EE 327 Analog Communications

Lecture-7

Double Sideband Suppressed Carrier (DSB-SC) Amplitude Modulation

The double sideband amplitude modulated signal, i.e., DSB-AM signal

$$s(t) = A_c[1 + k_a m(t)] \cos 2\pi f_c t \rightarrow s(t) = A_c \cos 2\pi f_c t + A_c k_a m(t) \cos 2\pi f_c t$$

has a bandwidth of

$$2W$$

where W is the bandwidth of the message signal $m(t)$, and it involves the transmission of the carrier signal $A_c \cos 2\pi f_c t$ which unnecessarily wastes the transmission power.

However, the modulator and demodulator circuits of DSB-AM are simple and low cost circuits.

To alleviate the high power consumption drawback of the DSB-AM, and improved version of the AM modulation called

double sideband suppresses carrier amplitude modulation

which eliminates the transmission of the carrier signal and saves power, is used.

Double Sideband Suppressed Carrier (DSB-SC) Amplitude Modulation

Using $m(t)$ we obtain a complex envelope signal as

$$s_c(t) = A_c m(t)$$

which is a low-pass signal. Using the baseband signal $s_c(t)$ we obtain a pass-band signal as

$$s(t) = Re\{s_c(t)e^{j2\pi f_c t}\}$$

leading to DSB-SC AM signal

$$s(t) = A_c \cos(2\pi f_c t)\, m(t).$$

That is, the message signal $m(t)$ is modulated using DSB-SC amplitude modulation method using the carrier signal

$$c(t) = A_c \cos 2\pi f_c t$$

as

$$s(t) = A_c \cos(2\pi f_c t)\, m(t)$$

where f_c is the carrier frequency.

Example: A time domain message signal $m(t)$ is given in Figure-1.

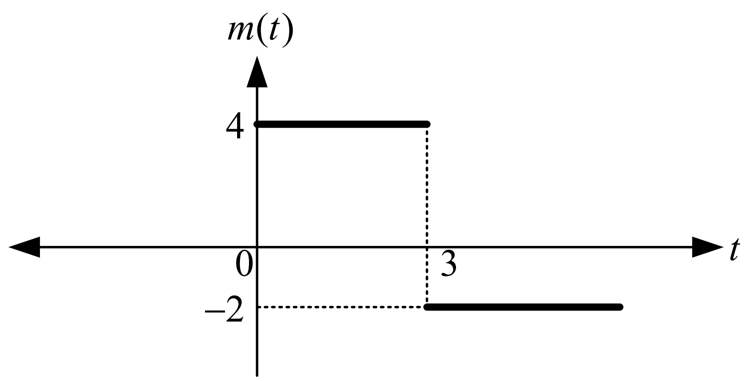


Figure-1

Obtain the DSB-SC amplitude modulated signal $s(t)$ and draw its graph.

Solution: Using the DSB-SC AM formula

$$s(t) = A_c \cos(2\pi f_c t)\, m(t)$$

we obtain the modulated signal as

$$s(t) = \begin{cases} 4A_c \cos(2\pi f_c t) & 0 \le t \le 3 \\ -2A_c \cos(2\pi f_c t) & t > 3. \end{cases}$$

To draw the graph of DSB-SC AM signal, first we draw the graph of $m(t)$ and $-m(t)$ as shown in Figure-2.

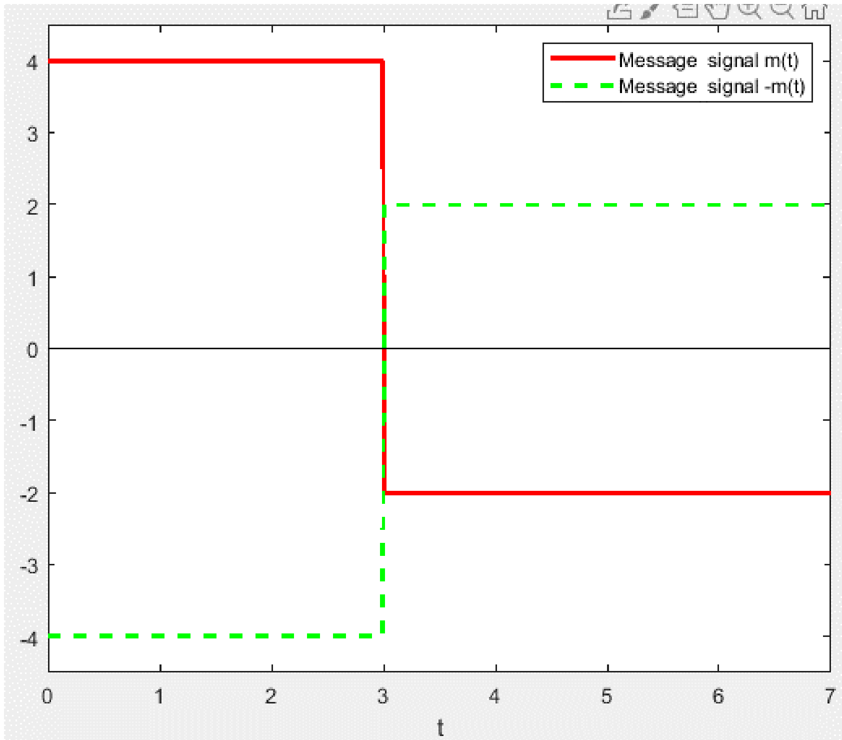


Figure-2

The matlab code to get Figure-2 is given below.

```
clc; clear all; close all;

t=0:0.01:7;
mt=my_message(t);
fc=2;

st=cos(2*pi*fc*t).*mt;

plot(t,mt,'r','Linewidth',2);
hold on;
plot(t,-mt,'g--','Linewidth',2);
plot(t,zeros(1,length(t)),'k');
legend('Message  signal m(t)','Message  signal -m(t)');

axis([0 7 -4.5 4.5]);
------------------------------------------------------------------------------------------
function ret=my_message(t)

ret=4*(t<=3)+(-2)*(t>=3);
```

Next, we fill the region between $m(t)$ and $-m(t)$ by the cosine signal and obtain the DSB-SC AM signal as in Figure-3 where the carrier frequency $f_c = 2$ is used.

