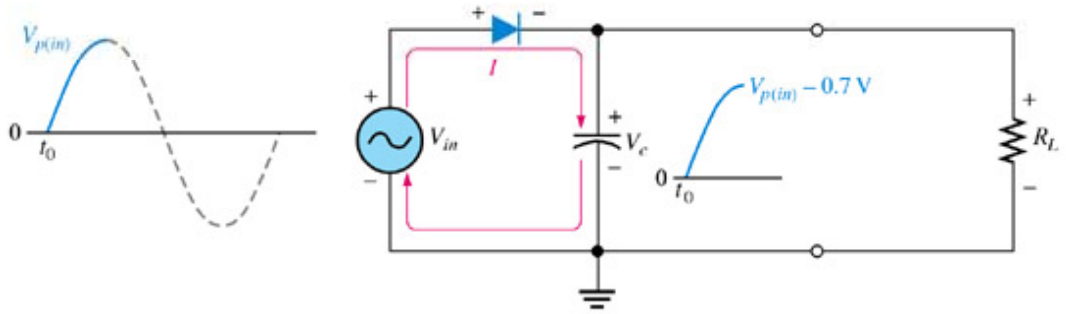
As we have seen, the output of a rectifier is a pulsating DC. With filtration and regulation this pulsating voltage can be smoothed out and kept to a steady value.



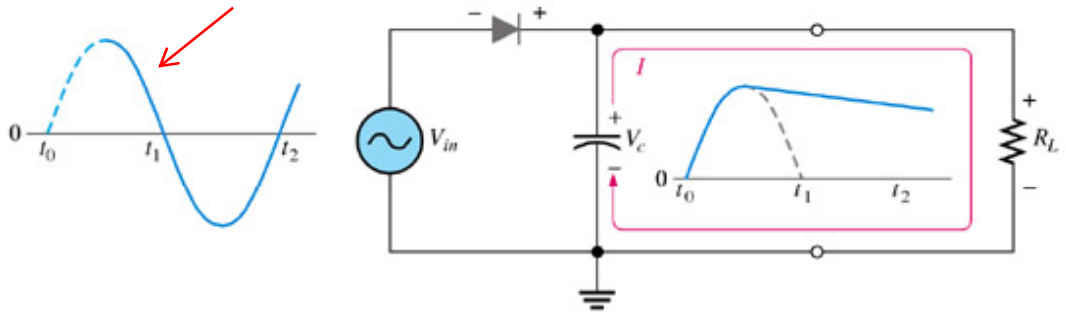
(a) Rectifier without a filter

(b) Rectifier with a filter (output ripple is exaggerated)

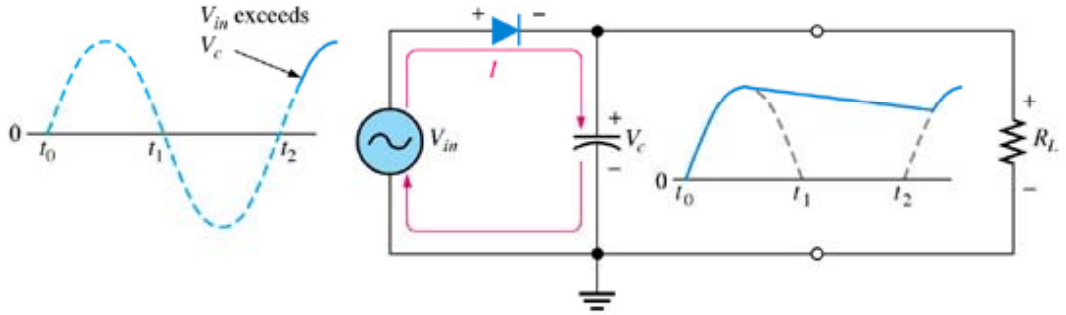
A capacitor-input filter will charge and discharge such that it fills in the “gaps” between each peak. This reduces variations of voltage. The remaining voltage variation is called ripple voltage.



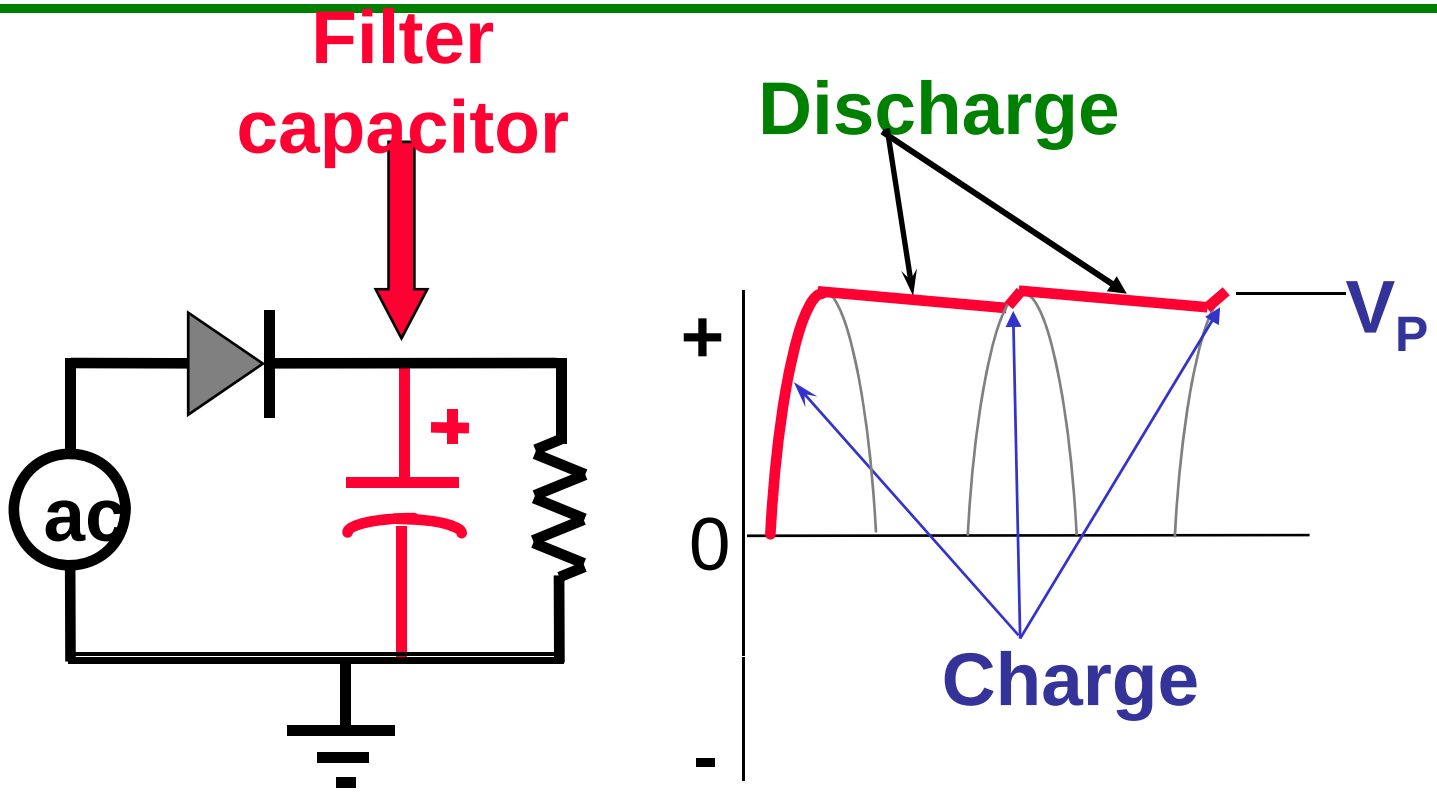
(a) Initial charging of capacitor (diode is forward-biased) happens only once when power is turned on.



