Analog Haberleşme

TB-ÇYB-GM (DSB-SC-AM): modülasyon ve demodülasyon

Orijinal not: Ders7.pdf

UYARI Bu belge, el yazısı ders notlarından Claude (Anthropic) yardımıyla dijitale aktarılmıştır. Yardımcı kaynak olarak hazırlanmıştır; hata veya eksik içerebilir. Lütfen orijinal notları ve ders kaynaklarını esas alın.

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orj. s. 1

Modülasyon

$BG\{m(t)\} = B$ Hz $M(f) = 0,\ |f| > B$

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

* Genlik modülasyonu (Amplitude modulation - AM)
* Frekans modülasyonu (Frequency modulation - FM) } Lineer olmayan (non linear)
* Faz modülasyonu (Phase modulation - PM) } üstel (exponential) mod

Double Sideband Suppressed Carrier AM (DSB-SC-AM)

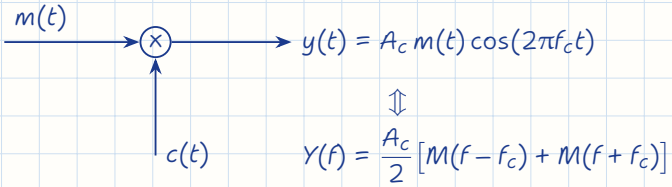
Taşıyıcısı Bastırılmış (TB) Çift Yan Bantlı (ÇYB)
Genlik modülasyonu (Gm)

$m(t)$: Mesaj haber işareti / modüle eden işaret (modulating signal)

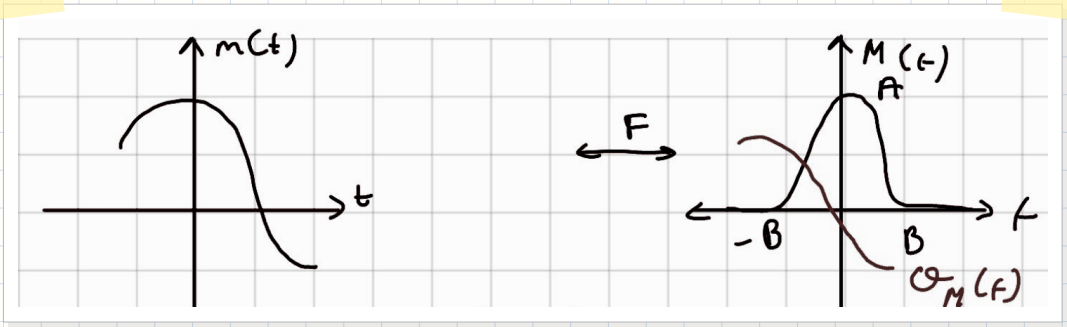
$c(t) = A_c \cos(2\pi f_c t)$ Taşıyıcı işaret (carrier signal)

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

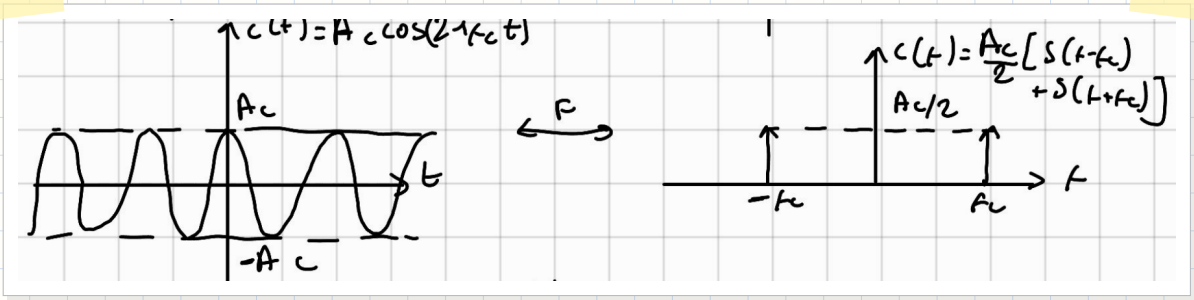
↪ modüle edilmiş işaret
(modüle edilmiş işaret) modulated signal



