DIODES -03

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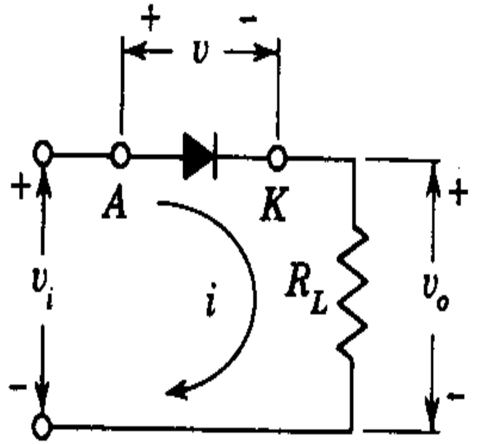
Electronics, PH3144
IISER-Pune

LOAD LINE

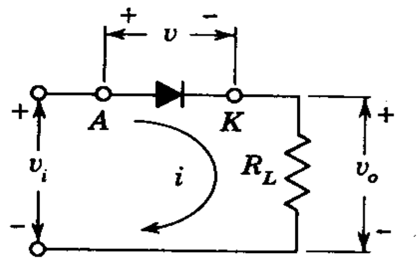


$$v = v_i - iR_L ; v_0 = iR_L$$

Fig. 4-1 The basic diode circuit. The anode (the *p* side) of the diode is marked *A*, and the cathode (the *n* side) is labeled *K*.

$$Diode\ \text{Characteristics} \Rightarrow i = i_0(e^{qv/kT} - 1)$$

DYNAMIC CHARACTERISTICS OUTPUT CURRENT VS INPUT



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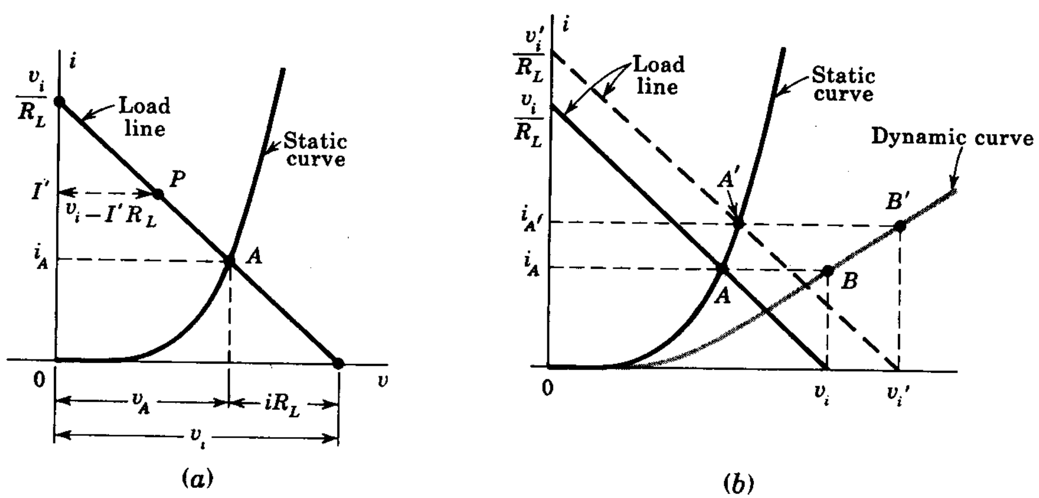


Fig. 4-2 (a) The intersection A of the load line with the diode static characteristic gives the current i_A corresponding to an instantaneous input voltage v_i. (b) The method of constructing the dynamic curve from the static curve and the load line.

Dynamic Characteristics

Plot of i *vs* v_{input}

TRANSFER CHARACTERISTICS OUTPUT VOLTAGE VS INPUT

$$v = v_i - iR_L ; v_0 = iR_L$$

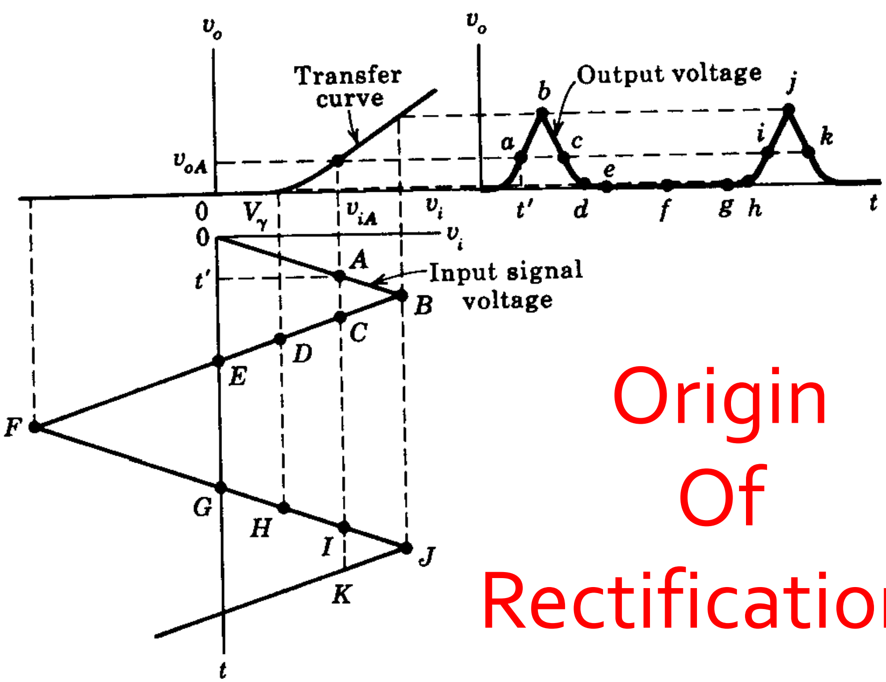


Fig. 4-3 The method of obtaining the output-voltage waveform from the transfer characteristic for a given input-signal-voltage waveform.