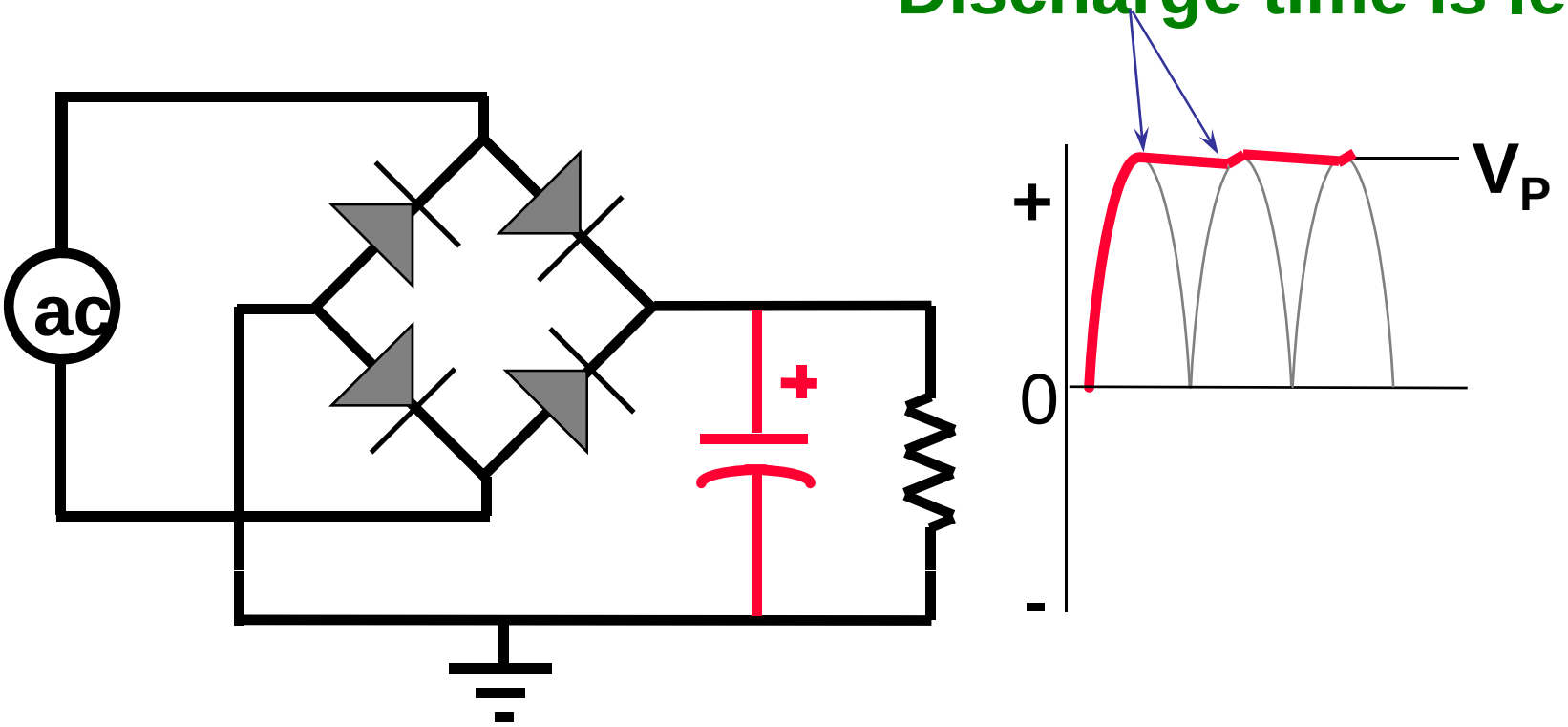
(b) The capacitor discharges through R_L after peak of positive alternation when the diode is reverse-biased. This discharging occurs during the portion of the input voltage indicated by the solid blue curve.



(c) The capacitor charges back to peak of input when the diode becomes forward-biased. This charging occurs during the portion of the input voltage indicated by the solid blue curve.

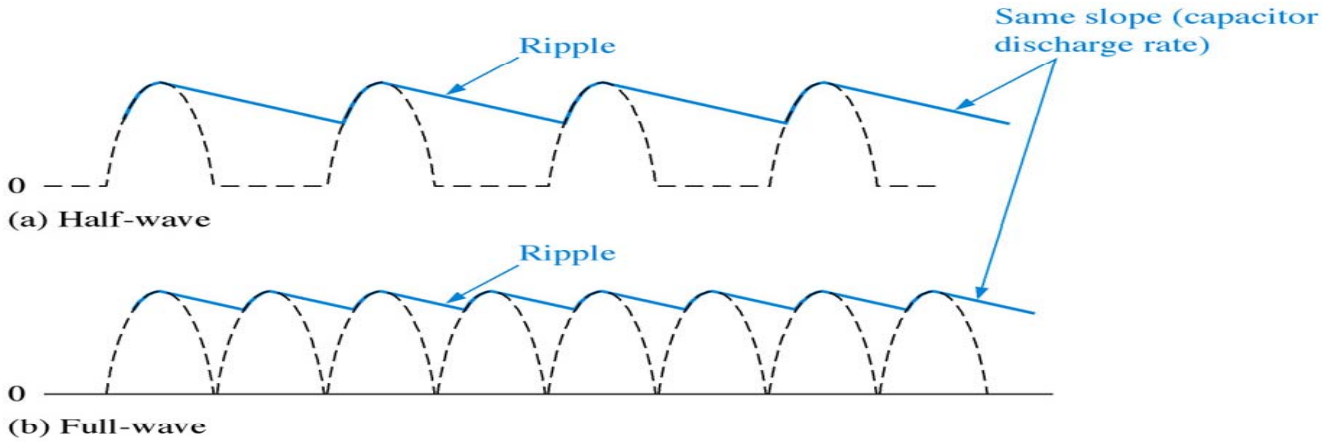


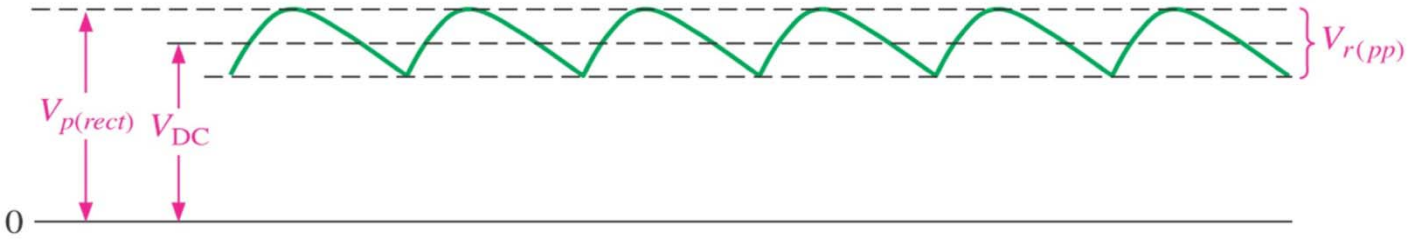
A relatively large filter capacitor will maintain the load voltage near the peak value of the waveform.



Full-wave is easier to filter since the discharge time is shorter than it is for half-wave rectifiers.

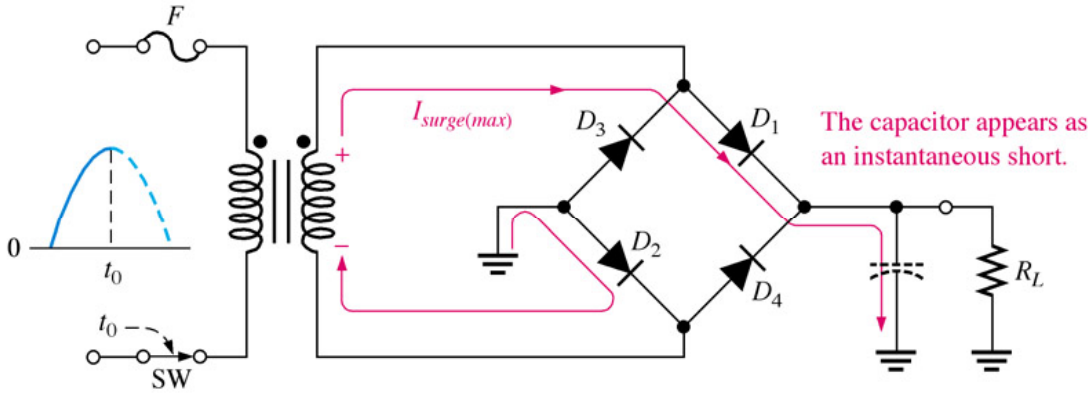
The advantage of a full-wave rectifier over a half-wave is quite clear. The capacitor can more effectively reduce the ripple when the time between peaks is shorter.