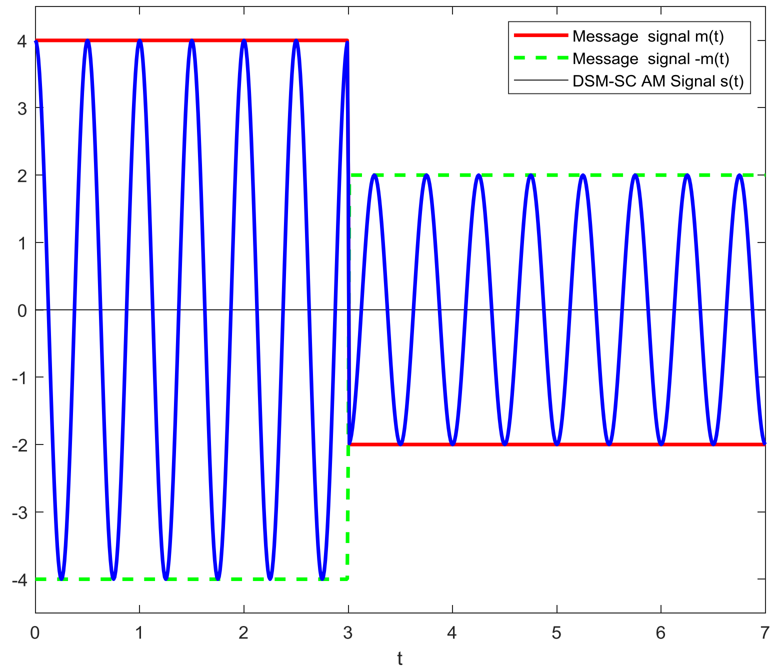


Figure-3

The matlab code is given below

```
clc; clear all; close all;

t=0:0.01:7;
mt=my_message(t);
fc=2;

st=cos(2*pi*fc*t).*mt;

plot(t,mt,'r','Linewidth',2);
hold on;
plot(t,-mt,'g--','Linewidth',2);
plot(t,zeros(1,length(t)),'k');
legend('Message  signal m(t)','Message  signal -m(t)');

plot(t,st,'b','Linewidth',2)
xlabel('t');

axis([0 7 -4.5 4.5]);
legend('Message  signal m(t)','Message  signal -m(t)','DSM-SC AM Signal s(t)');
```

```
function ret=my_message(t)

ret=4*(t<=3)+(-2)*(t>=3);
```

Example: For time domain message signal $m(t)$ given in Figure-4

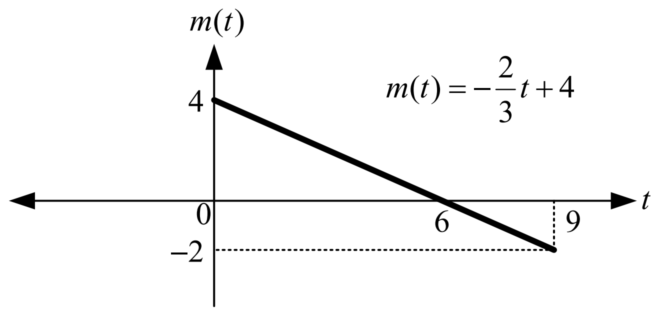


Figure-4

The formation of the DSB-SC AM signal for carrier frequency $f_c = 2$ is illustrated in Figures-5 and 6.

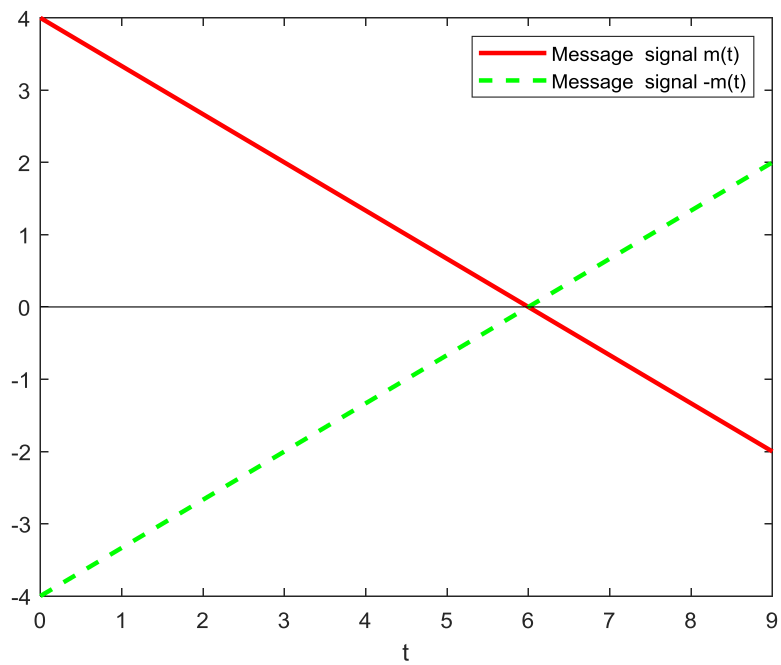


Figure-5

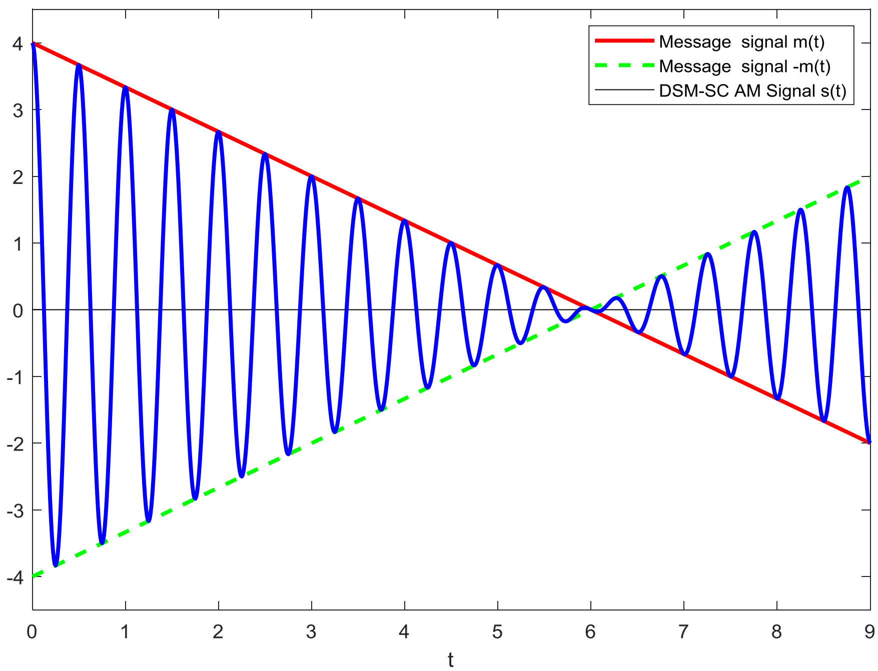


Figure-6

Note that only the modulated signal as shown in Figure-7 is transmitted.