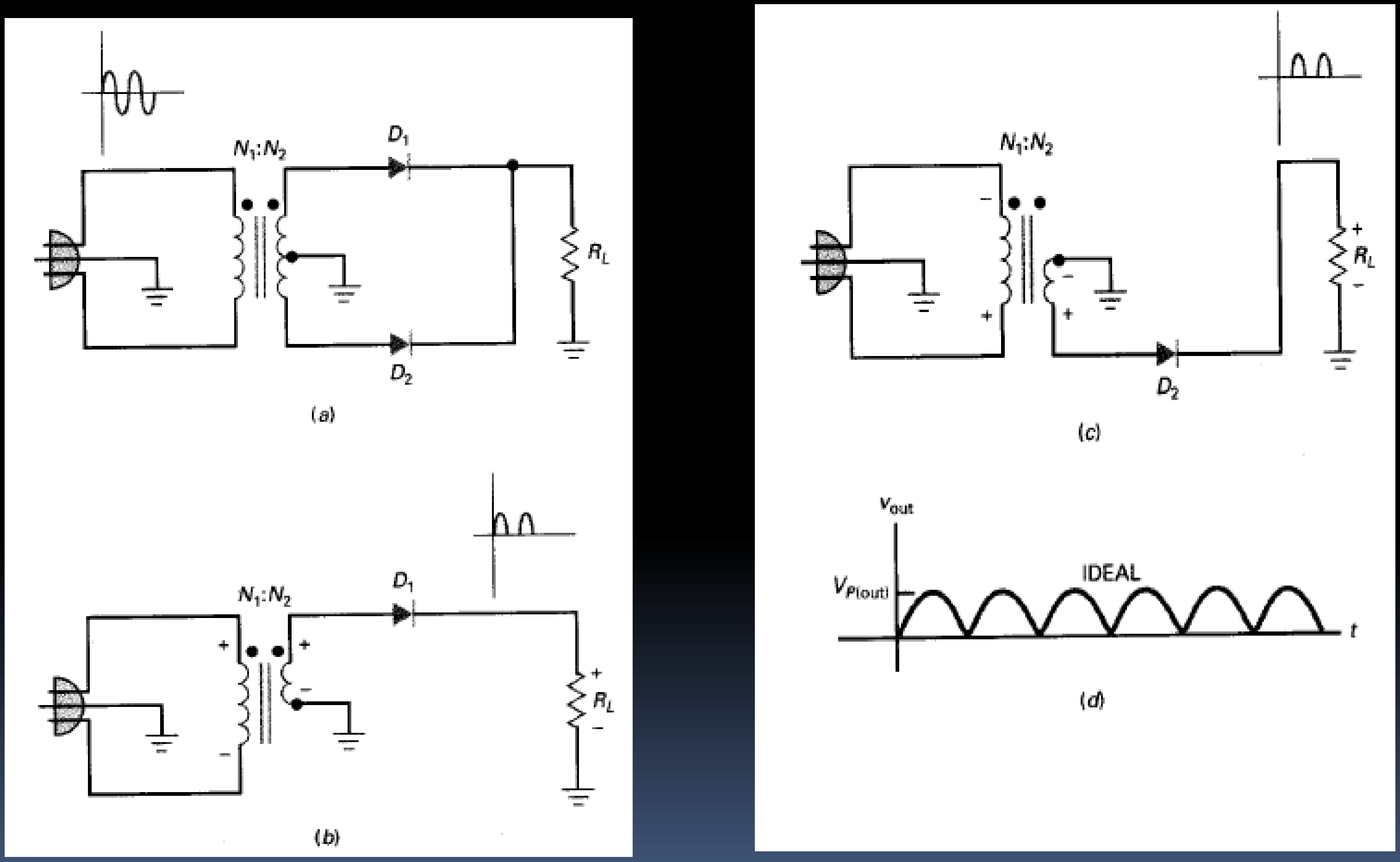
Origin Of Rectification !

$Transfer\,Characteristics$
$Plot\text{ of } v_{Output}\ vs\ v_{input}$

$Plot\text{ of } v_{Output}\ vs\ Time$

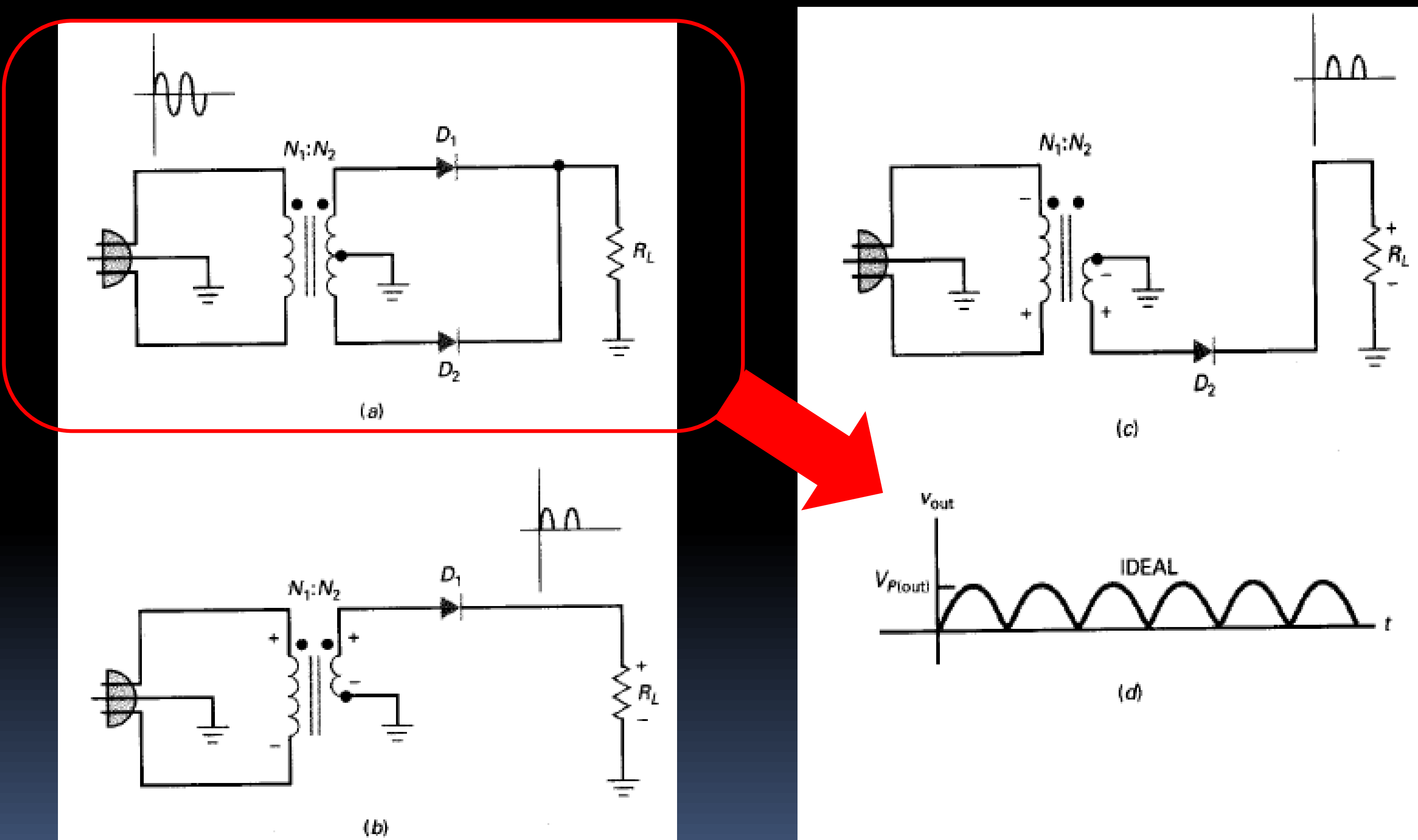
FULL WAVE RECTIFIER

Figure 4–6 (*a*) Full-wave rectifier; (*b*) equivalent circuit for positive half cycle; (*c*) equivalent circuit for negative half cycle; (*d*) full-wave output.



