Problem 3.29

(a) Using the terminated series expansion $\exp(-x) \approx 1 - x + \frac{x^2}{2} - \frac{x^3}{6}$ we may express the diode current i, normalized with respect to I_0, as

$$\frac{i}{I_0} = \exp\left(-\frac{v}{V_T}\right) - 1$$

$$= -\frac{v}{V_T} + \frac{1}{2}\left(\frac{v}{V_T}\right)^2 - \frac{1}{6}\left(\frac{v}{V_T}\right)^3 \quad (1)$$

(b) Given

$$\frac{v}{V_T} = \frac{0.01}{0.026}[\cos(2\pi f_m t) + \cos(2\pi f_c t)]$$

$$\approx 0.385[\cos(2\pi f_m t) + \cos(2\pi f_c t)] \quad (2)$$

we find that substitution of Eq. (2) into (1) yields

$$\frac{i}{I_0} \approx -0.385[\cos(2\pi f_m t) + \cos(2\pi f_c t)]$$

$$+ 0.074[\cos(2\pi f_m t) + \cos(2\pi f_c t)]^2$$

$$- 0.0095[\cos(2\pi f_m t) + \cos(2\pi f_c t)]^3 \quad (3)$$

Next, using the identities

$$\cos^2\theta = \frac{1}{2}[1 + \cos(2\theta)]$$

$$\cos^3\theta = \frac{3}{4}\cos\theta + \frac{1}{4}\cos(3\theta)$$

$$\cos\theta\cos\phi = \frac{1}{2}[\cos(\theta + \phi) + \cos(\theta - \phi)]$$

we may rewrite Eq. (3) in the form:

$$\frac{i}{I_0} = 0.074 - 0.406[\cos(2\pi f_m t) + \cos(2\pi f_c t)]$$

$$+ 0.037\{\cos(4\pi f_m t) + \cos(4\pi f_c t) + \cos[2\pi(f_c + f_m)t] + \cos[2\pi(f_c - f_m)t]\}$$

$$- 0.0016[\cos(6\pi f_m t) + \cos(6\pi f_c t)]$$

$$- 0.0071\{\cos[2\pi(f_c + 2f_m)t] + \cos[2\pi(f_c - 2f_m)t]$$

$$+ \cos[2\pi(2f_c + f_m)t] + \cos[2\pi(2f_c - f_m)t]\}$$

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Problem 3-29 continued

For f_m - 1 kHz and f_c = 100 kHz, we thus find that the discrete amplitude spectrum of the diode current i (for $f \geq 0$) is as shown in Fig. 1.

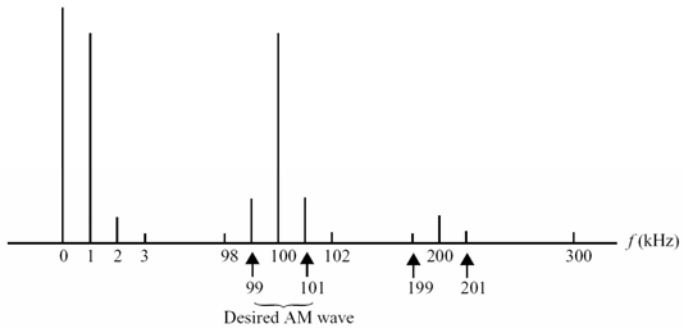

Figure 1

(c) From the amplitude spectrum of Fig. 1 we see that in order to extract an AM wave with carrier frequency f_c from the diode current i, we need a band-pass filter that passes only the frequency components: 99, 100 and 101 kHz, corresponding to f_c - f_m, f_c, and $f_c + f_m$, respectively. We therefore require a band-pass filter with center frequency 100 kHz and bandwidth 2 kHz.

(d) The resulting band-pass filter output is

$$\frac{i}{I_0} = -0.406\cos(2\pi f_c t) + 0.148\cos(2\pi f_c t)\cos(2\pi f_m t)$$

$$= -0.406[1 - 0.362\cos(2\pi f_m t)]\cos(2\pi f_c t)$$

The percentage modulation is therefore 36.2 percent.

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