orj. s. 2

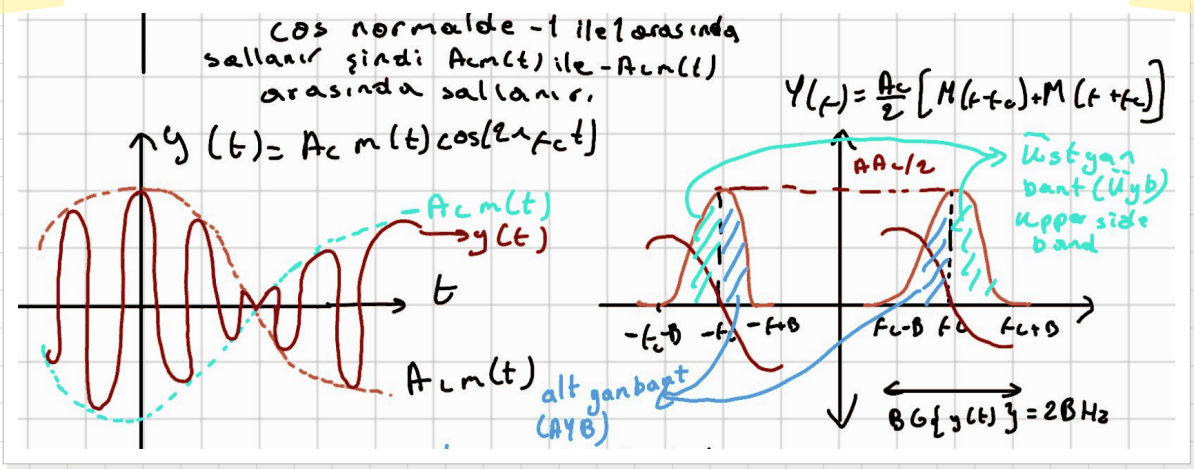


orijinal çizim, s. 2



orijinal çizim, s. 2

cos normalde –1 ile 1 arasında sallanır, şimdi $A_c m(t)$ ile $-A_c m(t)$ arasında sallanır.



orijinal çizim, s. 2

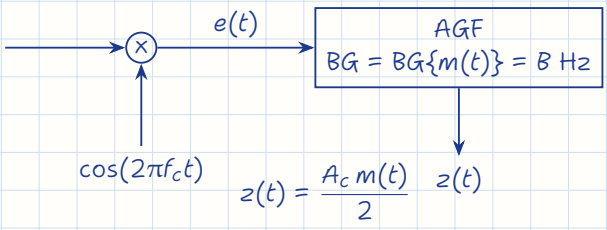
Modülasyon işlemi sonucunda bant genişliği iki katına çıkar. (İşaret Bant geçirene döner) Mesaj işaretleri temel banttadır her zaman.

Taşıyıcısı bastırılmış çünkü frekansa bakınca taşıyıcının frekans bileşenleri gözükmüyor.

orj. s. 3

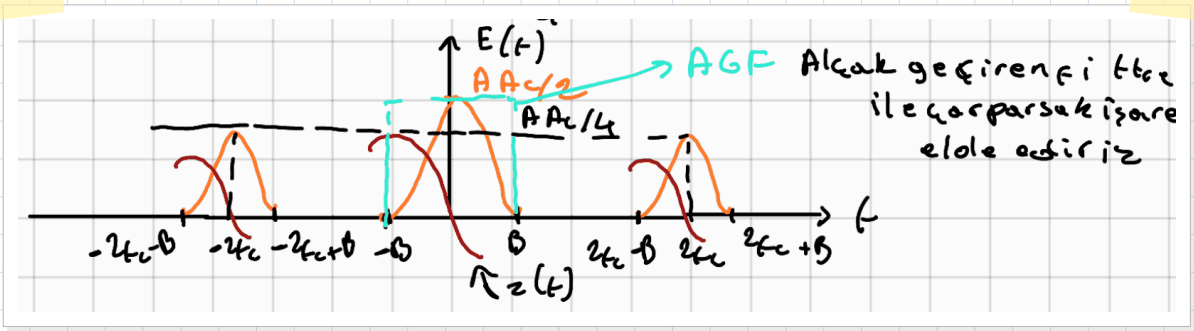
Demodülasyon

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



$$e(t) = y(t)\cos(2\pi f_c t) \quad \rightarrow \quad E(f) = \frac{1}{2}\left[Y(f-f_c) + Y(f+f_c)\right]$$
$$= A_c\, m(t)\cos^2(2\pi f_c t)$$
$$\downarrow \ \frac{1}{2}\left[1+\cos(4\pi f_c t)\right]$$
$$e(t) = \frac{A_c}{2}m(t) + \frac{A_c}{2}m(t)\cos(2\pi\cdot 2f_c t)$$

$$E(f) = \frac{A_c}{2}M(f) + \frac{A_c}{4}\left[M(f-2f_c) + M(f+2f_c)\right]$$



orijinal çizim, s. 3

AGF Alçak geçiren filtre ile çarparsak işareti elde ederiz.