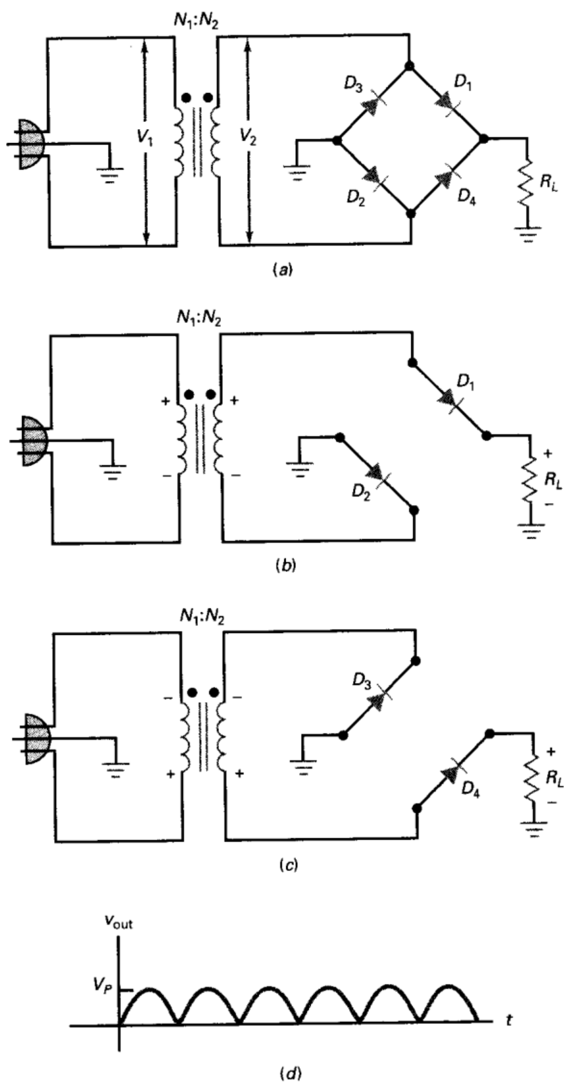
FULL WAVE RECTIFIER

Figure 4–6 (*a*) Full-wave rectifier; (*b*) equivalent circuit for positive half cycle; (*c*) equivalent circuit for negative half cycle; (*d*) full-wave output.



FULL WAVE RECTIFIER

Figure 4-8 (*a*) Bridge rectifier; (*b*) equivalent circuit for positive half cycle; (*c*) equivalent circuit for negative half cycle; (*d*) full-wave output; (*e*) bridge rectifier packages.

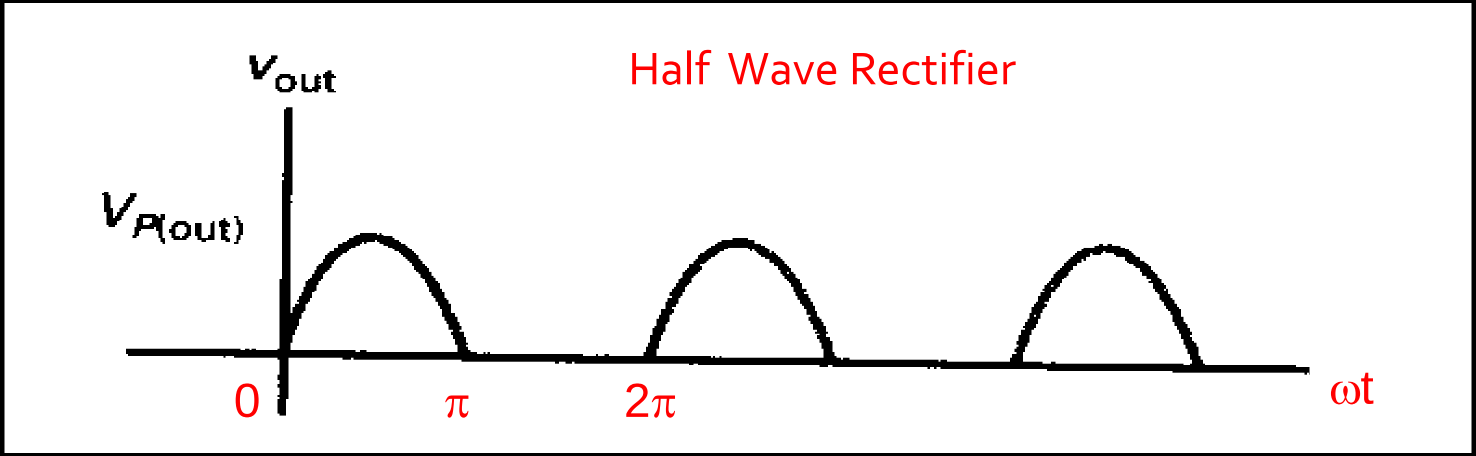


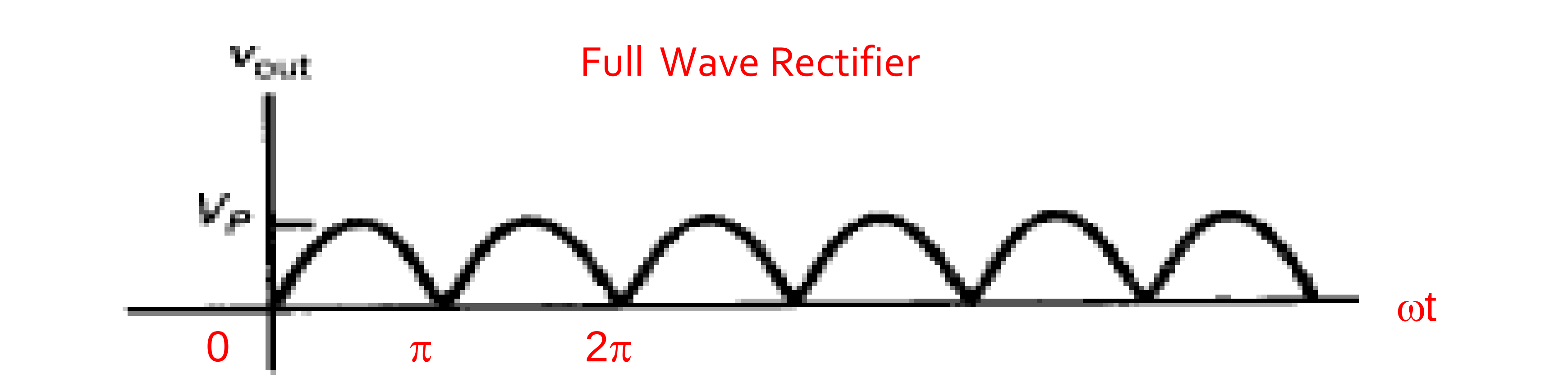
- Twice the $V_{(Peak\ to\ Peak)}$ & V_{DC} as compared to that of a full wave rectifier.

