通訊系統

期末考輔導課

2021.01.08

1. **Remaining part shall be done by yourself**

2. **Highly recommend to read text book!**

Q1

(1) Draw the model of FM receiver

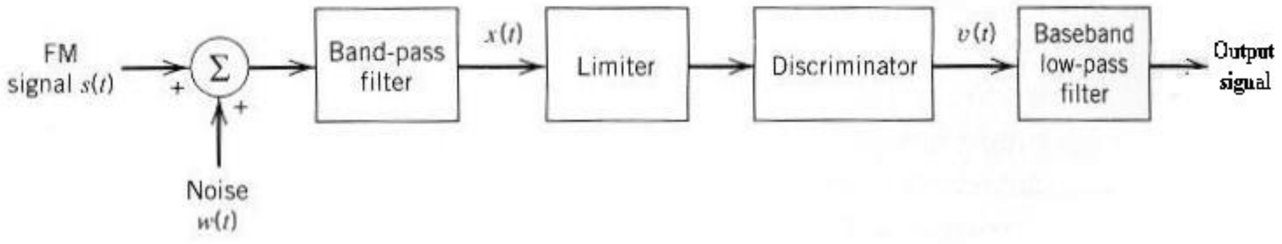

FIGURE 2.40 Model of an FM receiver.

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(2) Why add a limiter in the FM receiver

=> 限制訊號大小，砍掉其他雜訊，以避免失真。

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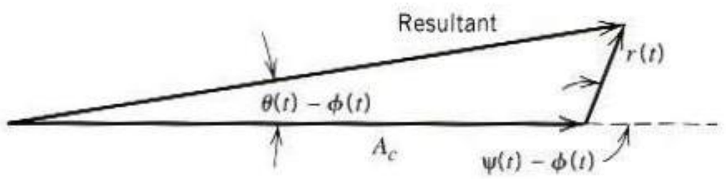
(3) Using the phasor diagram to determine the discriminator output θ(t) for FM in AWGN channel. Assuming high carrier to noise ratio.



$$\therefore \theta(t) = \phi(t) + \frac{r(t)\sin[\psi(t) - \phi(t)]}{A_c + 0}$$

$$\phi(t) = 2\pi k_f \int_0^t m(t)dt$$

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Q2 (1) What is the power spectral density of FM RCVR output ?

$$S_{N_0}(f) = \begin{cases} \dfrac{N_0 f^2}{A_c{}^2}, |f| \le W \\ 0, otherwise \end{cases}$$

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(2) What is the average signal power, average noise power and output SNR ?

$$(SNR)_o = \frac{k_f^{\,2}P}{\dfrac{2N_0W^3}{3A_c^{\,2}}} = \frac{3A_c^{\,2}k_f^{\,2}P}{2N_0W^3}$$

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average signal poewr : $k_f^{\,2}P$

noise power : $\dfrac{2N_0W^3}{3A_c^{\,2}}$

Q3 (1) what is the FM threshold effect ?

=> 当載波雜訊比(ρ)小於閘限值(ρ_{th})，其輸出訊雜比$(SNR)_o$会失真，明顯產生偏移

=> 当載波雜訊比ρ高，則$(SNR)_{o,FM} = 3\rho\left(\frac{B_t}{2W}\right)^3$

(2) Why FM is used for satellite communication? Please state the reasons.

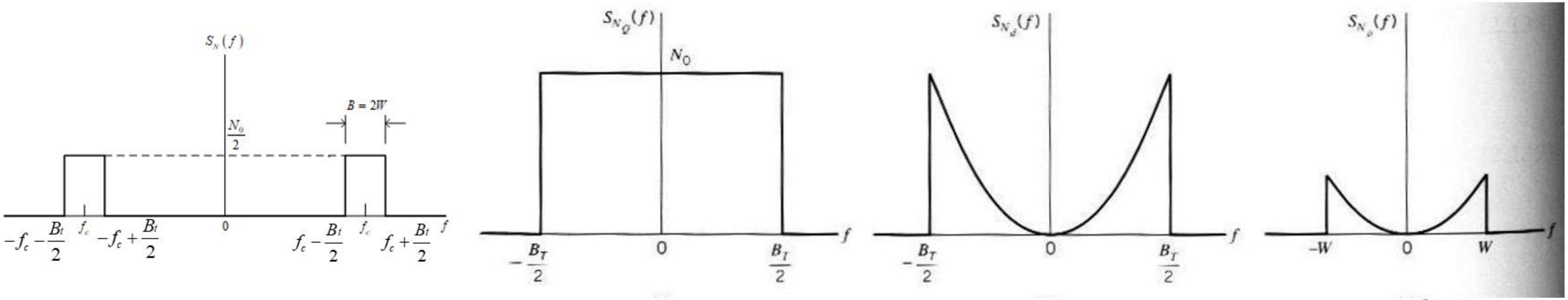
1、FM 閘限展延能使 P_{th} 下降，可以降低傳輸功率，就算收到弱訊号也不失真

2、发射机 PA 的非線性效應，只会改变震幅大小，不会改变相位

Q4

An FM signal with message bandwidth W Hz is passed through an AWGN channel with the white noise w(t).

