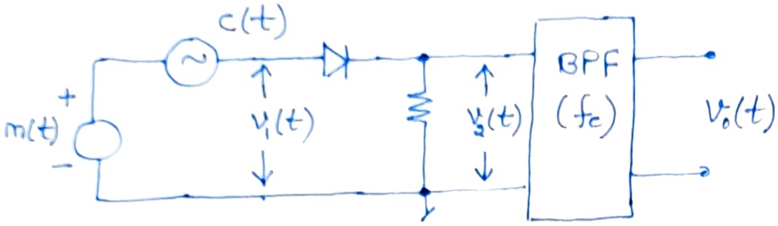
(Dr. Tarun Rawat)

Generation of DSB-FC wave:

1. Switching Modulator:-



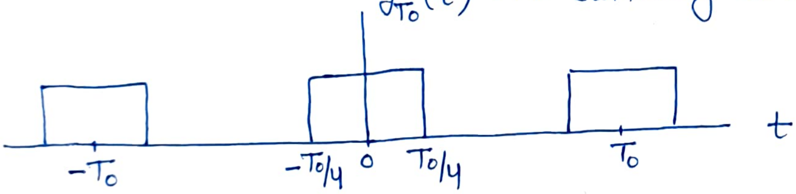
$c(t) = A_c \cos \omega_c t$ ... carrier signal

$v_1(t) = m(t) + c(t) = m(t) + A_c \cos \omega_c t$

$|m(t)| \ll A_c$, the resulting load voltage $v_2(t)$ varies between the values $v_1(t)$ and zero at a rate equal to f_c.

$$v_2(t) = \begin{cases} v_1(t) & c(t) > 0 \\ 0 & c(t) < 0 \end{cases}$$

$g_{T_0}(t)$ ..... switching action of the diode



$v_2(t) \cong [m(t) + A_c \cos \omega_c t] \cdot g_{T_0}(t)$

$$g_{T_0}(t) = \frac{1}{2} + \frac{2}{\pi} \sum_{n=1}^{\infty} \frac{(-1)^{n-1}}{2n-1} \cos[\omega_c t\,(2n-1)]$$ ... Fourier series of $g_{T_0}(t)$

$$= \frac{1}{2} + \frac{2}{\pi} \cos \omega_c t - \frac{2}{3\pi} \cos(3\omega_c t) + \cdots$$

$$\therefore v_2(t) = \underbrace{\frac{A_c}{2} \cos \omega_c t}_{\pm f_c} + \underbrace{\frac{2}{\pi} m(t) \cos \omega_c t}_{f_c \pm f_m} + \underbrace{\text{other terms}}_{\text{out of range}}$$

$\therefore$ o/p of the BPF

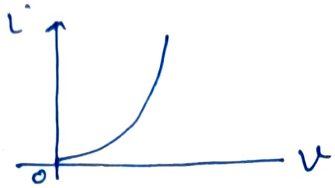
$$v_0(t) = \frac{A_c}{2} \cos \omega_c t + \frac{2}{\pi} m(t) \cos \omega_c t$$ ... DSB-FC wave

2. Square-law Modulator: (Power-law)

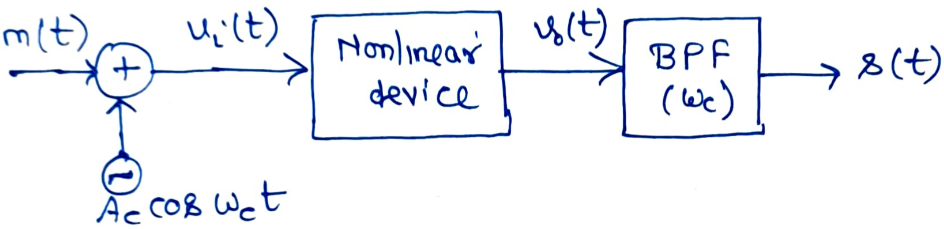
Diode

- 

PN diode is a nonlinear device.