- Less Ripple as compared to half Wave rectifier.

Malvino & Bates, Electronic Principles

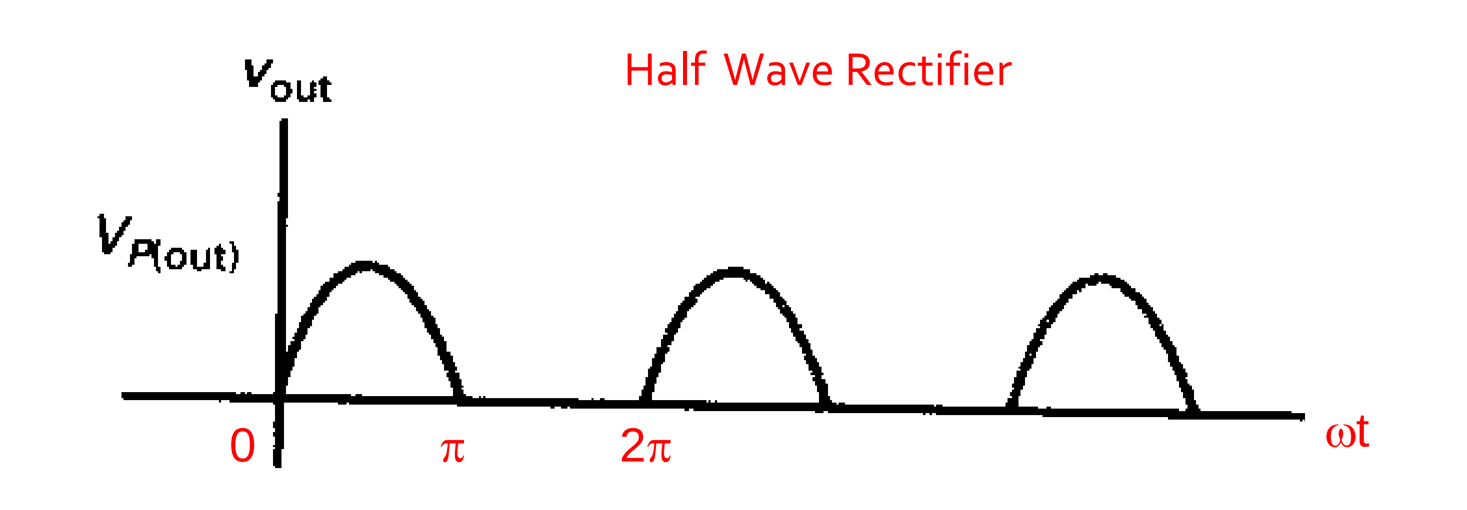
OUTPUT OF RECTIFIERS: RIPPLES





Frequency of the half wave rectifier output is same as the input frequency
Frequency of the full wave rectifier output is double the input frequency

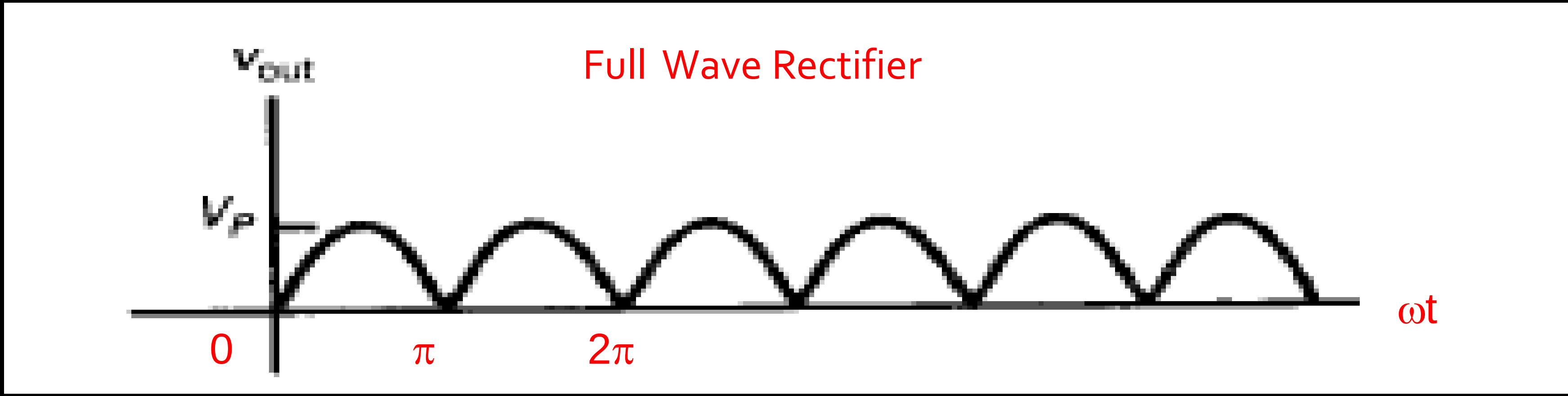
HALF WAVE : DC & RMS



$$I_{dc} = \frac{1}{2\pi}\int_0^{2\pi} I_P.d\alpha = \frac{1}{2\pi}\int_0^{\pi} I_P \sin\alpha.d\alpha = \frac{I_P}{\pi};V_{dc} = I_{dc}R_L$$

$$I_{rms} = \left[\frac{1}{2\pi}\int_0^{2\pi} I^2.d\alpha\right]^{1/2} = \left[\frac{1}{2\pi}\int_0^{\pi} I^2.d\alpha\right]^{1/2} = \frac{I_P}{2}$$