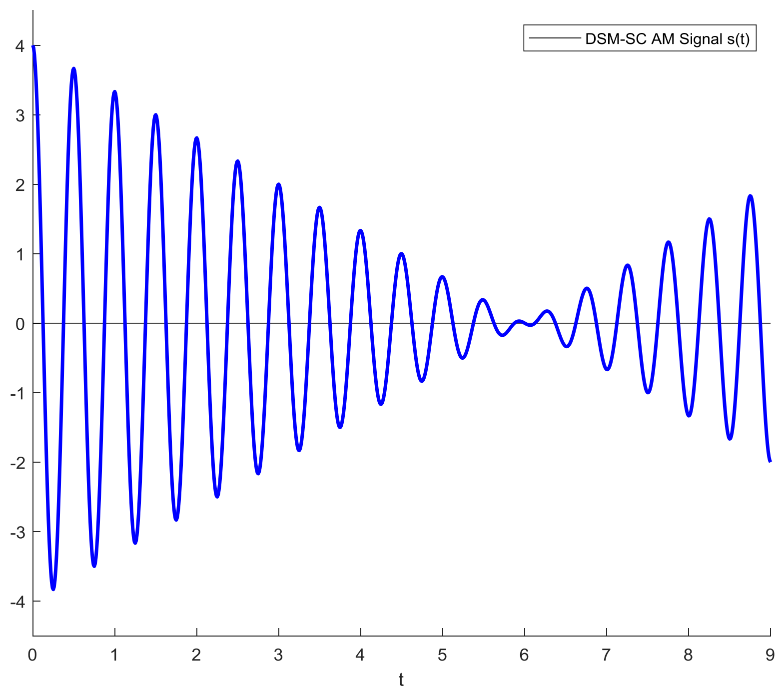


Figure-7

Example: For time domain message signal $m(t)$ given in Figure-8

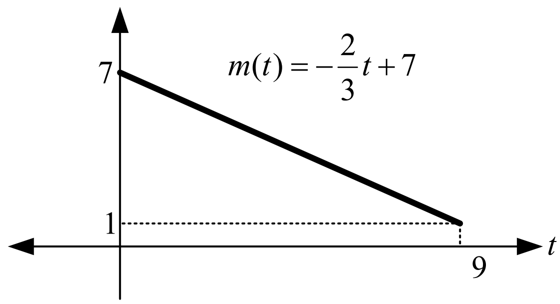


Figure-8

The formation of the DSB-SC AM signal for carrier frequency $f_c = 2$ is illustrated in Figures-9 and 10.

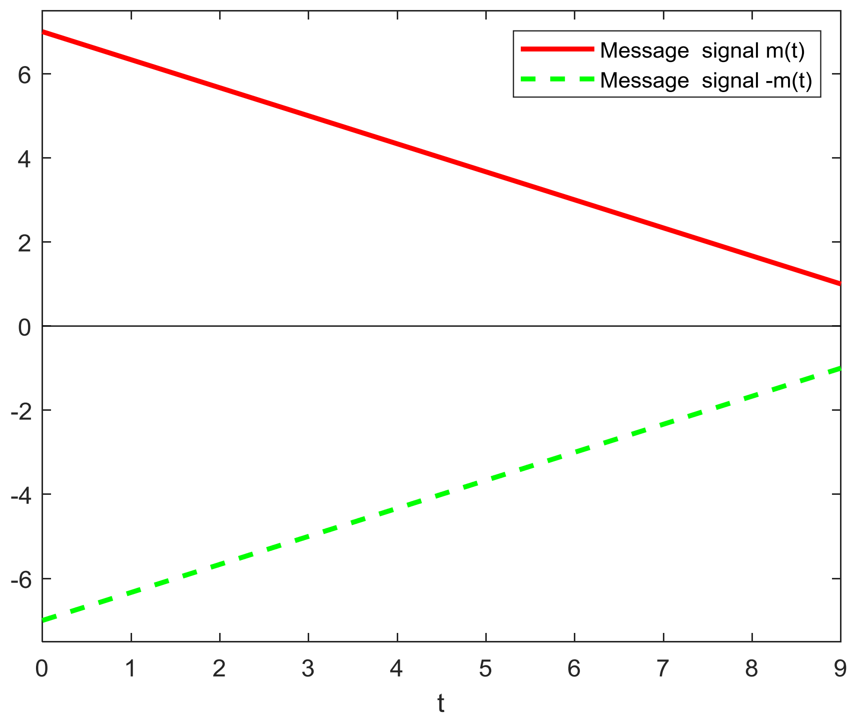


Figure-9

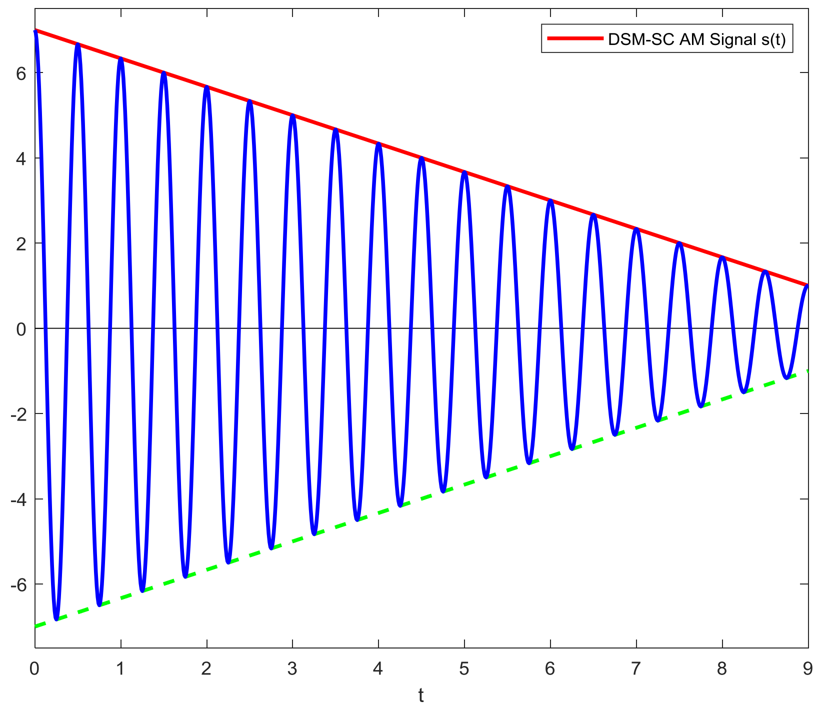


Figure-10

The block diagram of the DSB-SC amplitude modulator is shown in Figure-11.

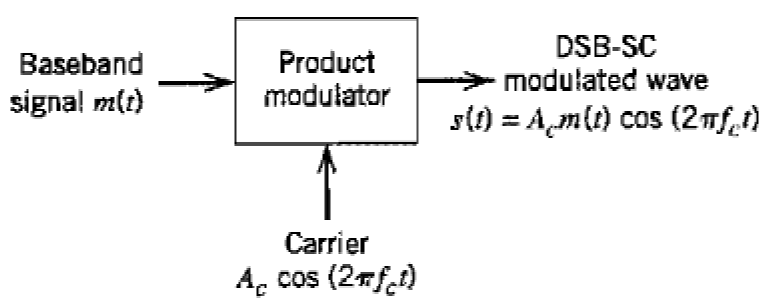


Figure-11

A modulating signal and DSB-SC modulated signal is depicted in Figure-12.