$$Z(f) = \frac{A_c}{2}M(f) \ \rightarrow \ z(t) = \frac{A_c}{2}m(t)$$

f_c'yi küçük seçersek frekansta bileşenler birbirinin üzerine biner ve sinyali tekrar ayıramayız

$$2f_c - B \geq B$$
$$2f_c \geq 2B$$
$$f_c \geq B$$

Birde $f_c - B \geq 0 \Rightarrow f_c \geq B$ Teorik

orj. s. 4

* Pratik olarak bir anten bir dar bantlı işareti ($f_c \gg B$) bozulmasız yayınlayabilir

$$\frac{f_c}{B} \gg 1$$

Ticari genlik modülasyonunda (Radyo yayınları): 550 kHz - 1600 kHz

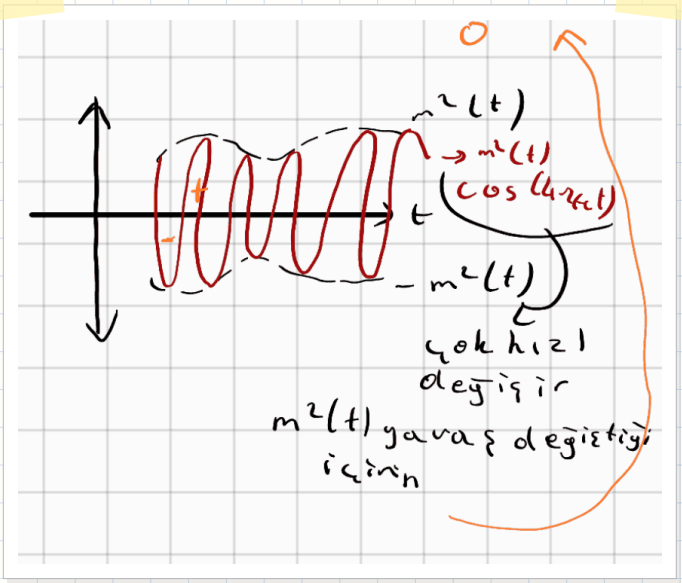
$$100 < \frac{f_c}{B} < 300$$

TB - ÇYB - GM'nin gücü

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

$$\begin{aligned} P_y &= \lim_{T\to\infty}\frac{1}{T}\int_{-T/2}^{T/2} y^2(t)\,dt \\ &= \lim_{T\to\infty}\frac{1}{T}\int_{-T/2}^{T/2} A_c^2\,m^2(t)\,\underbrace{\cos^2(2\pi f_c t)}_{\frac{1}{2}[1+\cos(4\pi f_c t)]}\,dt \\ &= \frac{A_c^2}{2}\Big[\lim_{T\to\infty}\frac{1}{T}\int_{-T/2}^{T/2} m^2(t)\,dt \\ &\quad + \underbrace{\lim_{T\to\infty}\frac{1}{T}\int_{-T/2}^{T/2} m^2(t)\cos(4\pi f_c t)\,dt}_{0}\Big] \\ &= \frac{A_c^2}{2} \end{aligned}$$

$$P_y = \frac{A_c^2}{2}P_m$$



orijinal çizim, s. 4

orj. s. 5

Synchronous / Phase coherent demod

Senkron / Faz tahminli demodülasyon

1) Phase Locked Loop (PLL) devresi
   (Faz kilitlemeli Döngü)

2) Pilot taşıyıcı kullanmak $y(t)$'ye $A_p \cos(2\pi f_c t)$ $(A_p \ll A_c)$ ve bununla sinyal çarpılıp demode edilir → Sayfa 133 Şekil 3.9 (2. baskı 126)