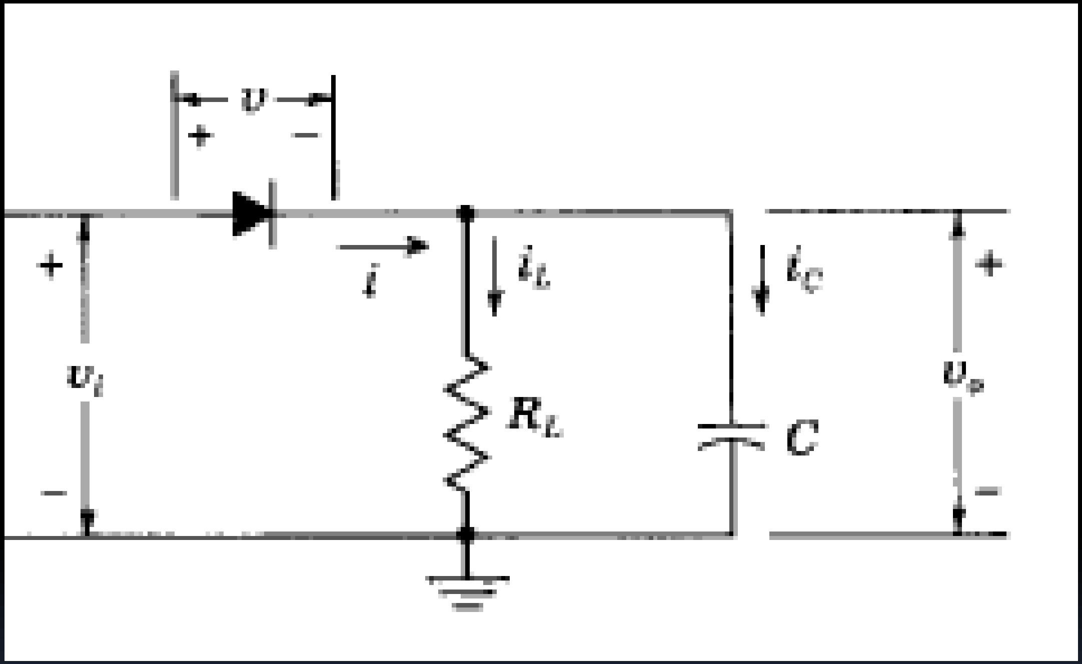
FULL WAVE : DC & RMS



$$I_{dc} = \frac{1}{2\pi}\int_0^{2\pi} I.d\alpha = \frac{1}{2\pi}\int_0^{2\pi} I_P \sin\alpha.d\alpha = \frac{2I_P}{\pi}; V_{dc} = I_{dc}R_L$$

$$I_{rms} = \left[\frac{1}{2\pi}\int_0^{2\pi} I^2.d\alpha\right]^{1/2} = \frac{I_P}{\sqrt{2}}$$

FILTER OUT THE RIPPLES



Malvino & Bates, Electronic Principles

FILTERED RECTIFIER OUTPUT

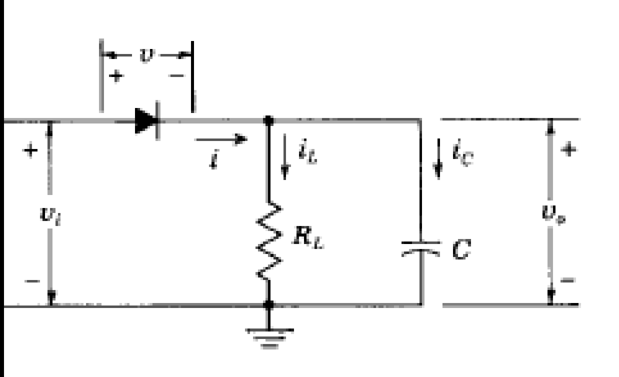
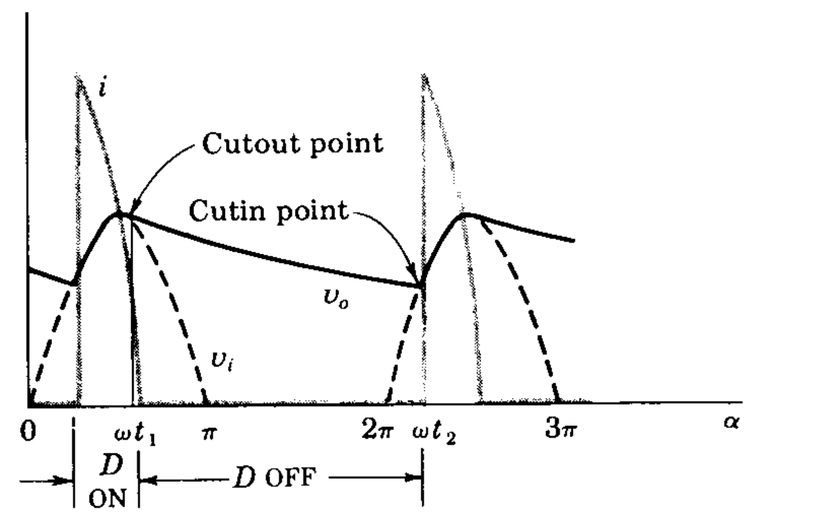


Fig. 4-25 Theoretical sketch of diode current i and output voltage v_o in a half-wave capacitor-filtered rectifier.



FILTER OUT THE RIPPLES

Diode Conducting If the diode drop is neglected, the transformer voltage is impressed directly across the load. Hence the output voltage is $v_o = V_m \sin \omega t$. The question immediately arises: Over what interval of time is this equation applicable? In other words, over what portion of each cycle does the diode remain conducting? The point at which the diode starts to conduct is called the *cutin point*, and that at which it stops conducting is called the *cutout point*. The cutout time t_1 and the cutin time t_2 are indicated in Fig. 4-25, where we observe that the output waveform consists of portions of sinusoids (when the diode is ON) joined to exponential segments (when the diode is OFF).

We now calculate the cutout angle by finding the expression for the diode current i and then noting when $i = 0$. When the diode conducts, $v_o = V_m \sin \omega t$ and i is the sum of the load resistor current i_L and the capacitor current i_C. Hence

$$i = \frac{v_o}{R_L} + C\frac{dv_o}{dt} = \frac{V_m}{R_L}\sin \omega t + \omega C V_m \cos \omega t \tag{4-24}$$

This current is of the form $i = I_m \sin(\omega t + \psi)$, where

$$I_m \equiv V_m \sqrt{\frac{1}{R_L{}^2} + \omega^2 C^2} \qquad \psi \equiv \arctan \omega C R_L \tag{4-25}$$

The cutout time t_1 is found by setting $i = 0$ at $t = t_1$, which leads to

$$\omega t_1 = \pi - \psi \tag{4-26}$$

for the cutout angle ωt_1 in the first cycle. The diode current is indicated in Fig. 4-25.

FILTERED RECTIFIER OUTPUT

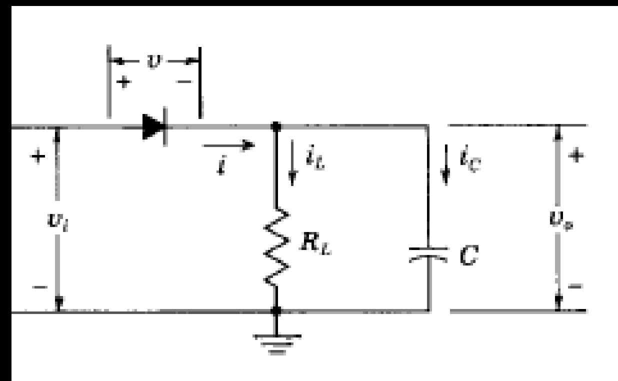
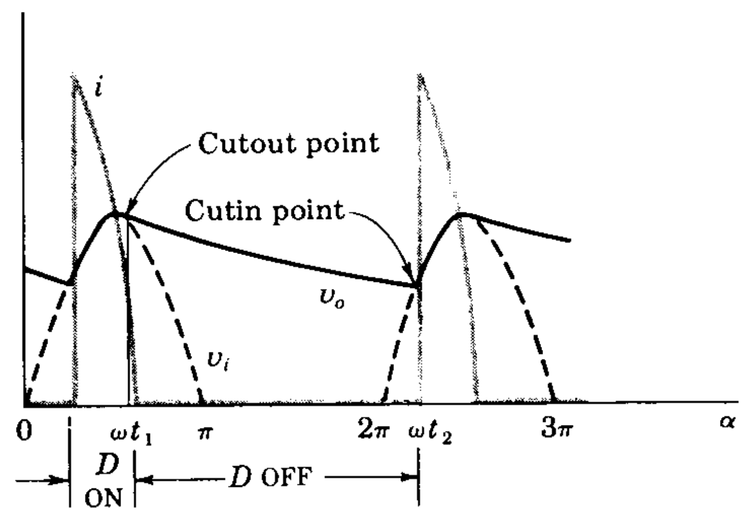