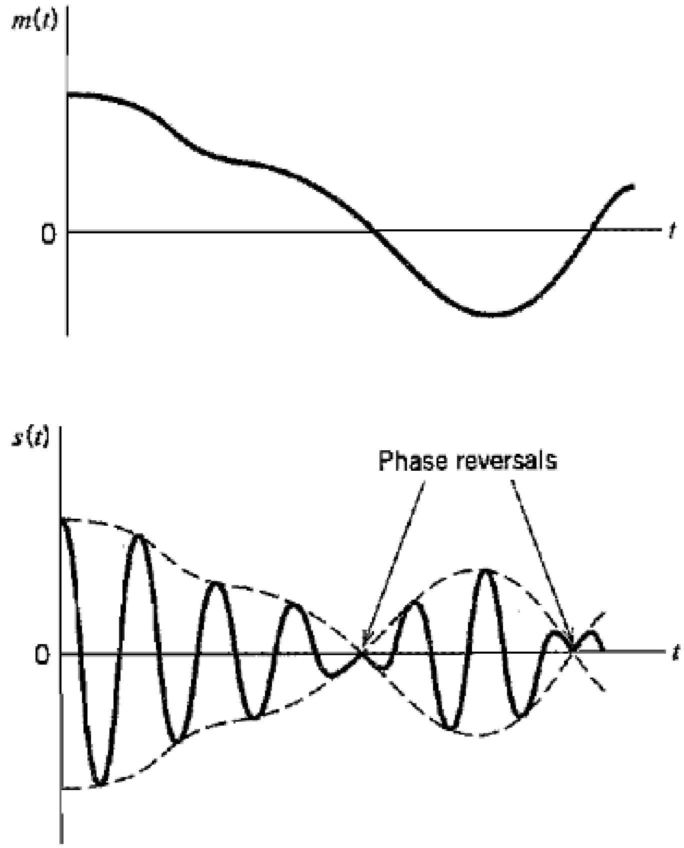


Figure-12

Fourier Transform of DSB-SC AM Signal

If we take the Fourier transform of DSB-SC AM signal

$$s(t) = A_c \cos(2\pi f_c t)\, m(t)$$

we get

$$S(f) = A_c FT\{\cos(2\pi f_c t)\} * M(f)$$

in which substituting

$$FT\{\cos(2\pi f_c t)\} = \frac{1}{2}\left(\delta(f - f_c) + \delta(f + f_c)\right)$$

and employing

$$\delta(f - f_o) * G(f) = G(f - f_0)$$

we obtain

$$S(f) = \frac{A_c}{2}[M(f - f_c) + M(f + f_c)]. \#(1)$$

If the Fourier transform if the message signal $m(t)$ is as shown in Figure-13, then the Fourier transform of the DSB-SC AM passband signal happens to be as in Figure-14.

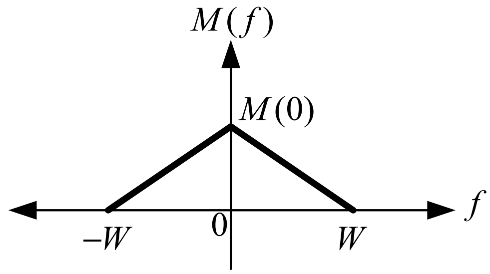


Figure-13

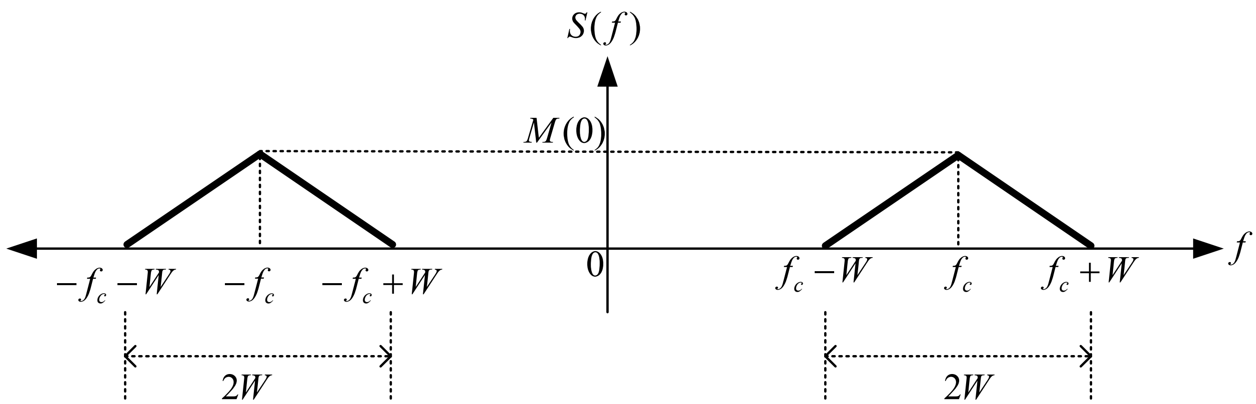


Figure-14

Note that the bandwidth of the DSB-SC AM passband signal is $2W$ whereas the bandwidth of the message signal $m(t)$ is W.

Generation of DSB-SC AM Signal

DSB-SC AM signal can be generated using the ring modulator shown in Figure-15.

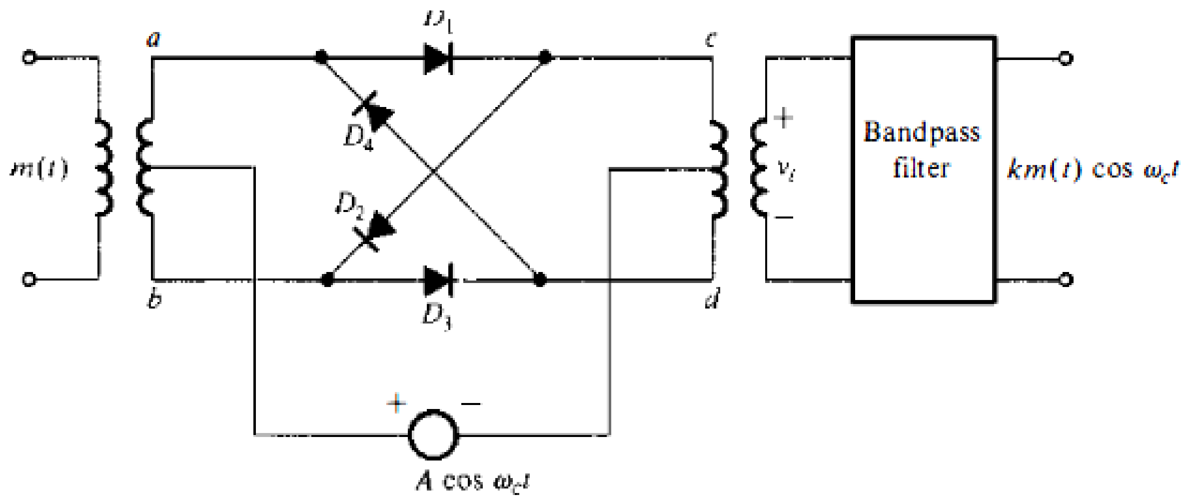


Figure-15

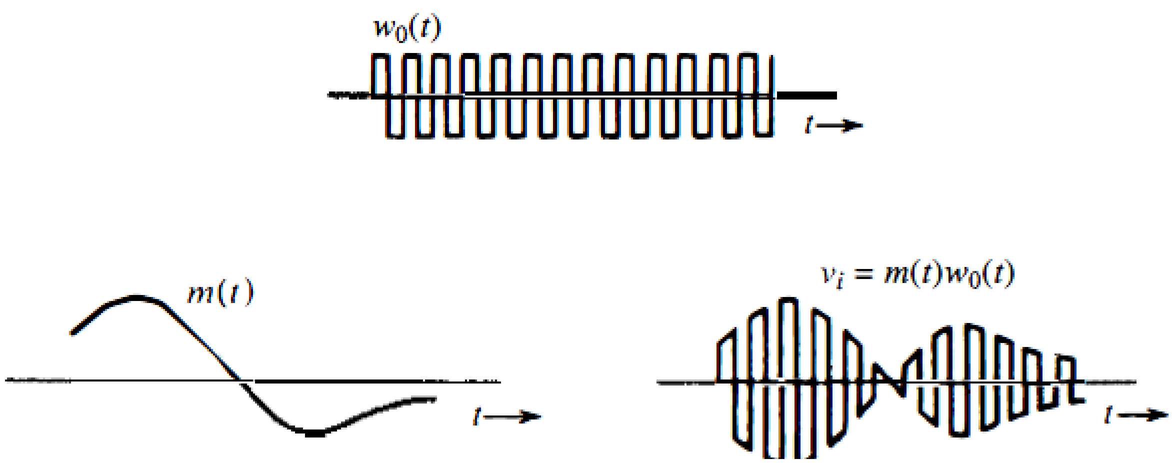


Figure-16

Before explaining the operation of the ring modulator let's give information about the center transformers and center tap transformer.