$$v_o(t) = a\,v_i(t) + b\,v_i^2(t)$$ .... i/p, o/p charac. of the nonlinear device



$$v_i(t) = m(t) + A_c \cos \omega_c t$$

$$v_o(t) = a\,v_i(t) + b\,v_i^2(t)$$ ...o/p of nonlinear device

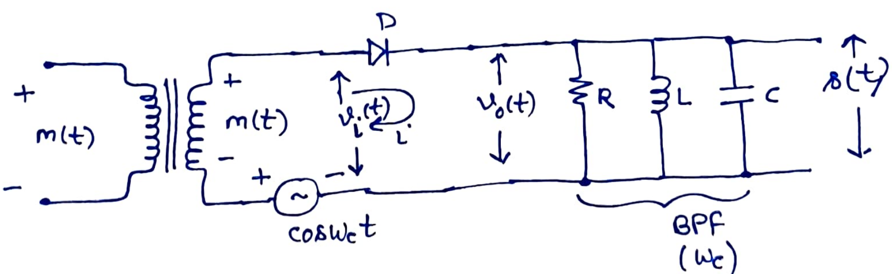
$$= a\left[m(t) + A_c \cos \omega_c t\right] + b\left[m(t) + A_c \cos \omega_c t\right]^2$$

$$= a\,m(t) + a A_c \cos \omega_c t + b\,m^2(t) + 2b\,m(t) A_c \cos \omega_c t + b A_c^2 \cos^2 \omega_c t$$

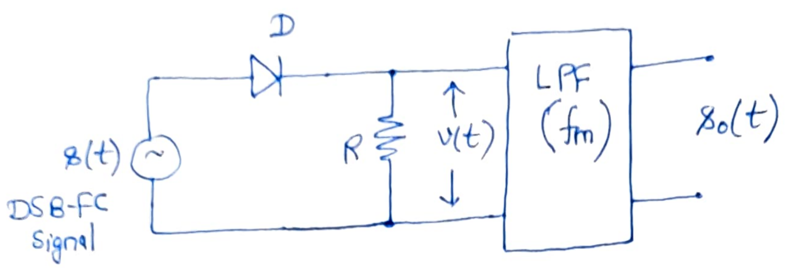
$$v_o(t) = a\,m(t) + b\,m^2(t) + b A_c^2 \cos^2 \omega_c t + a A_c\left[1 + \frac{2b}{a} m(t)\right] \cos \omega_c t$$

o/p of the BPF

$$s(t) = a A_c\left[1 + \frac{2b}{a} m(t)\right] \cos \omega_c t$$ .. DSB-FC wave



1. Rectifier detector:



$$s(t) = [A_c + m(t)] \cos \omega_c t \quad \text{... DSB-FC Signal}$$

$$v(t) = s(t)\, g_{T_0}(t) \quad \text{... i/p to the LPF}$$

$$= [A_c + m(t)] \cos \omega_c t \left[\frac{1}{2} + \frac{2}{\pi} \cos \omega_c t - \frac{2}{3\pi} \cos 3\omega_c t + \cdots \right]$$

$$= \frac{2}{\pi} [A_c + m(t)] \cos^2 \omega_c t + \text{other terms}$$

$$= \frac{2}{\pi} [A_c + m(t)] \frac{1}{2} (1 + \cos 2\omega_c t) + \text{other terms}$$

$$v(t) = \frac{1}{\pi} [A_c + m(t)] + \underbrace{\text{other terms}}_{\text{out of range}}$$

o/p of LPF

$$s_o(t) = \frac{1}{\pi} [A_c + m(t)]$$

$$\propto m(t)$$

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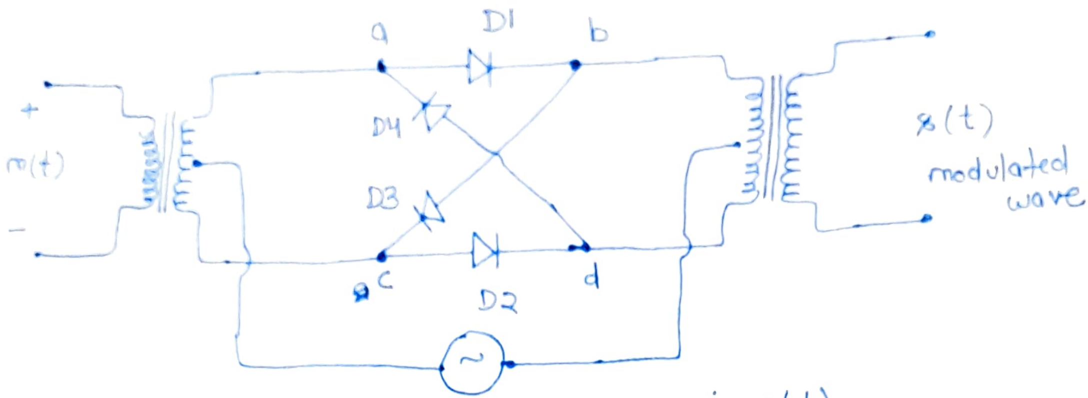
Generation of DSB-SC Signal:

1. Ring Modulator:



Square wave carrier $c(t)$ (f_c)

- The four diodes form a ring in which they all point in the same way - hence the name.
- The diodes are controlled by a square wave carrier $c(t)$ of frequency f_c.
- when $c(t) > 0$ Diode $D1, D_2 \rightarrow$ ON
  $D_3, D_4 \rightarrow$ off

  point 'a' is connected to 'b'
  and 'c' is connected to 'd'.
- when $c(t) < 0$ Diode $D1, D_2 \rightarrow$ off
  $D3, D4 \rightarrow$ ON

  point 'a' is connected to 'd'
  'c' is connected to 'b'
- The ring modulator is a product modulator for a square wave carrier and modulating signal.

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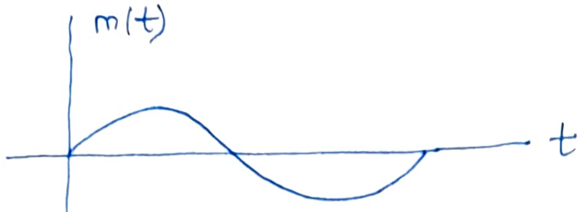
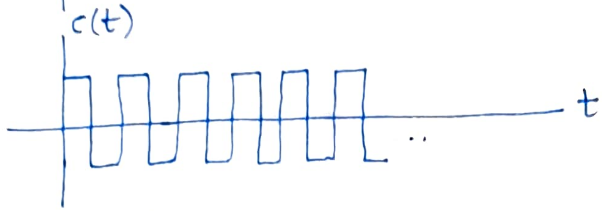
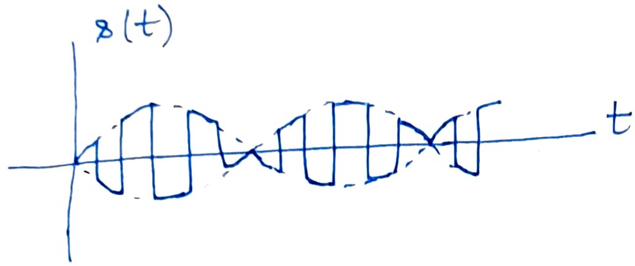






$$c(t) = \frac{4}{\pi} \sum_{n=1}^{\infty} \frac{(-1)^{n-1}}{2n-1} \cos\left(\omega_c t\,(2n-1)\right)$$

o/p of the ring modulator

$$v_1(t) = m(t)\,c(t)$$

$$= m(t) \cdot \frac{4}{\pi} \left[\cos \omega_c t - \frac{1}{3} \cos 3\omega_c t + \cdots \right]$$

$$v_1(t) = \underbrace{\frac{4}{\pi} m(t) \cos \omega_c t}_{f_c \pm f_m} - \frac{1}{3} \frac{4}{\pi} \underbrace{m(t) \cos 3\omega_c t}_{3f_c \pm f_m} + \cdots$$

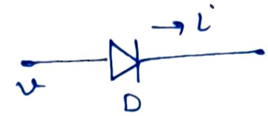
o/p of BPF

$$v_o(t) = \frac{4}{\pi} m(t) \cos \omega_c t \quad \cdots \text{DSB-SC wave.}$$

2. Square-law modulator (or Balanced modulator):

(Power law)

Diode is a nonliner device:

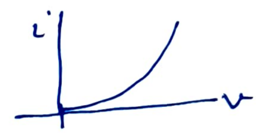


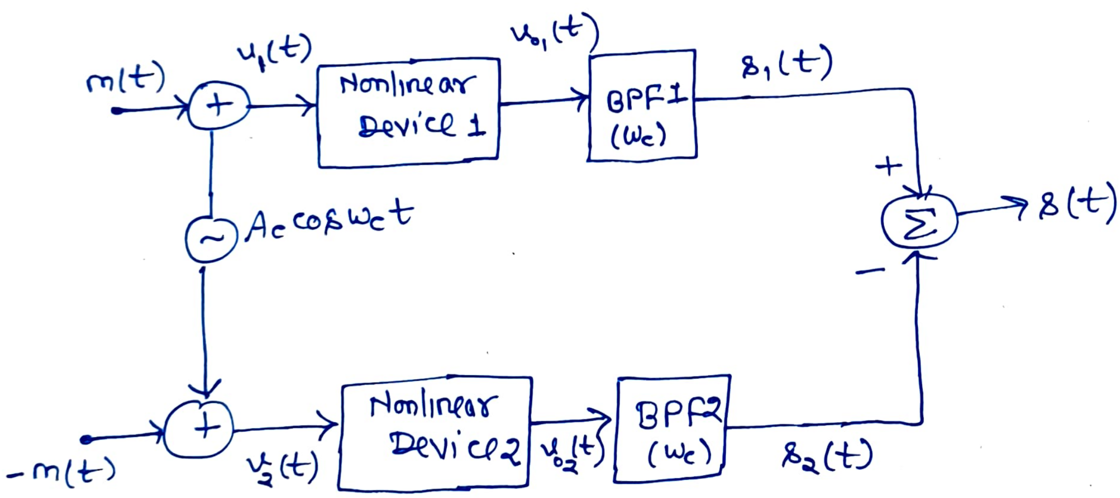
$$i = I_0\left(e^{v/\eta V_T} - 1\right)$$

$$= I_0\left(\cancel{1} + \frac{v}{\eta V_T} + \left(\frac{v}{\eta V_T}\right)^2 \frac{1}{2!} \cdots \cancel{-1}\right)$$

$$= I_0\left(\frac{v}{\eta V_T} + \frac{1}{2!}\frac{v^2}{\eta^2 V_T^2} + \cdots\right)$$

$$i = av + bv^2 \ldots$$





$$v_1(t) = m(t) + A_c \cos \omega_c t$$

$$v_2(t) = A_c \cos \omega_c t - m(t)$$

$$v_{o1}(t) = a v_1(t) + b v_1^2(t)$$

$$s_1(t) = aA_c\left[1 + \frac{2b}{a} m(t)\right] \cos \omega_c t \quad \ldots \text{o/p of BPF1.}$$

$$v_{o2}(t) = a\,v_2(t) + b\,v_2^2(t)$$

$$s_2(t) = aA_c\left[1 - \frac{2b}{a} m(t)\right] \cos w_c t$$ ... o/p of BPF2.

$$s(t) = s_1(t) - s_2(t)$$

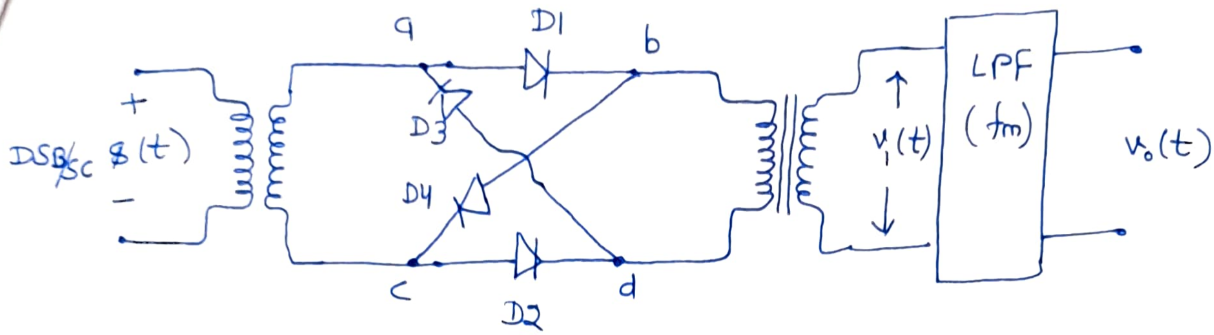
$$= \frac{4b}{a} \cdot aA_c\, m(t) \cos w_c t$$

$$s(t) = 4bA_c\, m(t) \cos w_c t$$

$$s(t) = k\, A_c\, m(t) \cos w_c t$$ ... DSB-SC wave.