Örnek

$m(t) = \text{sinc}(10^4 t)$

Find DSB-SC-AM signal and its BW if the carrier is a sinusoid with a frequency of 1 MHz

$$y(t) = m(t)\,c(t)$$
$$c(t) = 1\cos(2\pi \cdot 10^6 t)$$
$$y(t) = \text{sinc}(10^4 t)\cos(2\pi \cdot 10^6 t)$$

$$A\,2\,\text{sinc}(2t) \longleftrightarrow A\,\Pi\left(\frac{f}{2}\right)$$

$$\text{sinc}(10^4 t) \longleftrightarrow M(f) = \frac{1}{10^4}\,\Pi\left(\frac{f}{10^4}\right)$$

$$B = \frac{10^4}{2} = 5 \text{ kHz}$$
$$\text{BW}\{y(t)\} = 2B = 10 \text{ kHz}$$

orj. s. 6

Örnek

Tone modulation: $m(t) = A\cos(2\pi f_m t)$, $f_m \ll f_c$ (saf cosinüs ise; çünkü tek bir frekansı var)

$$M(f) = \frac{A}{2}\left[\delta(f - f_m) + \delta(f + f_m)\right]$$

$$\begin{aligned} y(t) = m(t)\,c(t) &= m(t)\,A_c\cos(2\pi f_c t) \\ &= AA_c\cos(2\pi f_m t)\cos(2\pi f_c t) \\ &= \frac{AA_c}{2}\left[\cos\left(2\pi \underbrace{(f_c - f_m)}_{=f_1} t\right) + \cos\left(2\pi \underbrace{(f_c + f_m)}_{f_2} t\right)\right] \end{aligned}$$

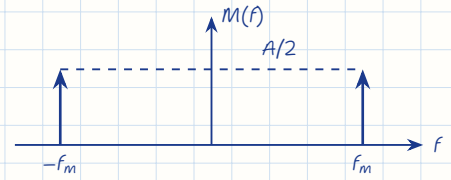
$$Y(f) = \frac{AA_c}{4}\left[\delta(f - f_1) + \delta(f + f_1) + \delta(f - f_2) + \delta(f + f_2)\right]$$

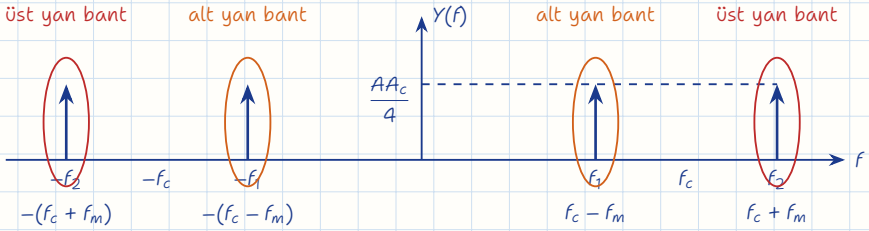
$$e(t) = y(t)\cos(2\pi f_c t) = A_c\,m(t)\,\underbrace{\cos^2(2\pi f_c t)}_{\frac{1}{2}[1+\cos(2\pi\,2f_c t)]}$$

$$= \frac{A_c}{2}\overbrace{m(t)}^{A\cos(2\pi f_m t)} + \frac{A_c}{2}\,m(t)\cos(2\pi\,2f_c t)$$

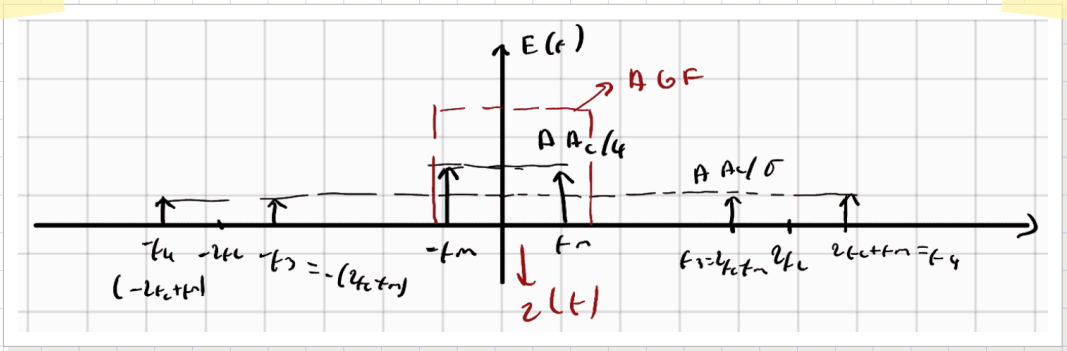
$$e(t) = \frac{AA_c}{2}\cos(2\pi f_m t) + \frac{AA_c}{2}\underbrace{\cos(2\pi f_m t)\cos(2\pi\,2f_c t)}$$
$$\frac{1}{2}\left[\cos\left(2\pi \underbrace{(2f_c - f_m)}_{=f_3} t\right) + \cos\left(2\pi \underbrace{(2f_c + f_m)}_{=f_4} t\right)\right]$$