Transformers

The Basic Transformer Source voltage is applied to the primary winding.

The load is connected to the secondary winding.

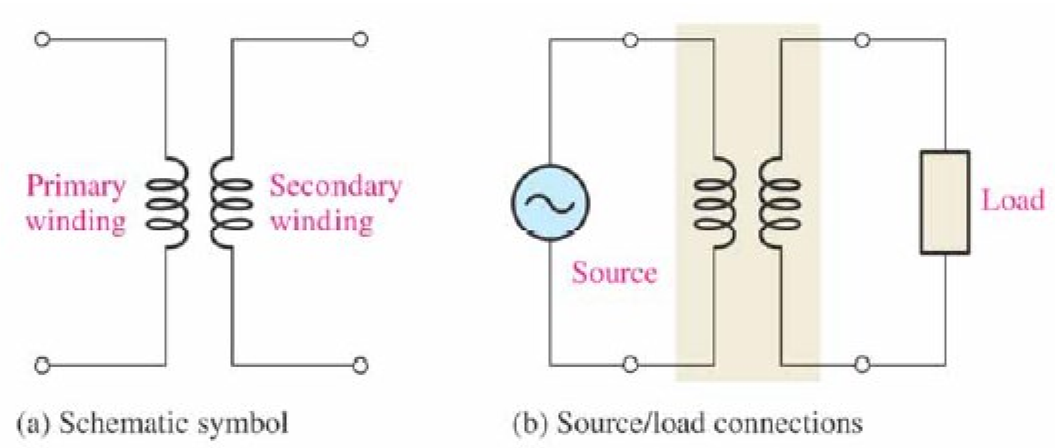


Figure-17

The windings of a transformer are formed around the core. The core provides both a physical structure for placement of the windings and a magnetic path so that the magnetic flux lines are concentrated close to the coils. There are three several categories of core material: air, ferrite, and iron. The schematic symbol for each type is shown in Figure below

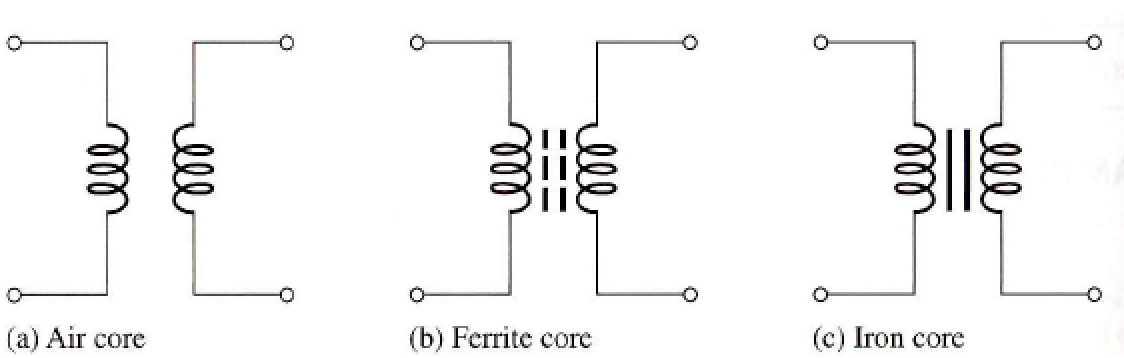
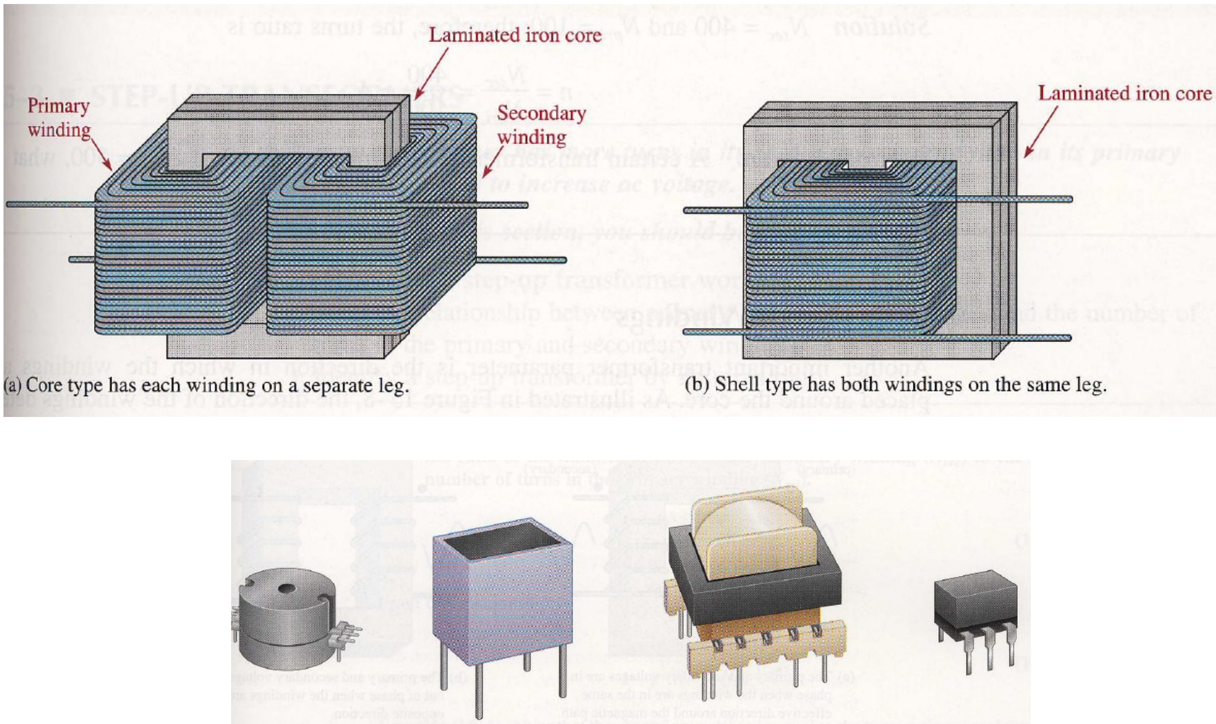