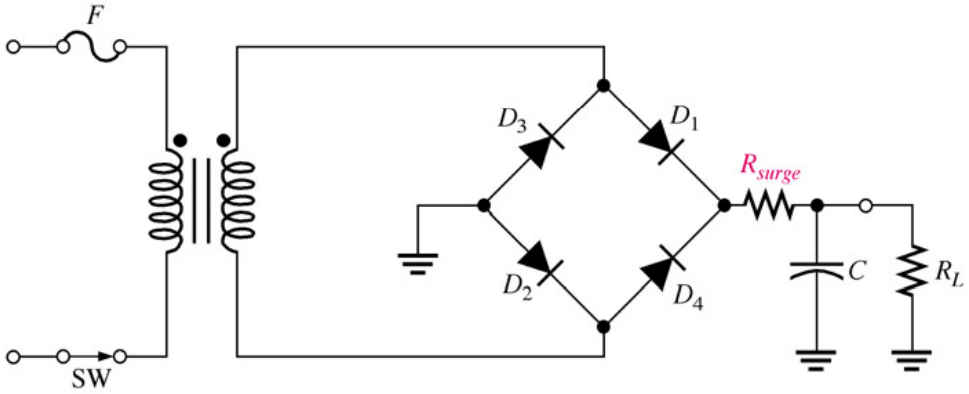


Protection

Being that the capacitor appears as a short during the initial charging, the current through the diodes can momentarily be quite high. To reduce risk of damaging the diodes, a surge current limiting resistor is placed in series with the filter and load.

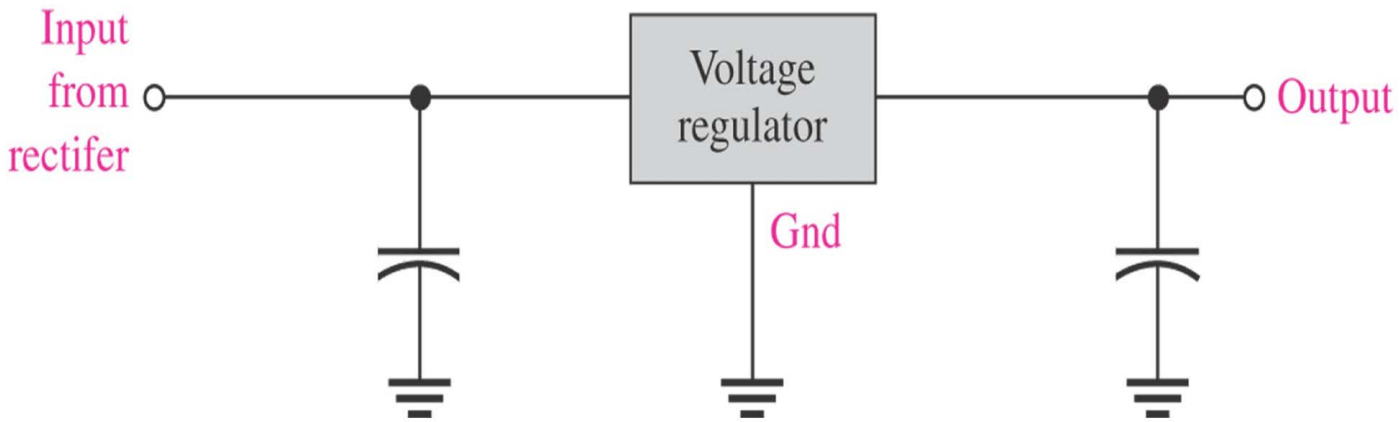


(a) Maximum surge current occurs when switch is closed at peak of an input cycle.



(b) A series resistor (R_{surge}) limits the surge current.

Voltage Regulator

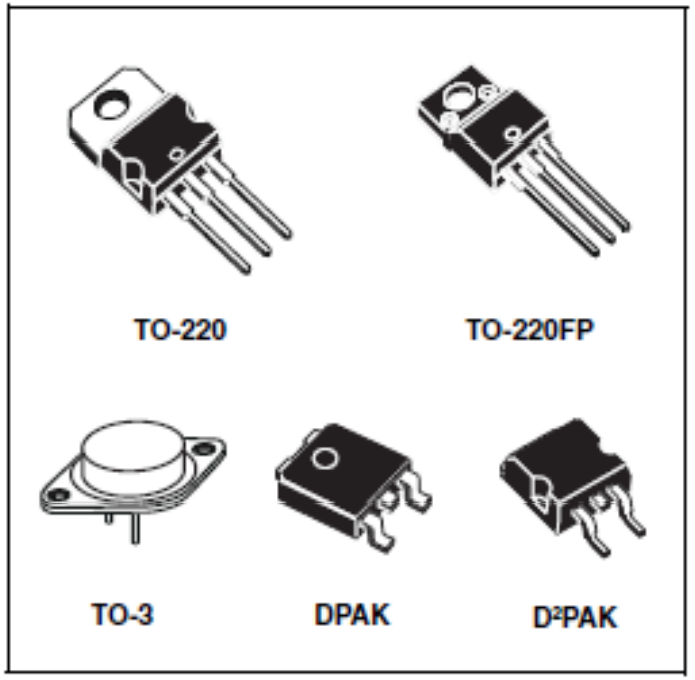


L78xx
L78xxC

Positive voltage regulators

Features

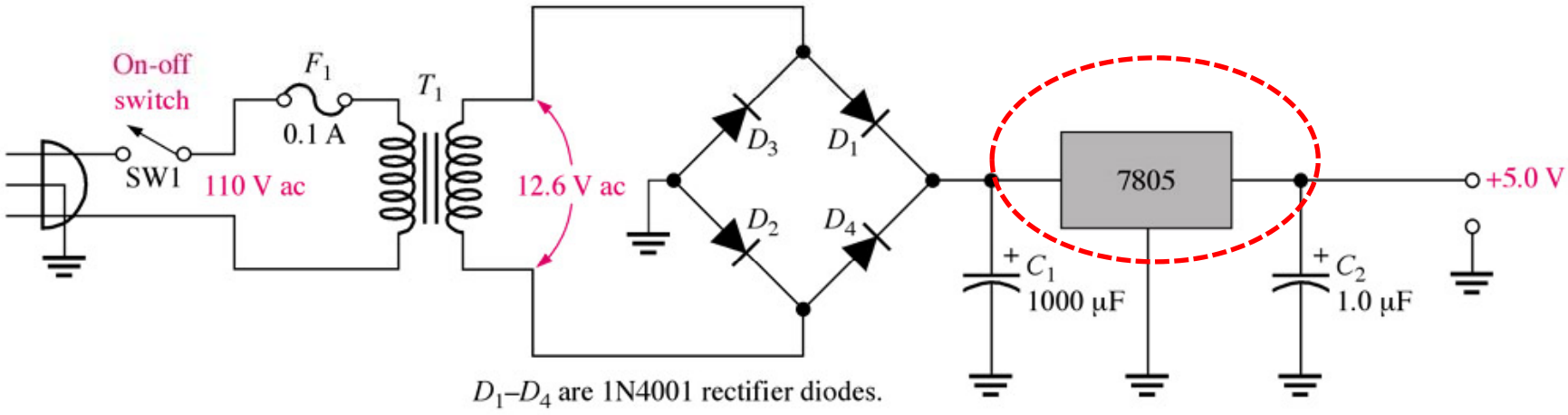
- Output current to 1.5 A
- Output voltages of 5; 6; 8; 8.5; 9; 12; 15; 18; 24 V
- Thermal overload protection
- Short circuit protection
- Output transition SOA protection



Description

The L78xx series of three-terminal positive regulators is available in TO-220, TO-220FP, TO-3, D^2PAK and DPAK packages and several fixed output voltages, making it useful in a wide range of applications. These regulators can provide local on-card regulation, eliminating the distribution problems associated with single point regulation. Each type employs internal current limiting, thermal shut-down and safe area protection, making it essentially indestructible. If adequate heat sinking is provided, they can deliver over 1 A output current. Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable voltage and currents.

Regulation is the last step in eliminating the remaining ripple and maintaining the output voltage to a specific value. Typically this regulation is performed by an integrated circuit regulator. There are many different types used based on the voltage and current requirements.