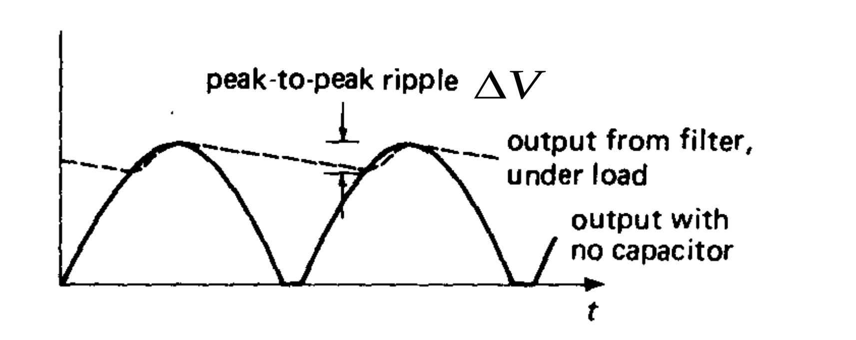
Fig. 4-25 Theoretical sketch of diode current i and output voltage v_o in a half-wave capacitor-filtered rectifier.



$$V_{Load} = v_o = V_P\left(1 - e^{-\frac{t}{R_L C}}\right)$$

$$R_L C >> \frac{1}{f},\ f = \text{Ripple Frequency}$$

FILTERED OUTPUT OF FULL WAVE RIPPLES



$$I = C\frac{dV}{dt} \Rightarrow \Delta V = \frac{I}{C}\Delta t = \frac{I}{C}\times\frac{1}{f};\ \Delta t = \text{Discharging Period},\ f \text{ is Ripple Frequency}$$

$$\text{For Smaller Charging Time, } \Delta t \cong \frac{1}{f} \text{ for Half Wave Ripples and, } \Delta t \cong \frac{1}{2f} \text{ for Full Wave Ripples}$$

$$\Delta V_{Half} = \frac{I_{Load}}{fC} \quad \& \quad \Delta V_{Half} = \frac{I_{Load}}{2fC}$$

Horrowitz & Hill, Art of Electronics AND Milman & Halkias, Integrated Electronics.

REGULATION

$$\%\text{Regulation} = \frac{\left(V_{Load} - V_{Open}\right)}{V_{Load}} \times 100\%$$

In an IDEAL power supply the output voltage is independent of the LOAD (the output current) and the Percentage regulation is ZERO for ideal power supply.

IN PRACTICE…

$$\%\text{Regulation} = \frac{\left(V_{Load} - V_{Open}\right)}{V_{Load}} \times 100\%$$

1. Peak Current may be much more the current limit of the diode $\Rightarrow$ Damage at High Peak current.

2. The required large capacitors for $R_L C >> 1/f$ may be too bulky and expensive.

3. Fluctuations due to the variations of dc output voltage with ac input voltage.

4. Changes of Load voltage with load current

* Use an active feedback circuit to regulated the filtered output

POSITIVE CLIPPING

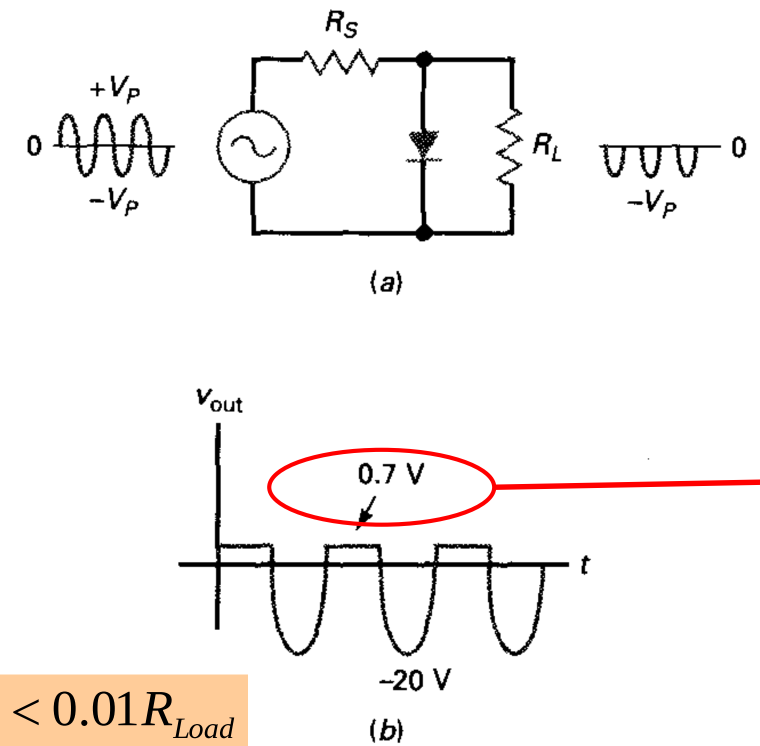


Figure 4–24 (a) Positive clipper; (b) output waveform.

$100\,R_{Bulk} < R_S < 0.01\,R_{Load}$

Malvino & Bates, Electronic Principles

Due to diode threshold voltage ~ 0.7 V

As the diode turns on, most of the current pass through it . Thus a conducting diode acts as a short across the Load Resistance (R_L). No voltage drop across the load resistance during that half cycle when the diode is turned on $\Rightarrow$ Clips off positive part of the signal !