Demodulation of DSB-SC:

Ring Demodulator:



$$s(t) = A_c\, m(t) \cos \omega_c t \quad \text{...DSB-SC wave}$$

$$c(t) = \frac{4}{\pi} \sum_{n=1}^{\infty} \frac{(-1)^{n-1}}{2n-1} \cos[\omega_c t\,(2n-1)]$$

$$c(t) = \frac{4}{\pi} \cos \omega_c t - \frac{4}{3\pi} \cos 3\omega_c t + \cdots$$

i/p to the BPF:

$$v_1(t) = s(t) \cdot c(t)$$

$$= A_c m(t) \cos \omega_c t \left[\frac{4}{\pi} \cos \omega_c t - \frac{4}{3\pi} \cos 3\omega_c t + \cdots\right]$$

$$= \frac{4A_c}{\pi} m(t) \cos^2 \omega_c t + \text{other terms}$$

$$= \frac{4A_c}{\pi} m(t) \frac{1}{2}[1 + \cos 2\omega_c t] + \text{other terms}$$

$$v_1(t) = \frac{2A_c}{\pi} m(t) + \frac{2A_c}{\pi} m(t) \cos 2\omega_c t + \text{other terms}$$

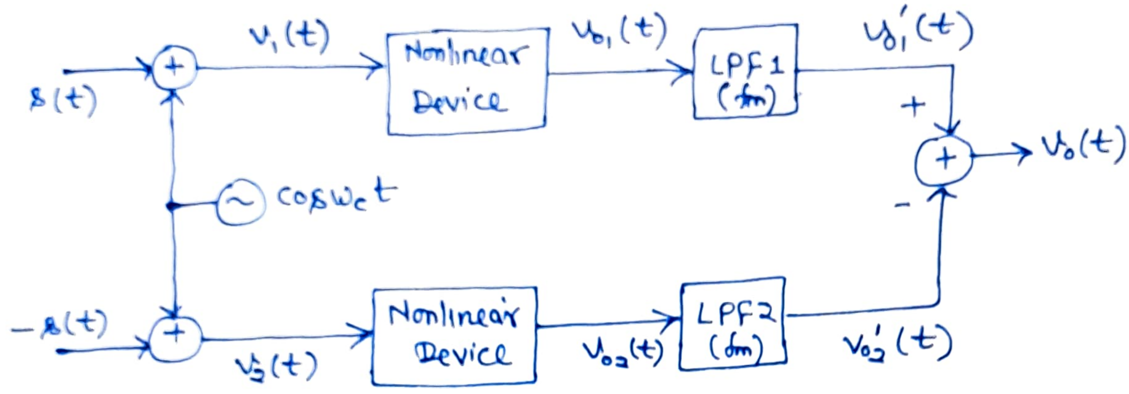
o/p of LPF (fm)

$$v_0(t) = \frac{2A_c}{\pi} m(t)$$

$$\propto m(t)$$

Square-law Demodulator:

$$s(t) = m(t)\cos\omega_c t \quad \because \text{DSB-SC wave}$$



$$v_1(t) = s(t) + \cos\omega_c t$$

$$v_2(t) = \cos\omega_c t - s(t)$$

$$v_{o1}(t) = a\,v_1(t) + b\,v_1^2(t)$$

$$= a[s(t) + \cos\omega_c t] + b[s(t) + \cos\omega_c t]^2$$

$$= a[s(t) + \cos\omega_c t] + b\,s^2(t) + 2b\,s(t)\cos\omega_c t + b\cos^2\omega_c t$$

$$\cancel{= b\,m^2(t)\cos^2\omega_c t \pm \text{other terms}}$$

$$= \cancel{\tfrac{b}{2}}\; 2b\,s(t)\cos\omega_c t + \text{other terms}$$

$$= 2b\,m(t)\cos^2\omega_c t + \text{other terms}$$

$$v_{o1}(t) = b\,m(t) + b\,m(t)\cos 2\omega_c t + \text{other terms}$$

o/p of LPF1.

$$v_{o1}'(t) = b\,m(t)$$

Similarly o/p of LPF2:

$$v_{o2}'(t) = -b\,m(t)$$

$$\therefore v_o(t) = 2b\,m(t)$$

$$\propto m(t)$$