Regulator Efficiency

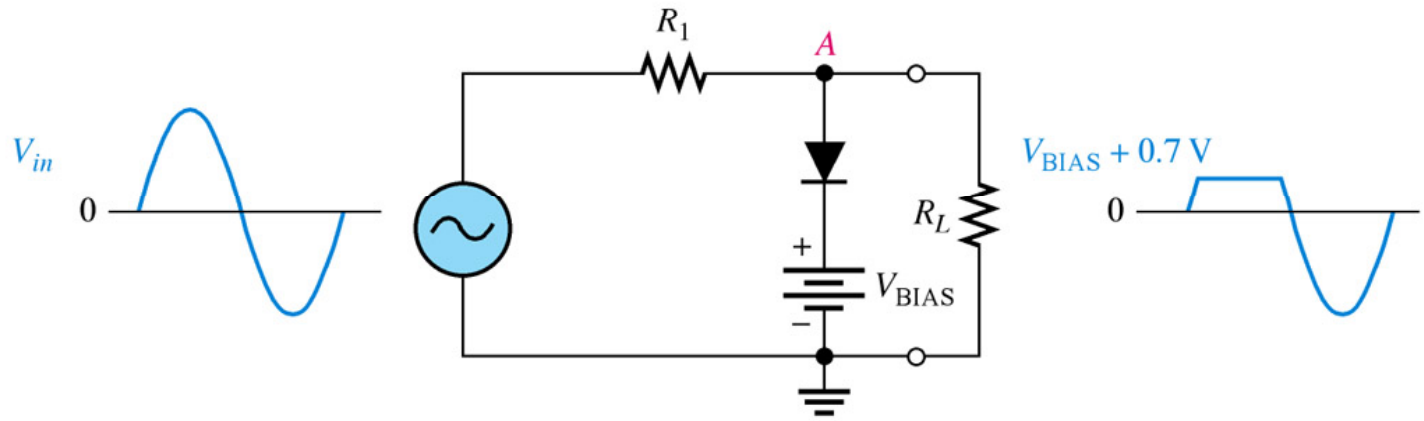
How well the regulation is performed by a regulator is measured by it's regulation percentage. There are two types of regulation, line and load. Line and load regulation percentage is simply a ratio of change in voltage (line) or current (load) stated as a percentage.

$$\textbf{\textit{Line Regulation} = } (\Delta V_{OUT}/\Delta V_{IN})100\%$$

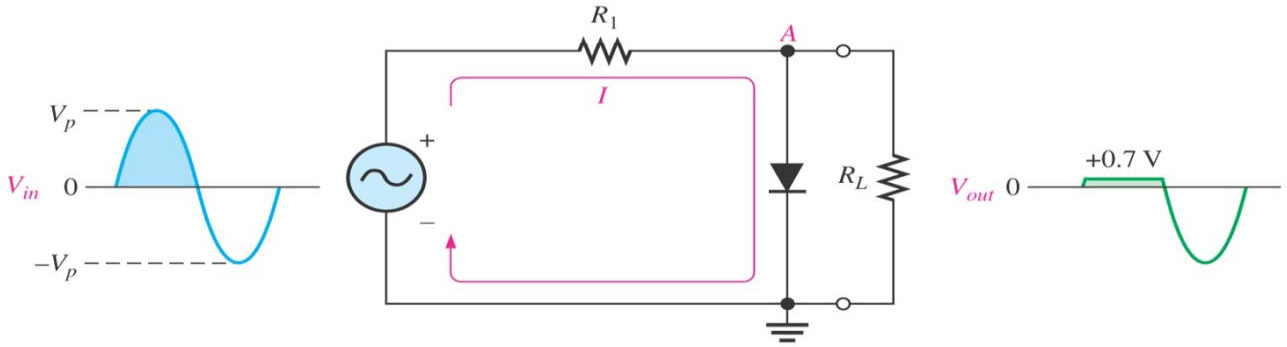
$$\textbf{\textit{Load Regulation} = } (V_{NL} - V_{FL})/V_{FL})100\%$$

Diode Limiter(Clippers)

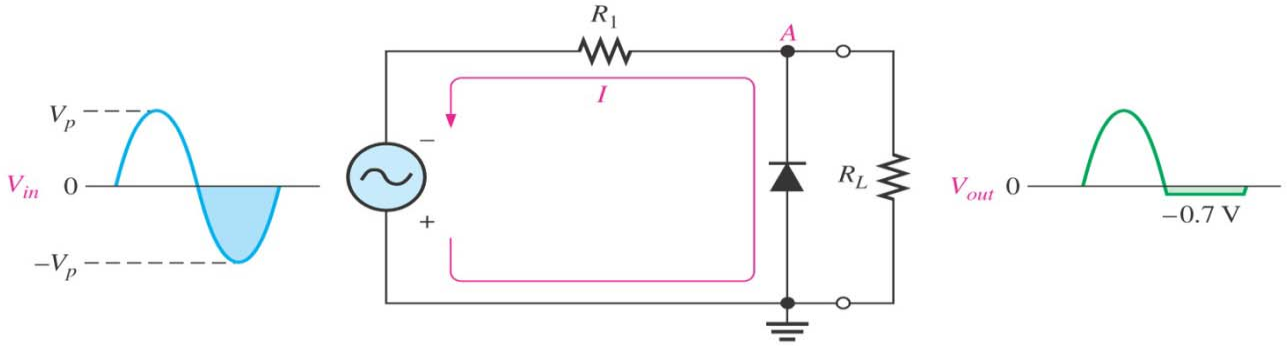
Limiting circuits limit the positive or negative amount of an input voltage to a specific value.



This positive limiter will limit the output to V_{BIAS} + .7V

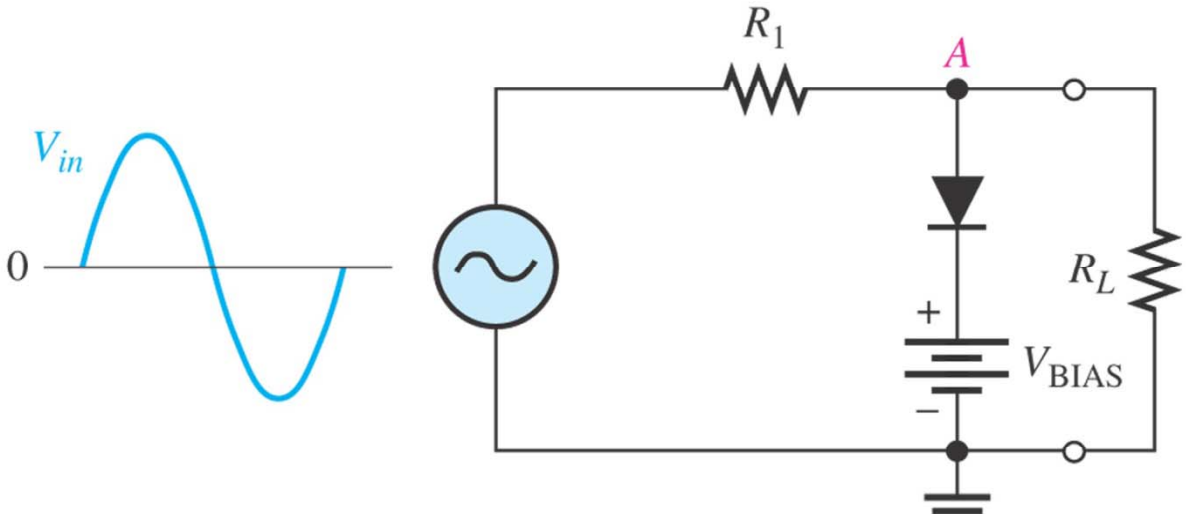


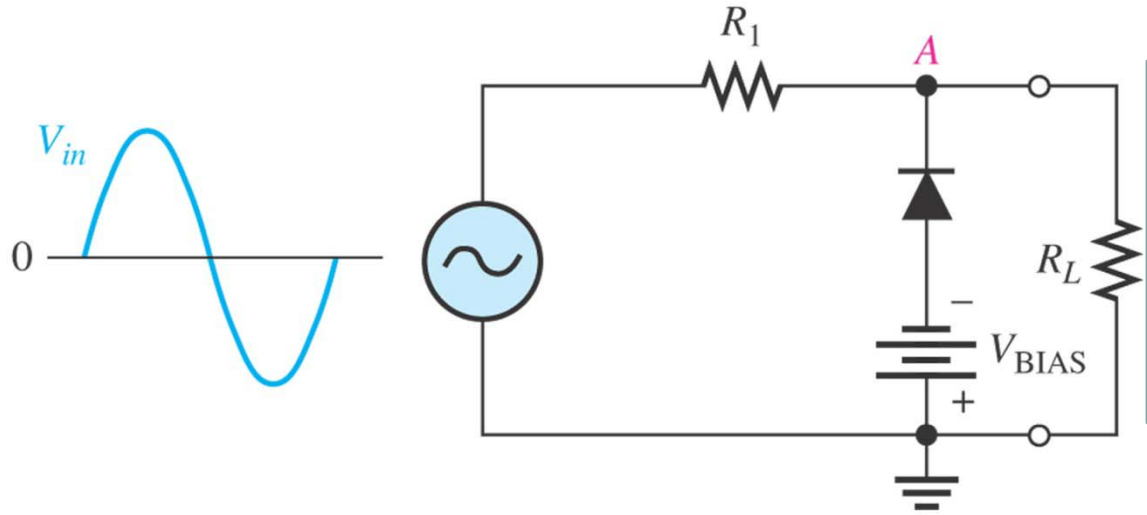
(a) Limiting of the positive alternation. The diode is forward-biased during the positive alternation (above 0.7 V) and reverse-biased during the negative alternation.