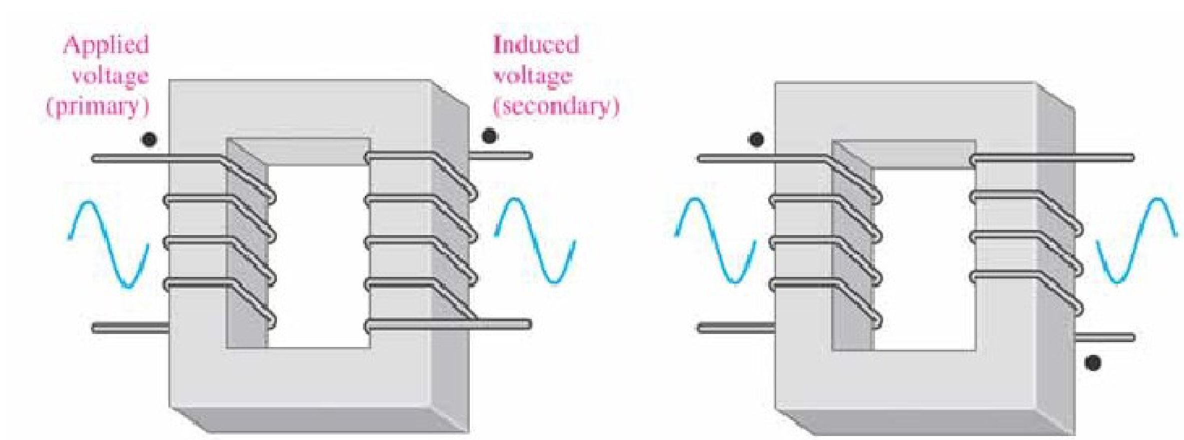
Figure-18



(a) Core type has each winding on a separate leg.
(b) Shell type has both windings on the same leg.

Figure-19

The direction of the windings determines the polarity of the voltage across the secondary winding with respect to the voltage across the primary



(a) The primary and secondary voltages are in phase when the windings are in the same effective direction around the magnetic path.
(b) The primary and secondary voltages are 180° out of phase when the windings are in the opposite direction.

Figure-20

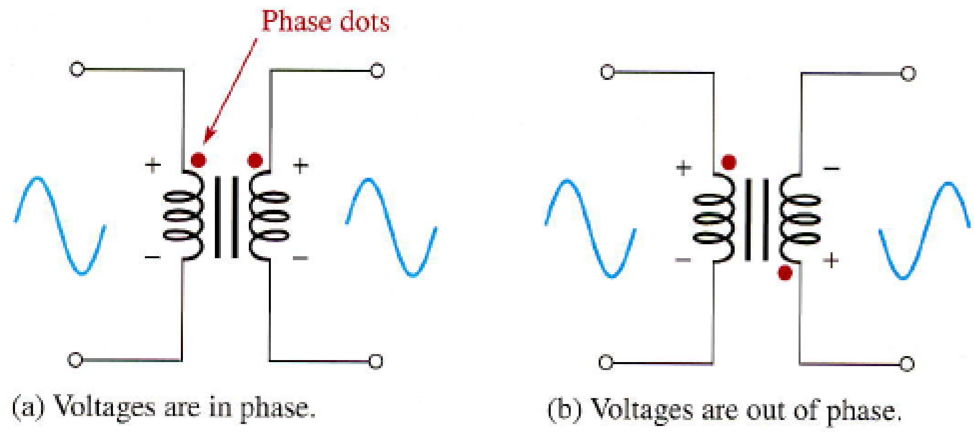


Figure-21

The voltage and turn number relation for the transformer is given as

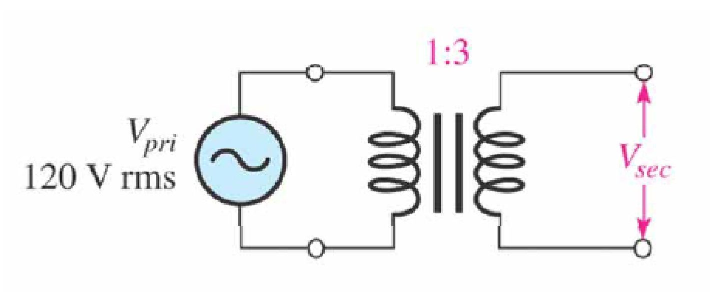
$$\frac{V_{primary}}{V_{secondary}} = \frac{N_{primary}}{N_{secondary}} = \frac{1}{n}$$

where n is called the turn ration of the transformer such that

$$V_{secondary} = nV_{primary}.$$

Example: The transformer is part of a laboratory power supply and has a turns ratio of 0.2. What is the secondary voltage?

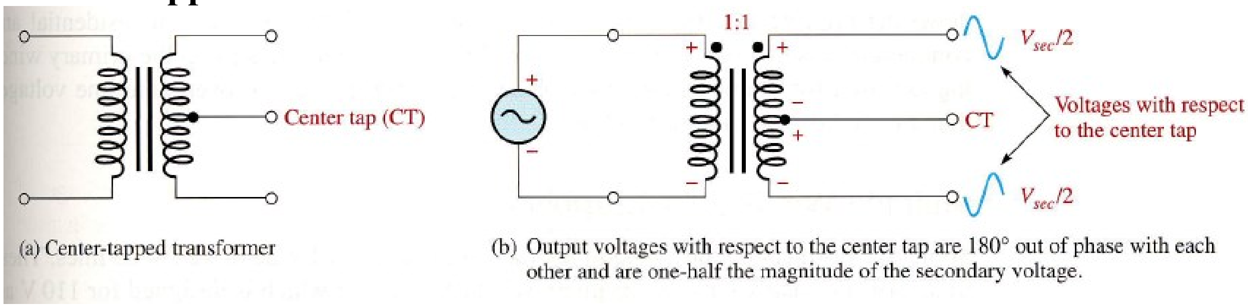
Solution:



$$V_{sec} = (3/1)(120V) = 360 \text{ V}$$

Figure-22

Center Tapped Transformer



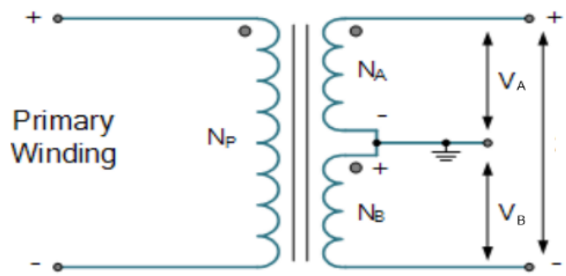


Figure-23

$$V_A = \frac{N_A}{N_P} * V_P \qquad V_B = \frac{N_B}{N_P} * V_P$$

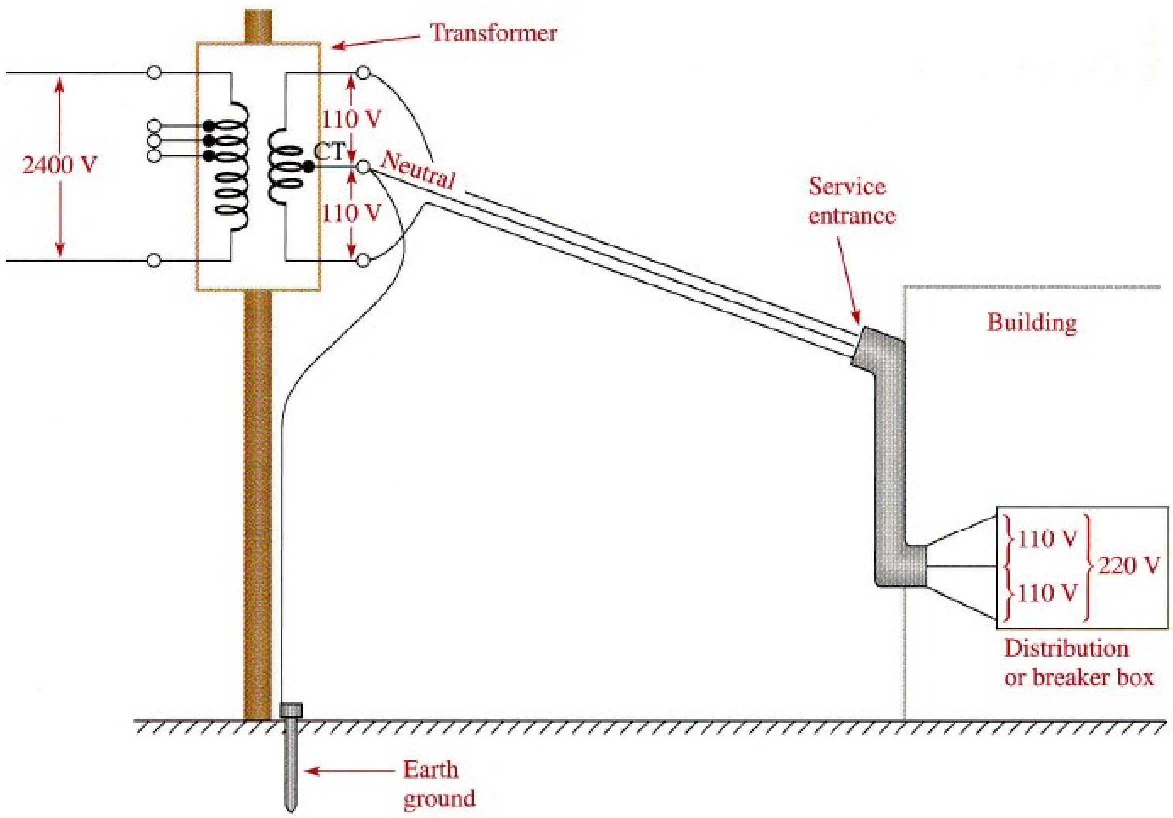


Figure-24

Now we can continue on analyzing the Ring modulator. Initially assume that $m(t) = 0$. On the positive half cycle of the carrier signal, the modulator happens to be as in Figure-25.

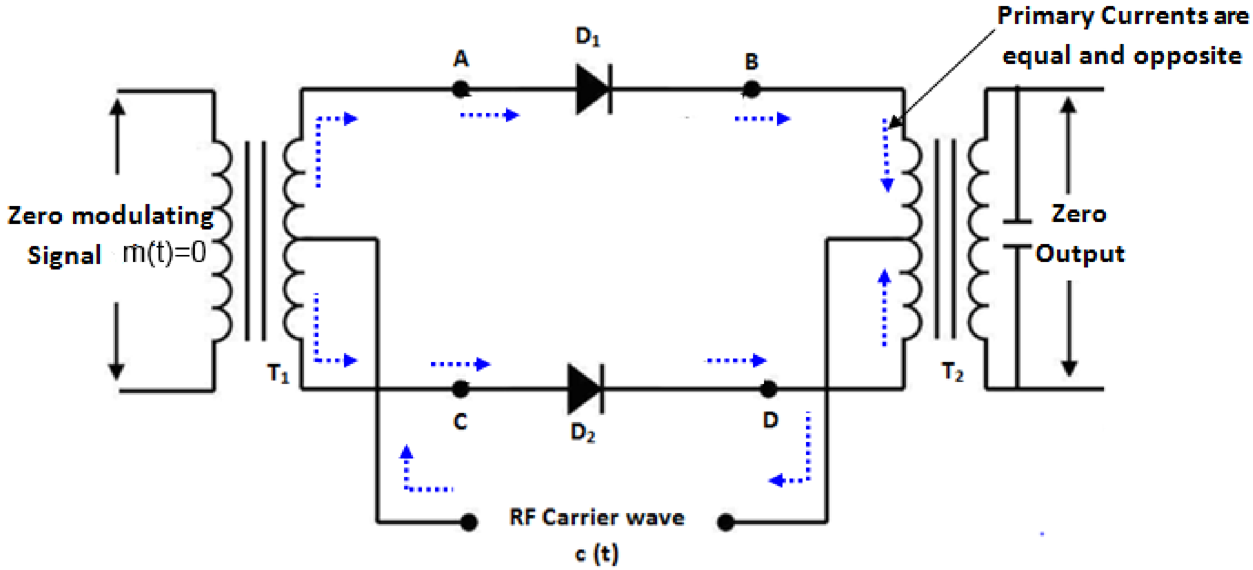


Figure-25

On the negative half cycle of the carrier signal, the modulator happens to be as in Figure-26.

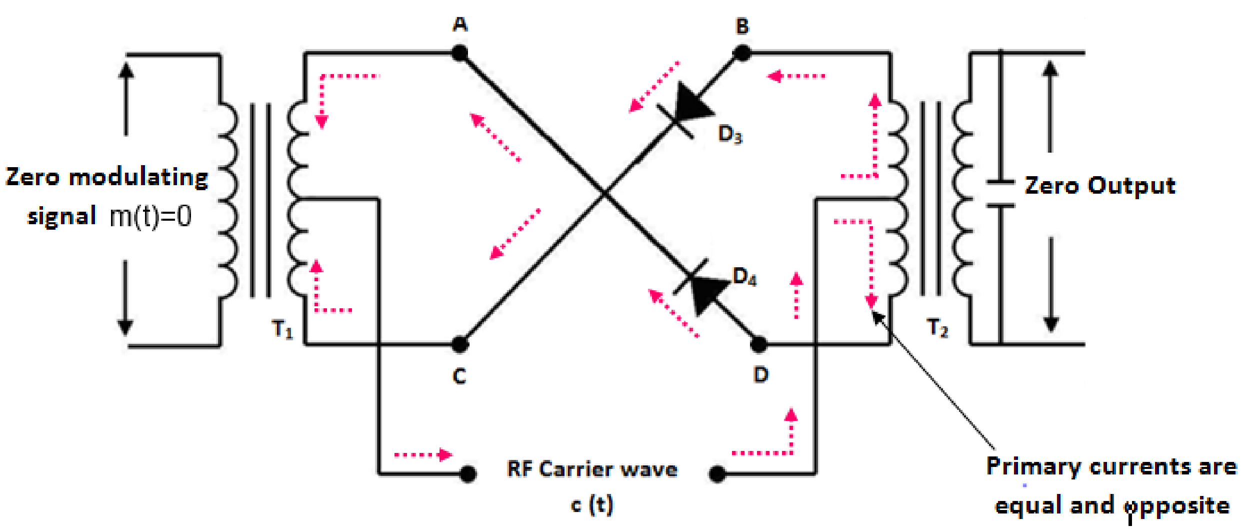


Figure-26

Operation when $m(t)$ is available.