$$E(f) = \frac{AA_c}{4}\left[\delta(f - f_m) + \delta(f + f_m)\right] + \frac{AA_c}{8}\left[\delta(f - f_3) + \delta(f + f_3) + \delta(f - f_4) + \delta(f + f_4)\right]$$





orj. s. 7



orijinal çizim, s. 7

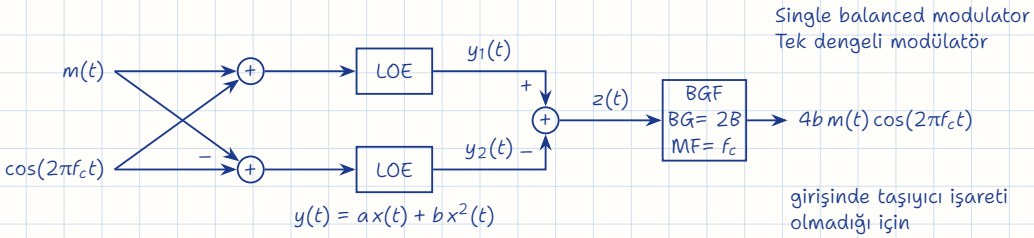
$$P_y = \frac{A_c^2}{2}P_m = \frac{A_c^2}{2}\cdot\frac{A^2}{2} = \frac{A^2A_c^2}{4}$$

$$y_a(t) = \frac{AA_c}{2}\cos(2\pi f_1 t) \quad \rightarrow P_{y_a} = \frac{A^2A_c^2}{8}$$

$$y_{ü}(t) = \frac{AA_c}{2}\cos(2\pi f_2 t) \quad \rightarrow P_{y_{ü}} = \frac{A^2A_c^2}{8}$$

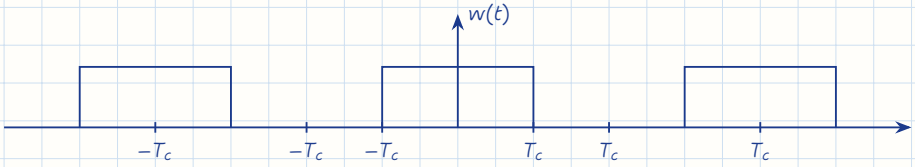
Modülatörler

- Multiplier modulator (Çarpım modülatörü)
- Nonlinear modulator (Lineer olmayan modülatör)



$$\left.\begin{aligned} x_1(t) &= m(t) + \cos(2\pi f_c t) \\ x_2(t) &= -m(t) + \cos(2\pi f_c t) \end{aligned}\right\} \quad \begin{aligned} z(t) &= y_1(t) - y_2(t) \\ &= 2a\,m(t) + 4b\,m(t)\cos(2\pi f_c t) \end{aligned}$$

Anahtarlama modülatörü (Switching modulator)

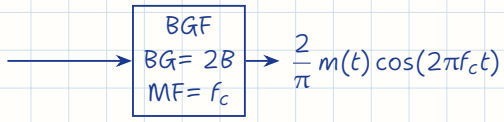


$$w(t) = \frac{1}{2} + \frac{2}{\pi}\left[\cos(2\pi f_c t) - \frac{1}{3}\cos(2\pi\, 3 f_c t) + \frac{1}{5}\cos(2\pi\, 5 f_c t) + \cdots\right]$$

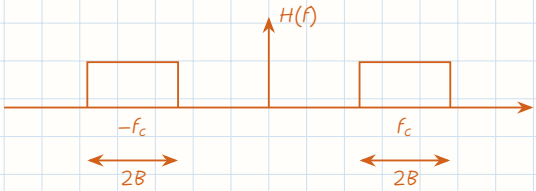
$$m(t)\,w(t) = \frac{1}{2}m(t) + \frac{2}{\pi}\left[m(t)\cos(2\pi f_c t) - \frac{1}{3}m(t)\cos(2\pi\, 3 f_c t) + \frac{1}{5}m(t)\cos(2\pi\, 5 f_c t) + \cdots\right]$$

(Orijinalde $\frac{1}{2}m(t)$, $\cos(2\pi\, 3 f_c t)$ ve $\cos(2\pi\, 5 f_c t)$ terimlerinin üzeri kırmızı kalemle çizilmiş.)