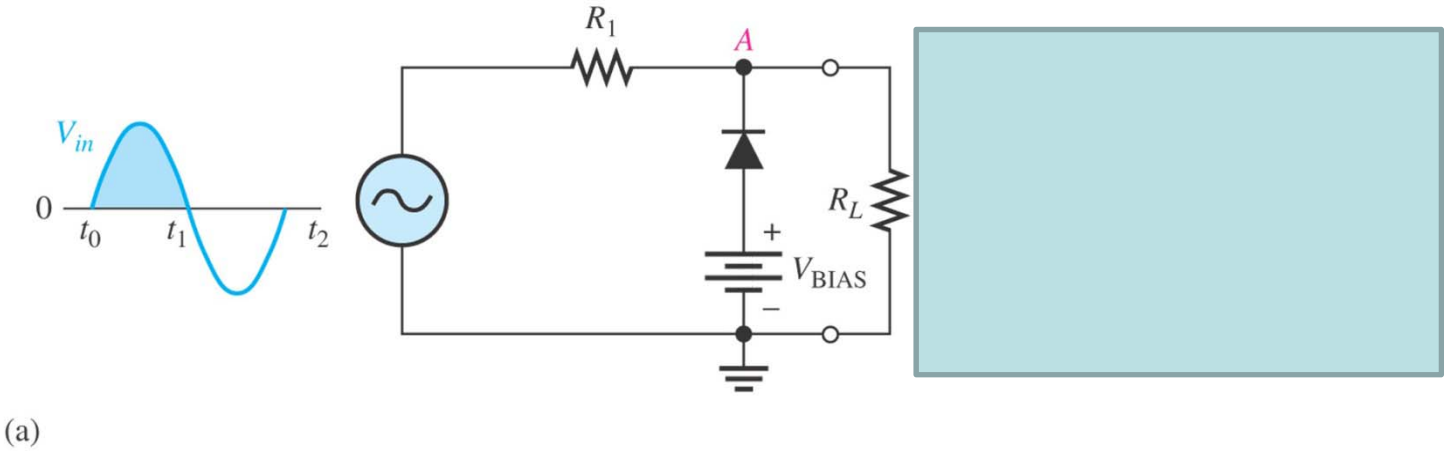
(b) Limiting of the negative alternation. The diode is forward-biased during the negative alternation (below −0.7 V) and reverse-biased during the positive alternation.

Positive and Negative Limiter

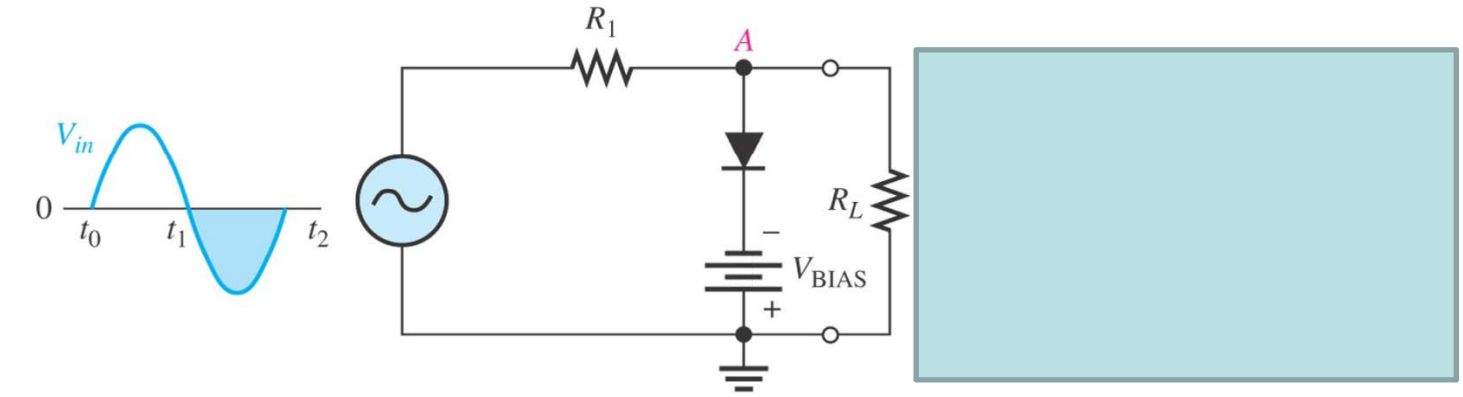




Example1

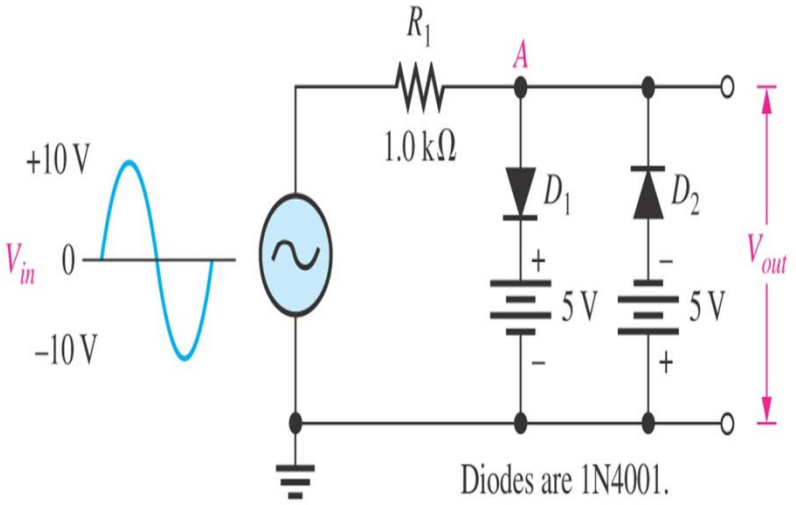


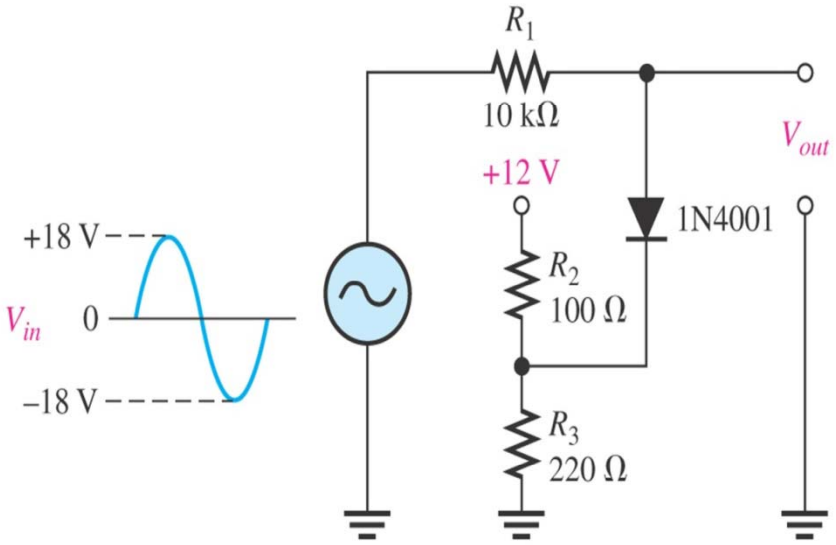
(a)



(b)