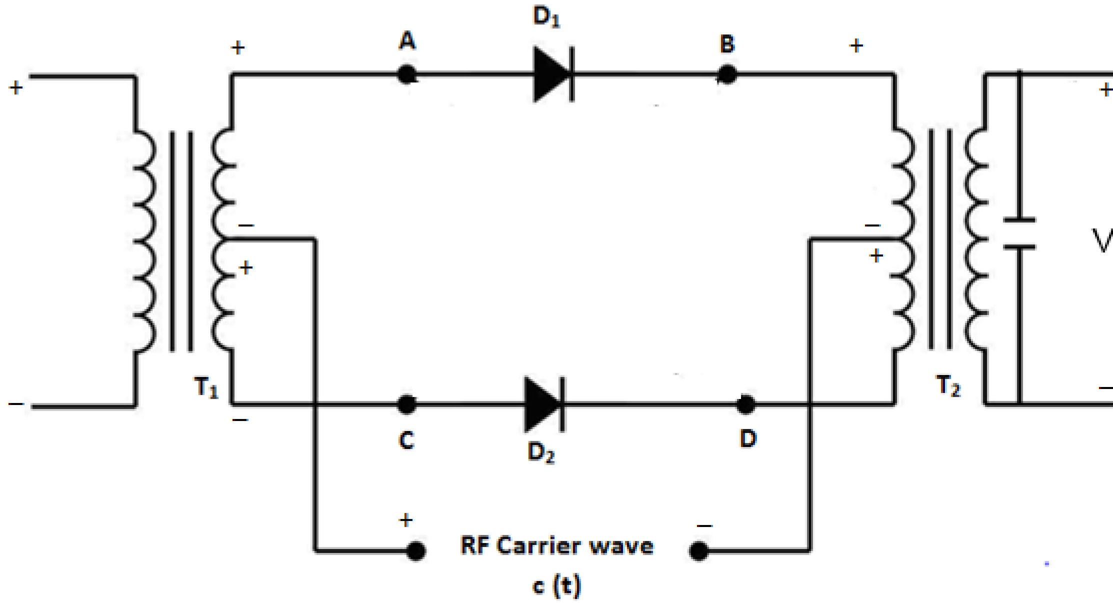


Figure-27

On the positive half cycle of the carrier signal, we can arrange the turn ratios of the transformers such that $V_o = m(t)$.

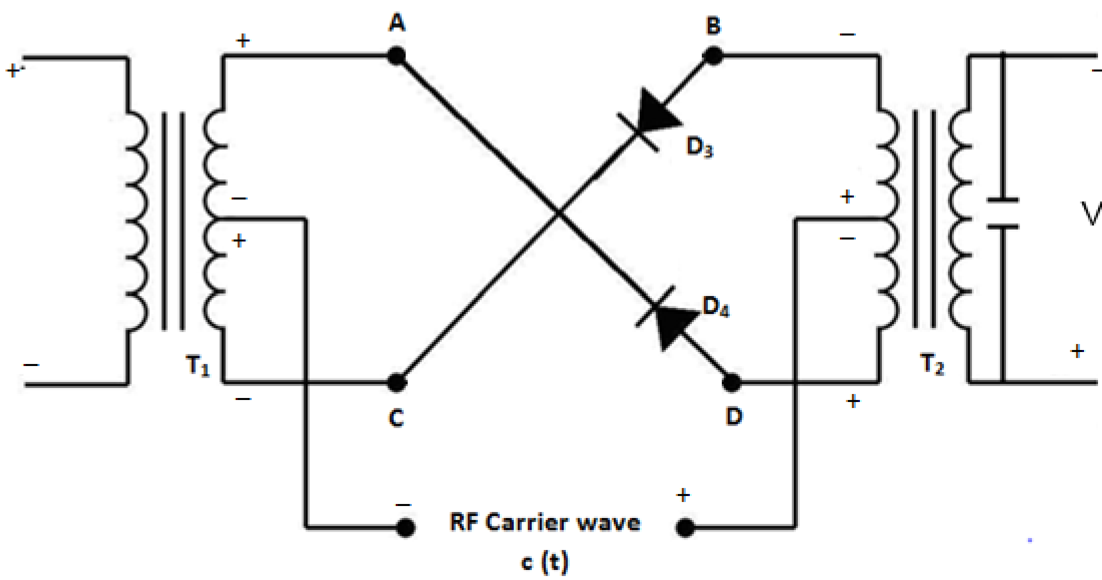


Figure-28

On the negative half cycle of the carrier signal, we can arrange the turn ratios of the transformers such that $V_o = -m(t)$.

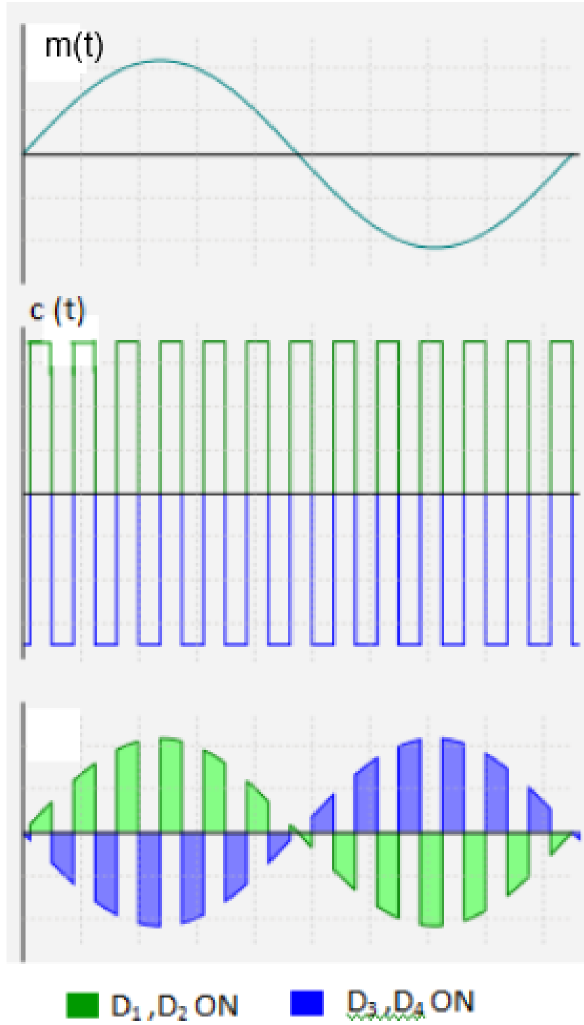


Figure-29

If we place a bandpass filter at the output of the ring modulator we get the filtered signal in Figure-30 which is the DSB-SC AM signal.

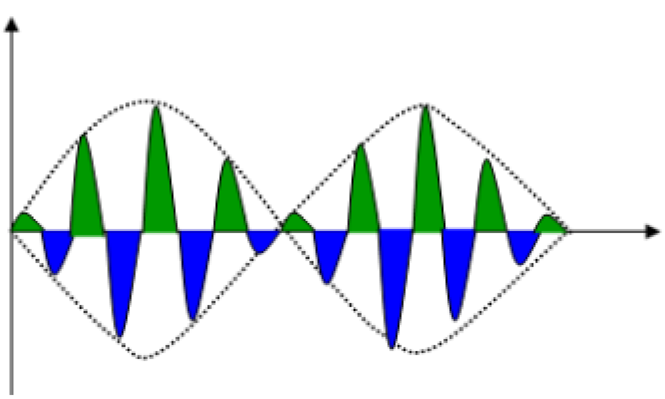


Figure-30 DSB-SC AM Signal