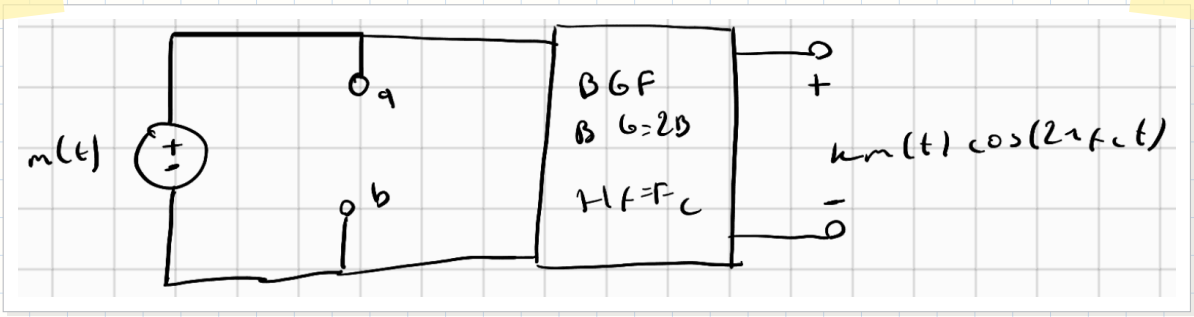
orj. s. 8



$B = BG\{m(t)\}$

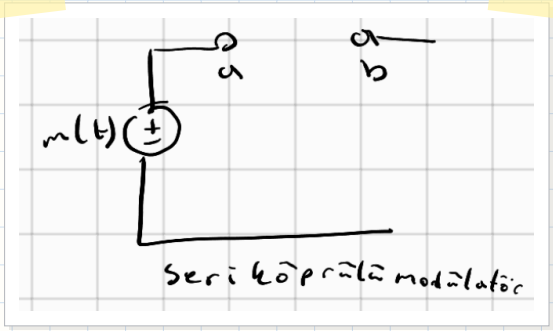


Nasıl çarpım yaparız



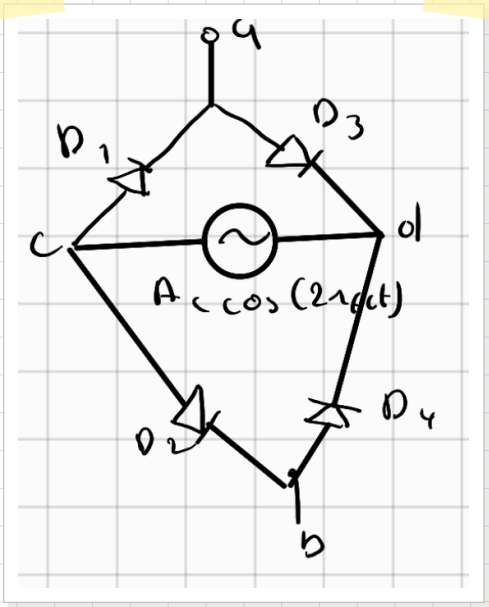
orijinal çizim, s. 8

Shunt bridge modulator (paralel köprülü modülatör)



orijinal çizim, s. 8

Seri köprülü modülatör



orijinal çizim, s. 8

$$D_1 \equiv D_2, \qquad D_3 \equiv D_4$$

$v_c > v_d \Rightarrow$ Diyotlar iletimde $\Rightarrow a = b$

$V_a = V_b$ kısa devre

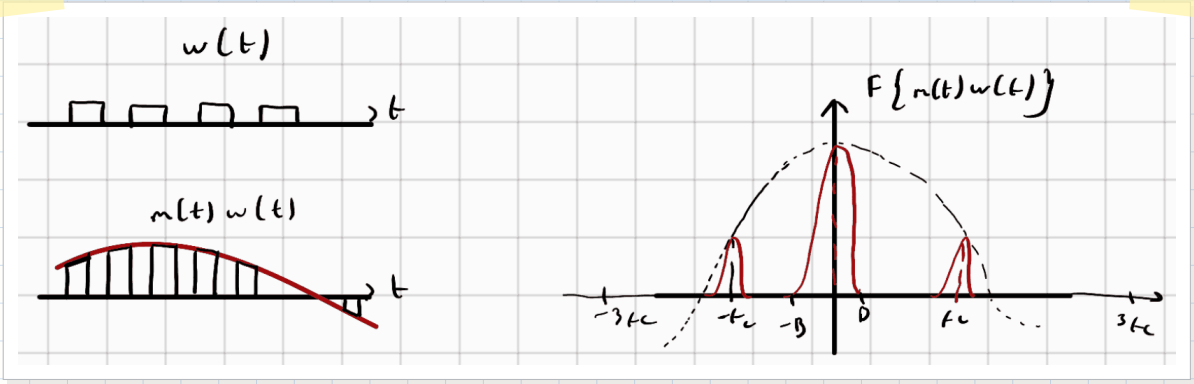
$v_c < v_d \Rightarrow$ Diyotlar kesimde $\Rightarrow a$ ve b arası açık devre