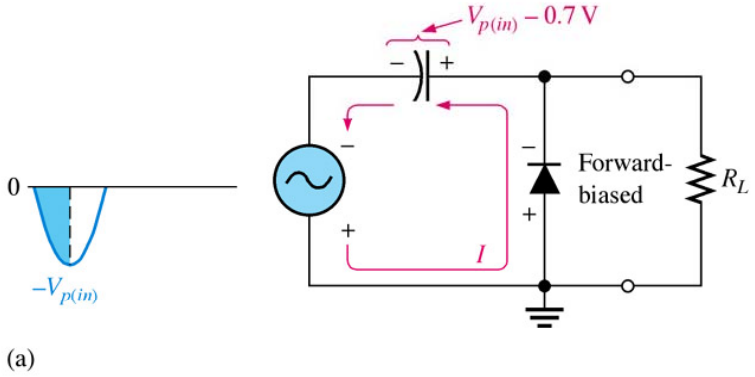
Example2

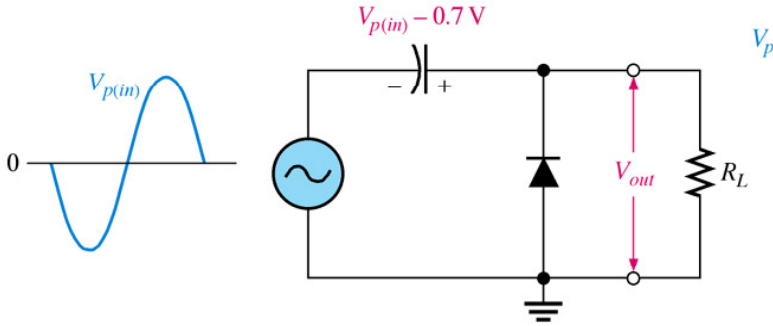


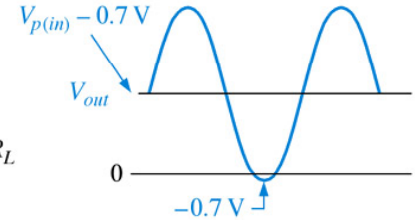

R_1
10 kΩ
V_{out}
+12 V
1N4001
+18 V
V_{in}
0
–18 V
R_2
100 Ω
R_3
220 Ω

Diode Clamper

A diode clamper adds a DC level to an AC voltage. The capacitor charges to the peak of the supply minus the diode drop. Once charged, the capacitor acts like a battery in series with the input voltage. The AC voltage will “ride” along with the DC voltage. The polarity arrangement of the diode determines whether the DC voltage is negative or positive.





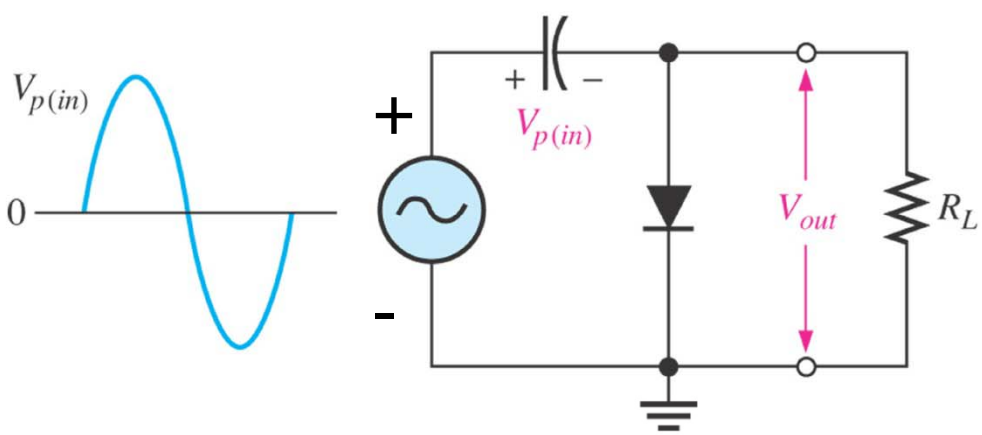


Positive Clamper

$$+V_{p(in)}-V_c-0.7=0$$

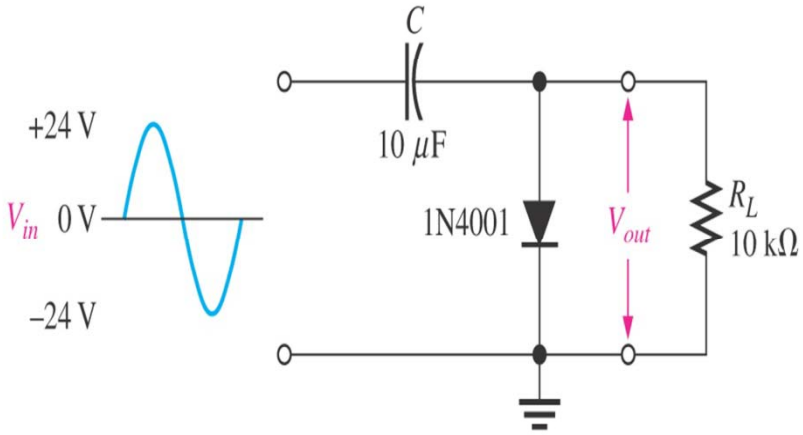
Hint: Find voltage across C first. This will be a voltage shift level.

Negative Clamper



$$-V_{p(in)}-V_c+0.7=0$$

Example

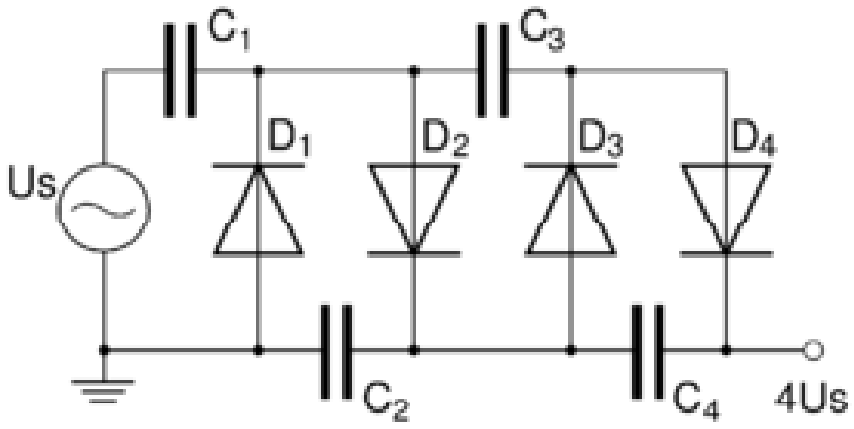


Voltage Multiplier

A **voltage multiplier** is an electrical circuit that converts AC electrical power from a lower voltage to a higher DC voltage, typically by means of a network of capacitors and diodes.

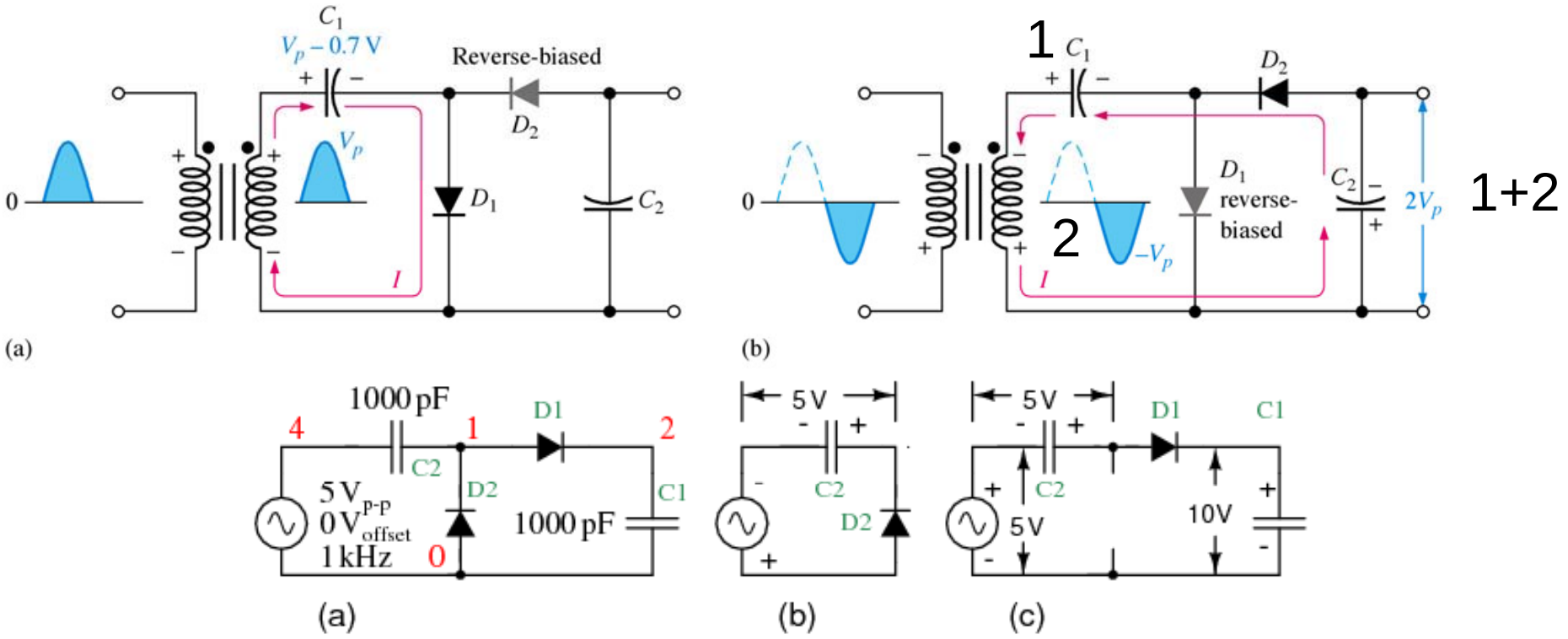
Voltage multipliers can be used to generate bias voltages ranging from a few volts for electronic appliances, to millions of volts for purposes such as high-energy physics experiments and lightning safety testing.