NEGATIVE CLIPPING

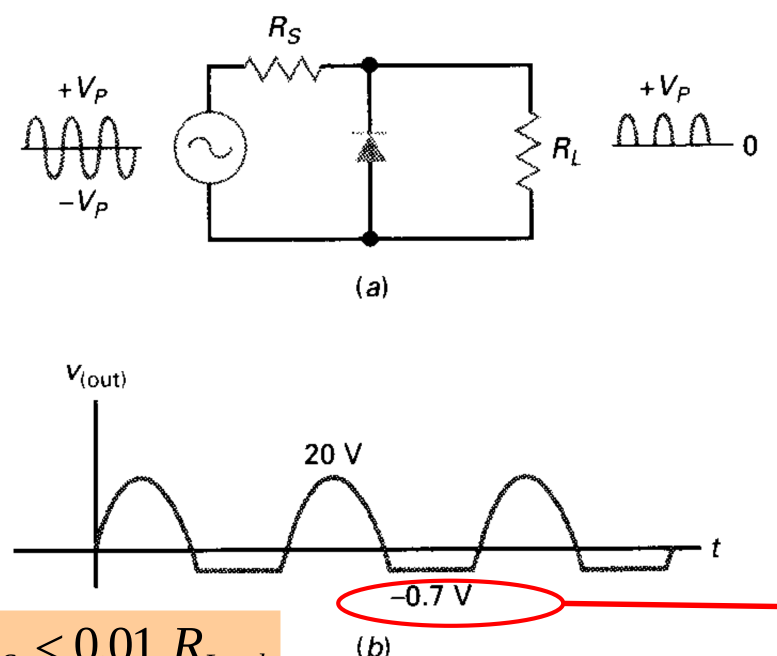


Figure 4-25 (a) Negative clipper; (b) output waveform.

$100\ R_{Bulk} < R_S < 0.01\ R_{Load}$

Malvino & Bates, Electronic Principles

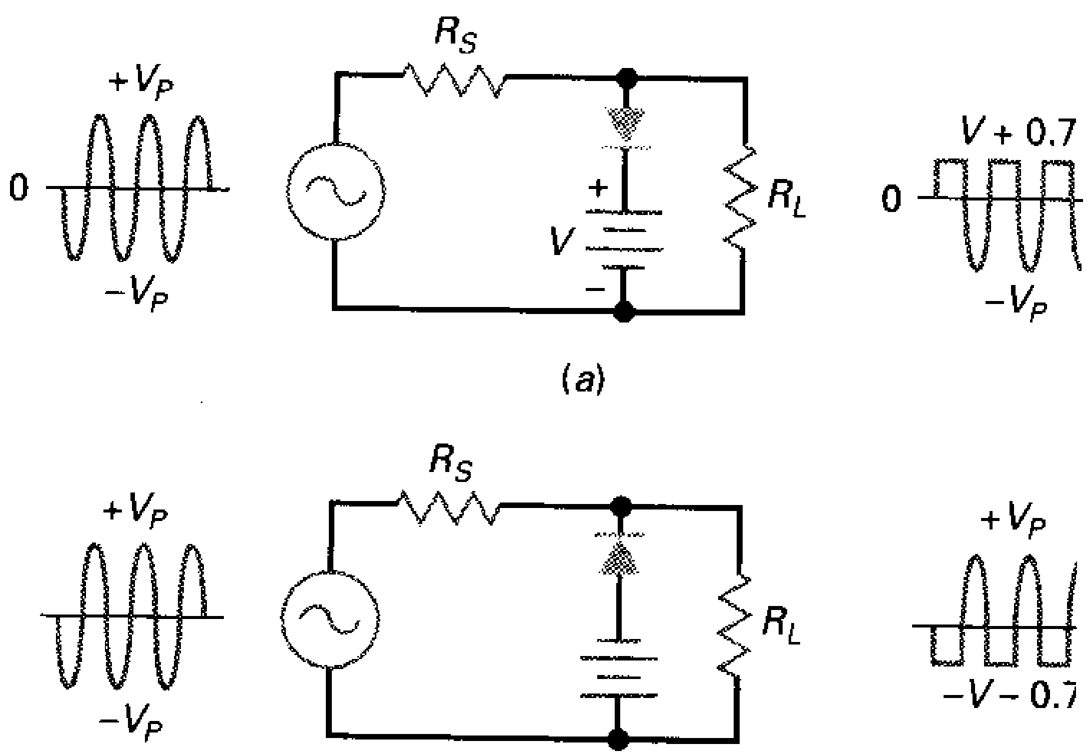
Due to diode threshold voltage ~0.7 V

As the diode turns on, most of the current pass through it . Thus a conducting diode acts as a short across the Load Resistance (R_L). No voltage drop across the load resistance during that half cycle when the diode is turned on $\Rightarrow$ Clips off positive part of the signal !

BIASED CLIPPING

$|V| \ll |V_P|$

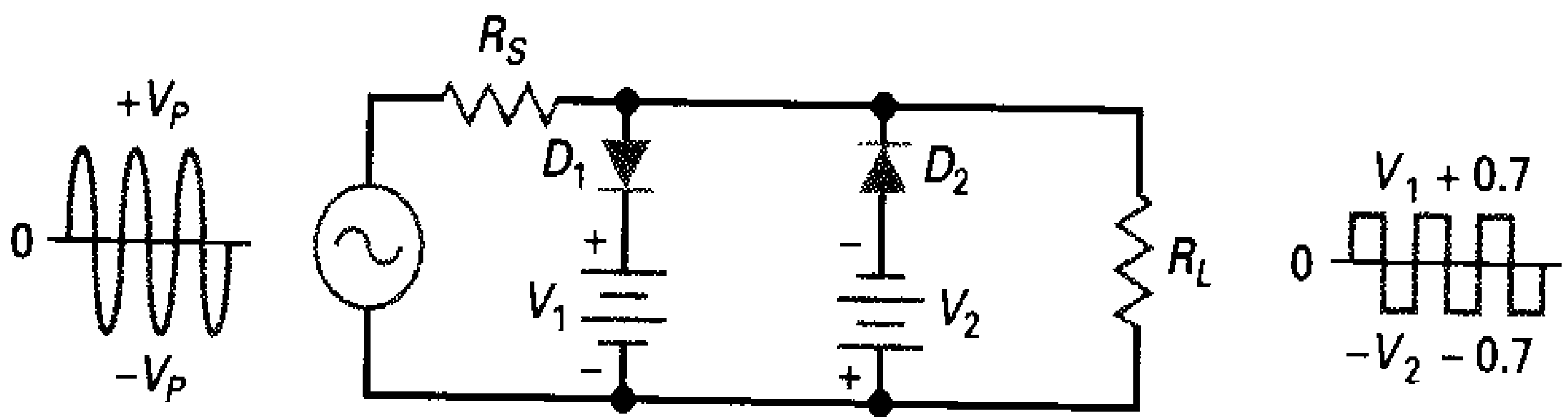
Figure 4–27 (*a*) Biased positive clipper; (*b*) biased negative clipper.



COMBINATION CLIPPING

$|V_1|$ & $|V_2| << |V_P|$

Figure 4-28 Biased positive-negative clipper.



Rectangular Wave from Sinusoidal Wave !

In case of $V_1 = V_2 \Rightarrow$ Square Wave.