Bu olay T_c ile periyodik olarak gerçekleşir.

orj. s. 9

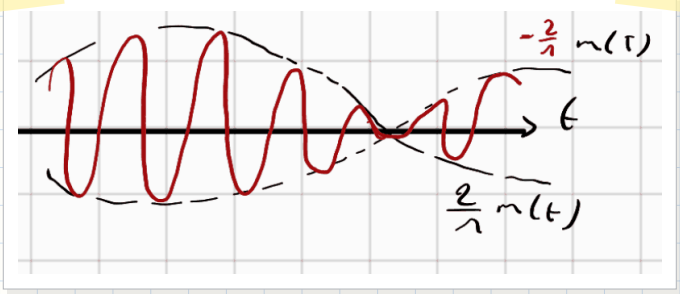


orijinal çizim, s. 9



orijinal çizim, s. 9

BGF
BG= 2B
MF= f_c
→ $\frac{2}{\pi} m(t)\cos(2\pi f_c t)$



orijinal çizim, s. 9

Ring modulator (Double balanced mod.) okuyunuz *

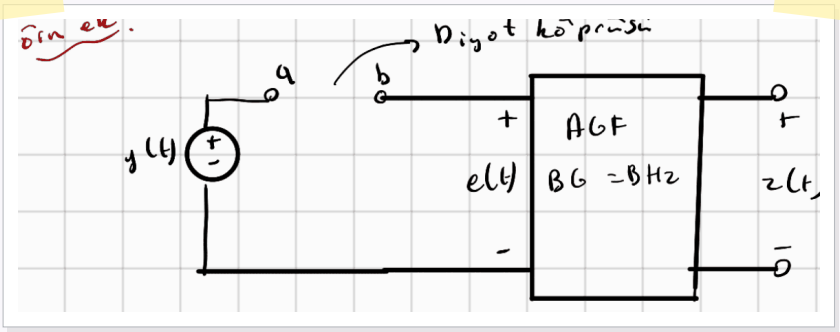
Demodülasyon ? anahtarlama nasıl yapılır??

Demodülatör

Çarpıcı + AGF

Senkron demodülasyon yapılmalı

Örnek



orijinal çizim, s. 9

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

orj. s. 10

$$\begin{aligned} e(t) &= y(t)\, w(t) \\ &= A_c\, m(t) \cos(2\pi f_c t) \cdot \underbrace{\left\{ \frac{1}{2} + \frac{2}{\pi}\left[\cos(2\pi f_c t) - \frac{1}{3}\cos(2\pi\, 3 f_c t) + \frac{1}{5}\cos(2\pi\, 5 f_c t) + \cdots \right] \right\}}_{w(t)} \\ &= \underbrace{\frac{2A_c}{\pi}\, m(t) \cos^2(2\pi f_c t)}_{\frac{2A_c}{\pi}\, m(t)\, \frac{1}{2}\left[1+\cos(2\pi\, 2 f_c t)\right]} + \overbrace{\underbrace{k\, m(t) \cos(2\pi f_c t)}_{k\, m(t)\cos(2\pi n f_c t),\ n \neq 1}}^{\text{genellikle}} \\ &= \frac{A_c}{\pi}\, m(t) + \frac{A_c}{\pi}\, m(t) \cos(2\pi\, 2 f_c t) \end{aligned}$$

(Orijinalde son satırdaki ikinci terim ile daire içindeki terimin altındaki ifade kırmızı kalemle işaretlenmiş/çizilmiş.)

$$e(t) \rightarrow \boxed{AG} \rightarrow \frac{A_c}{\pi}\, m(t) = z(t)$$