The most common type of voltage multiplier is the half-wave series multiplier, also called the Villard cascade.



Operation

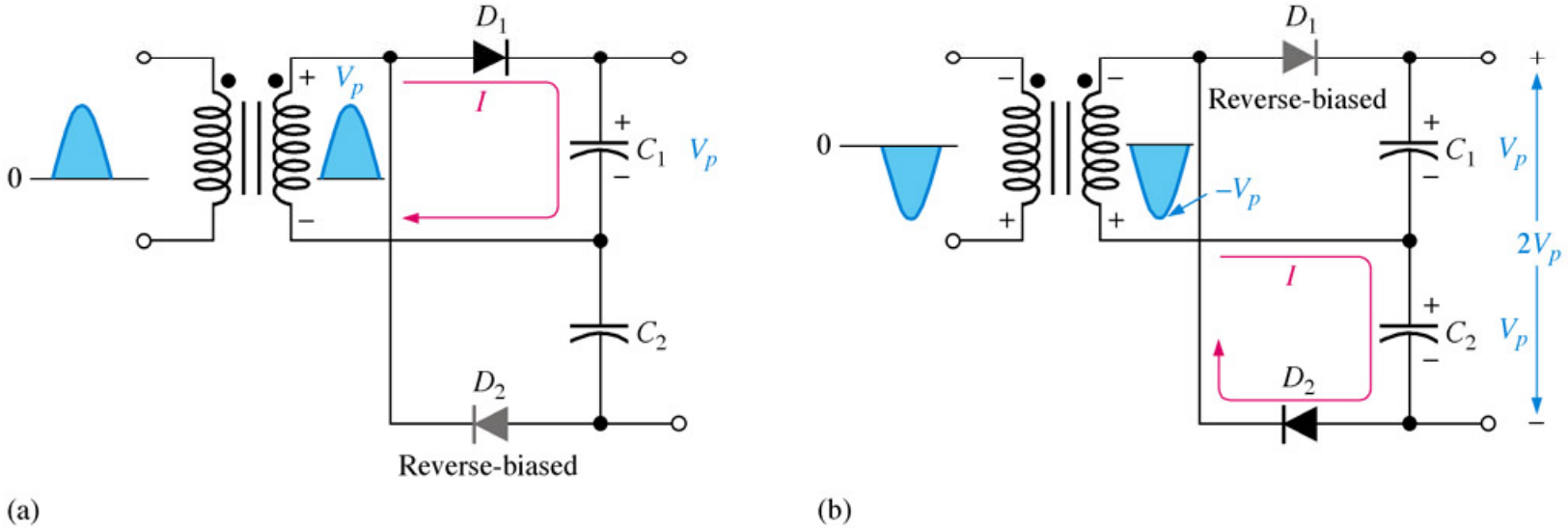
Clamping action can be used to increase peak rectified voltage. Once C_1 and C_2 charges to the peak voltage they act like two batteries in series, effectively doubling the voltage output. The current capacity for voltage multipliers is low.



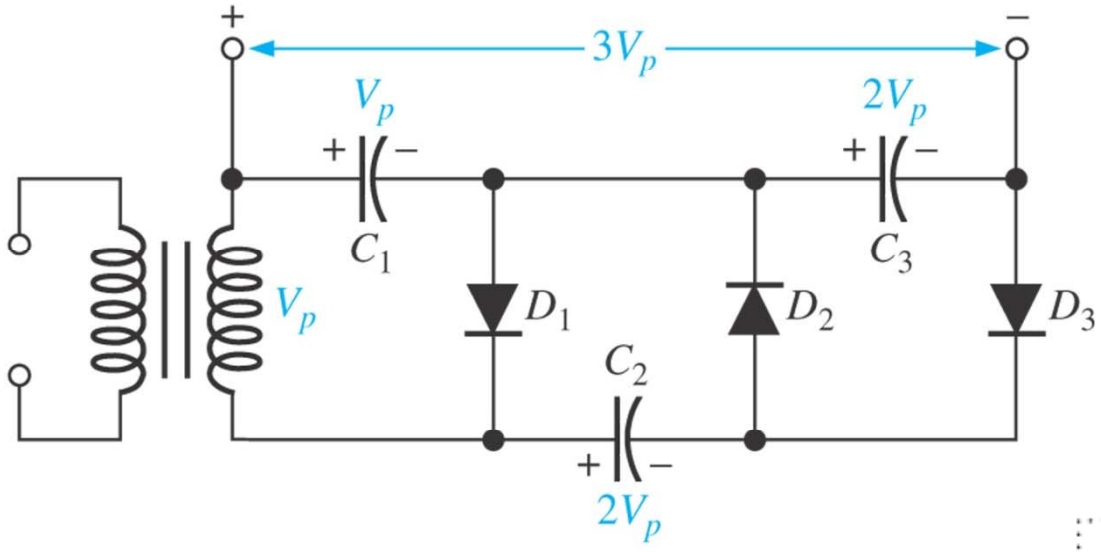
Half-wave voltage doubler (a) is composed of (b) a clamper and (c) a half-wave rectifier.

Full-wave Voltage Multiplier

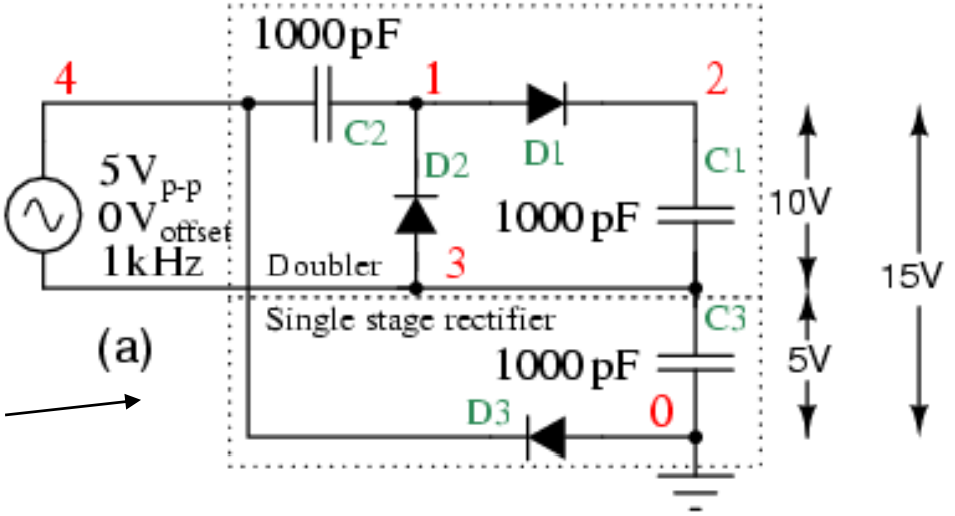
The full-wave voltage doubler arrangement of diodes and capacitors takes advantage of both positive and negative peaks to charge the capacitors giving it more current capacity. Voltage triplers and quadruplers utilize three and four diode-capacitor arrangements respectively.