Malvino & Bates, Electronic Principles

CONVERSION OF SINE WAVEFORM TO RECTANGULAR WAVEFORM

1. Combination of Biased Clipper, Fig 4.27.

2. Using 741 OpAmp as Comparator, Fig 22.1 & 22.3.

3. Using Schmitt Trigger, Fig 22.27.

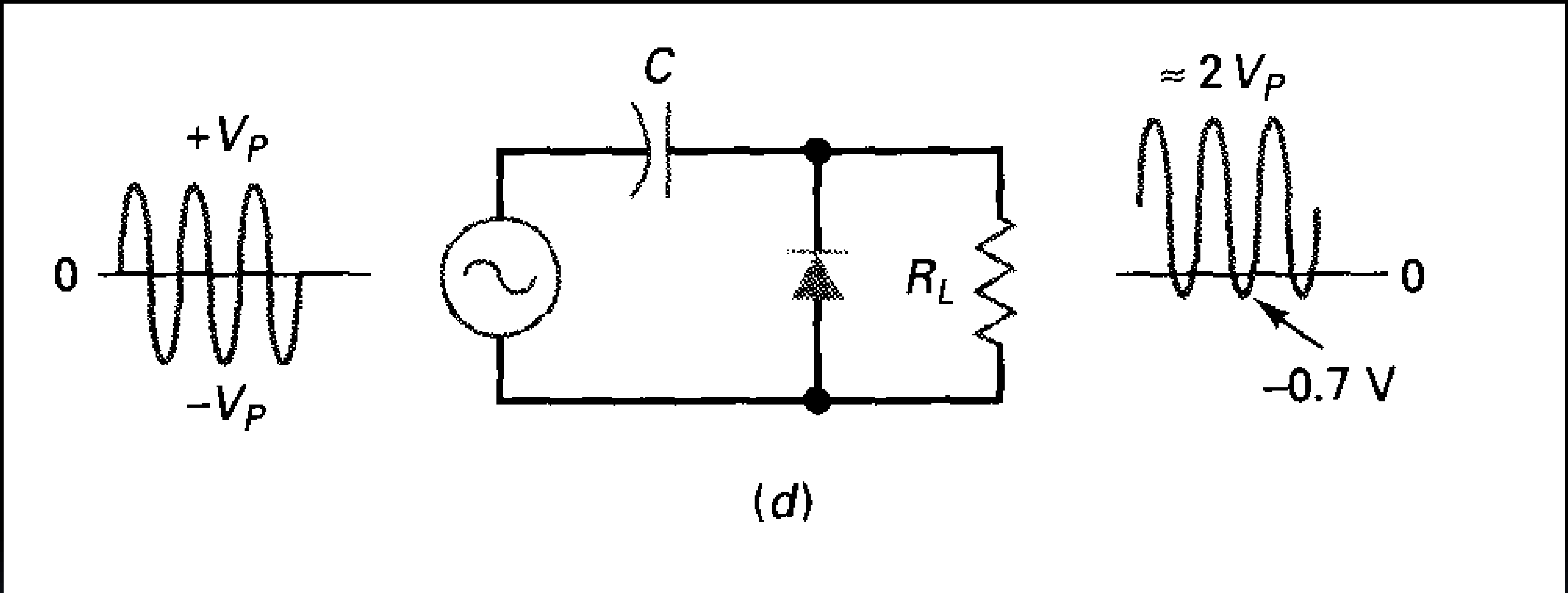
4. Direct Digital Synthesis.

Which is the best Method ?
Under What Conditions ?

Additional reading for interested students only

POSITIVE CLAMPING

$R_L C > 100T; T = Time\ Period$

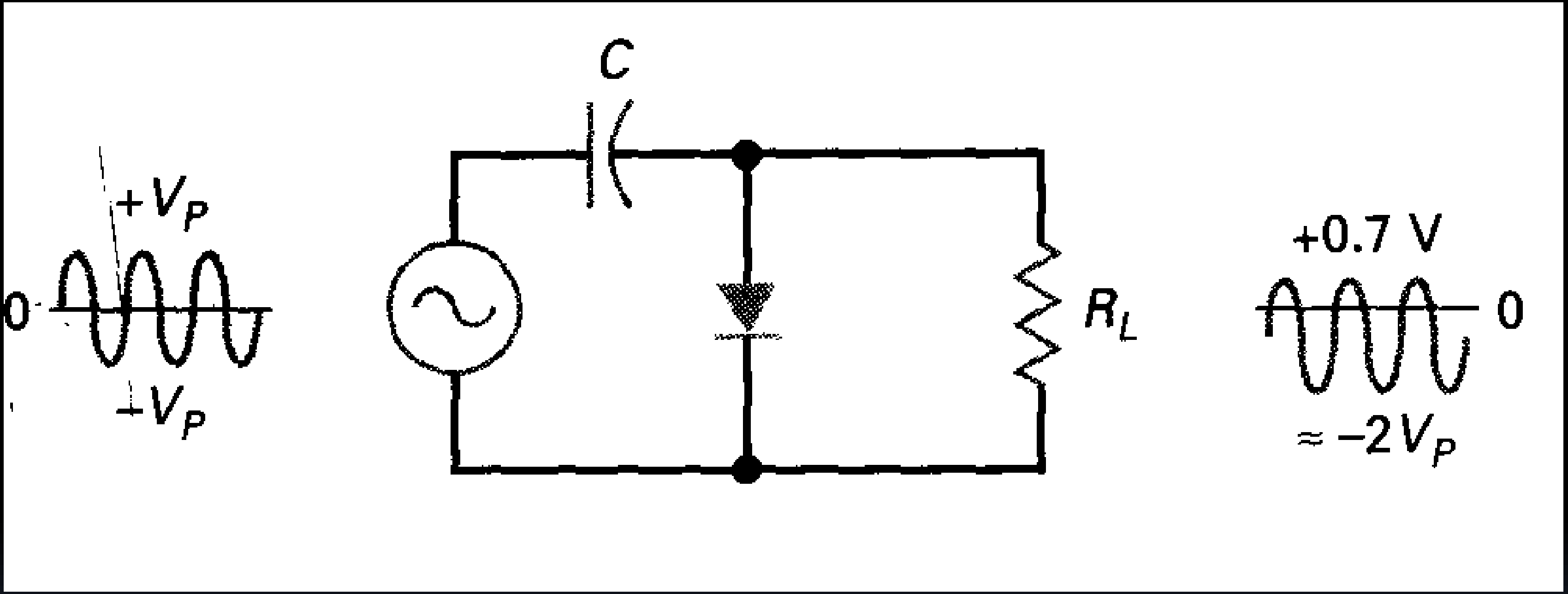


A positive clamper raise the ac reference level of a sine wave input to a dc level.

The capacitor behaves as a battery of V_P volts.

NEGATIVE CLAMPING

$$R_L C > 100T; T = Time\ Period$$



A positive clamper raise the ac reference level of a sine wave input to a dc level.

The capacitor behaves as a battery of $-V_P$ volts.

PEAK TO PEAK DETECTION