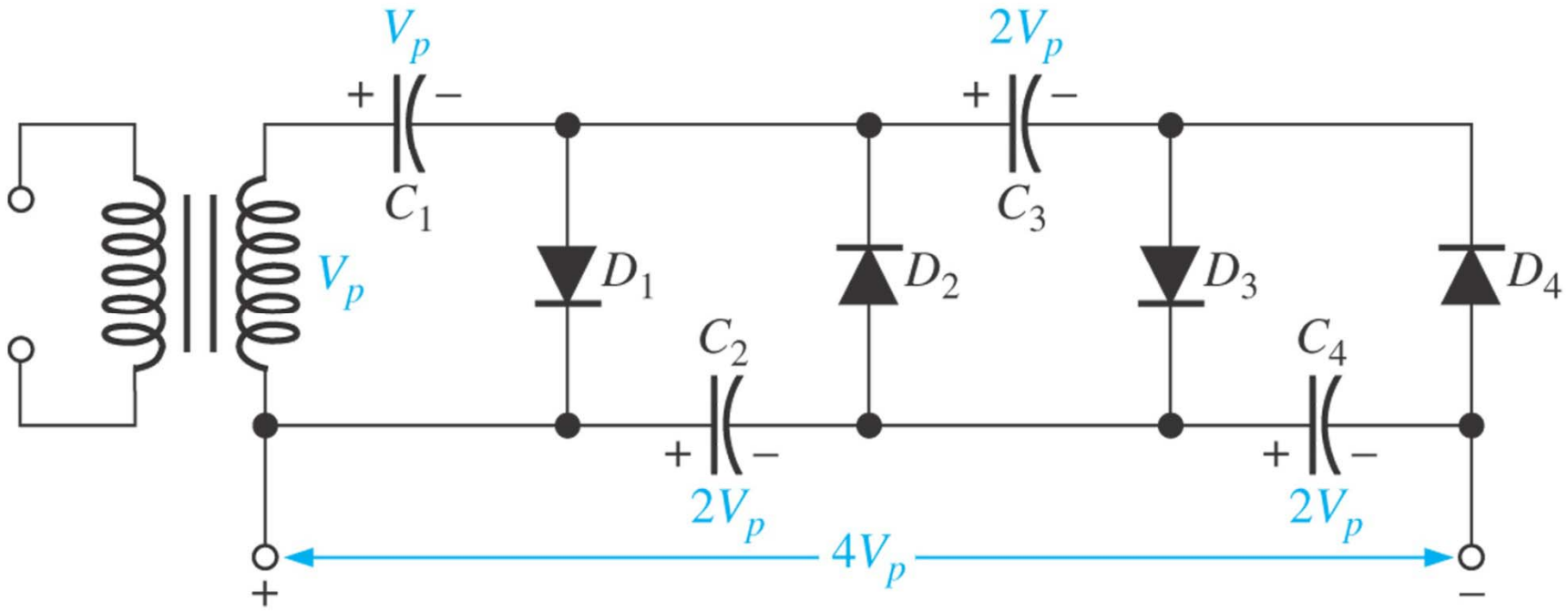
Voltage tripler



A combination of a doubler and a half wave rectifier (C3, D3). The half-wave rectifier produces 5 V (4.3 V) at node 3. The doubler provides another 10 V (8.4 V) between nodes 2 and 3. for a total of 15 V (12.9 V) at the output node 2 with respect to ground.



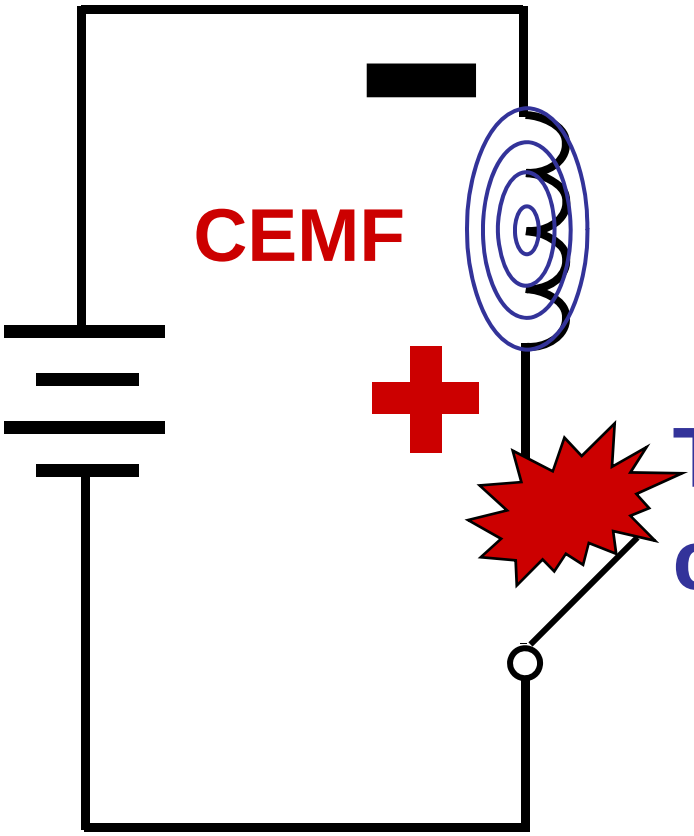
Voltage Quadrupler



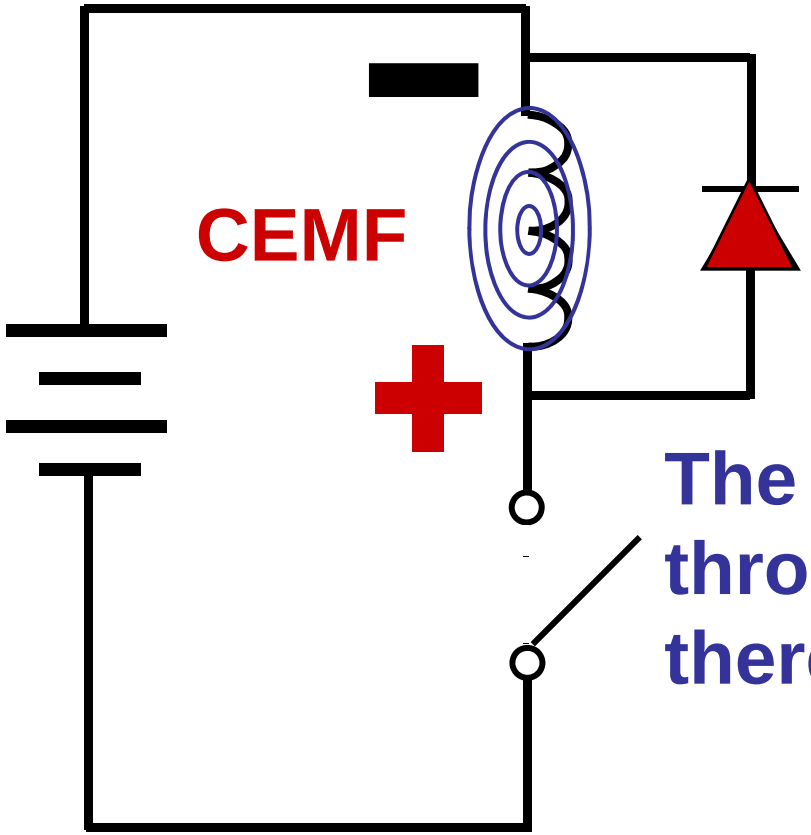
Rectifier Diode Selection

- Average forward current (I_o)
- Reverse blocking voltage
- Transient capability; peak, surge current and voltage

Transient Suppression



The inductive kick can cause damage.



The coil discharges through the diode and there is no arc.

Summary(1)

- The basic function of a power supply to give us a smooth ripple free DC voltage from an AC voltage.
- Half-wave rectifiers only utilize half of the cycle to produce a DC voltage.
- Transformer Coupling allows voltage manipulation through its windings ratio.
- Full-Wave rectifiers efficiently make use of the whole cycle. This makes it easier to filter.
- The full-wave bridge rectifier allows use of the full secondary winding output whereas the center-tapped full wave uses only half.

Summary(2)

- Filtering and Regulating the output of a rectifier helps keep the DC voltage smooth and accurate.
- Limiters are used to set the output peak(s) to a given value.
- Clampers are used to add a DC voltage to an AC voltage.
- Voltage Multipliers allow a doubling, tripling, or quadrupling of rectified DC voltage for low current applications.
- The Data Sheet gives us useful information and characteristics of device for use in replacement or designing circuits.
- Troubleshooting requires use of common sense along with proper troubleshooting techniques to effectively determine the point of failure in a defective circuit or system.