Write the equation to generate power spectral density of w(t), n(t), nQ(t), nd(t), no(t)



$S_w(f) = \frac{N_0}{2}$

$S_n(f) = \frac{N_0}{2}, -\frac{B_t}{2} \le f \le \frac{B_t}{2}$

$S_{N_Q}(f) = N_0, -\frac{B_t}{2} \le f \le \frac{B_t}{2}$

$S_{N_d}(f) = \begin{cases} \frac{N_0 f^2}{A_c^2}, -\frac{B_t}{2} \le f \le \frac{B_t}{2} \\ 0, otherwise \end{cases}$

$S_{N_0}(f) = \begin{cases} \frac{N_0 f^2}{A_c^2}, |f| \le W \\ 0, otherwise \end{cases}$

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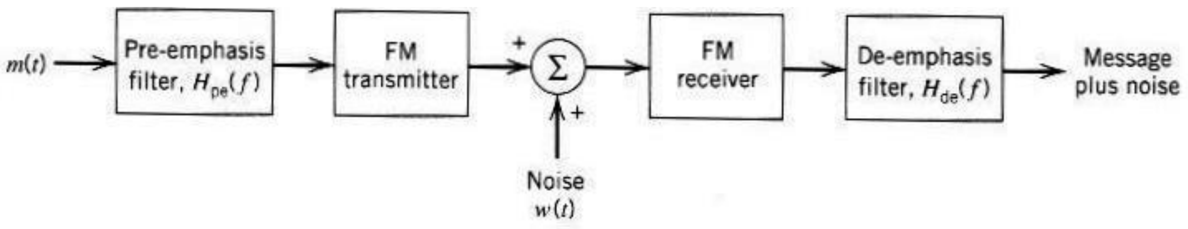
Q5 (1) What is the function of pre-emphasis filter and De-emphasis filter in FM transceiver.

$$H_{Pe}(f) = 1 + \frac{jf}{f_0}$$

$$H_{De}(f) = \frac{1}{1 + \frac{jf}{f_0}}$$



(2) Why they are needed.

pre-emphasis filter(預強化濾波器): 強化高頻訊號

De-emphasis filter(去強化濾波器): 將高頻部分雜訊抑制掉，使訊號還原

Q6 Please draw the block diagram of PLL and state the major components.

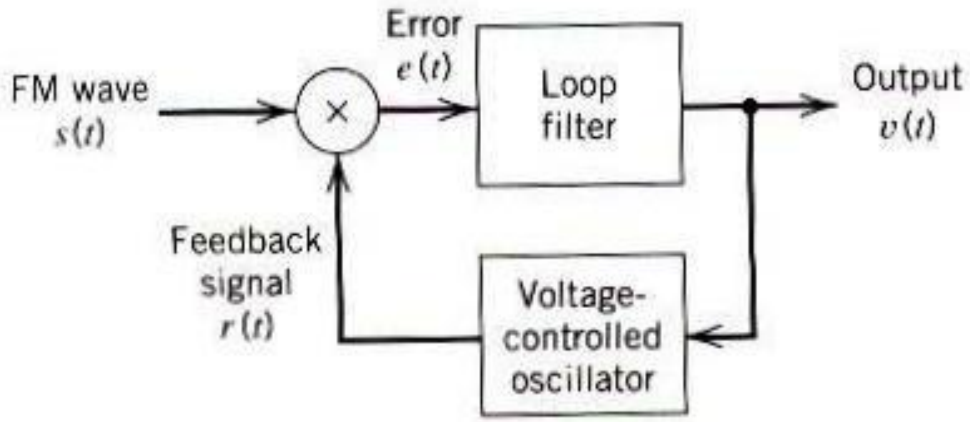


FIGURE 2.51 Phase-locked loop.

① 相位偵測器 (phase detector)

② 迴路濾波器 (LPF loop filter)

③ 電壓控制震盪器 (voltage - controlled oscillator)

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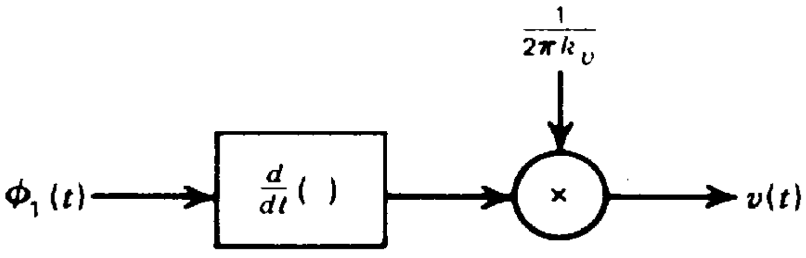
Q7 (1). Please draw the block diagram of simplified linear model of PLL, when loop gain is greater than 1.



(b)

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Q8: Compare the (1) figure of merit, (2) output signal to noise ratio for a fixed channel signal to noise ratio and (3) Transmission bandwidth for AM, DSBSC, LSBSC with beta = 2.5 respectively

(1) $FOM_{AM} = \frac{u^2}{2+u^2} < 1$, $FOM_{AM,100\%} \; (u=1) = \frac{1}{3}$

$FOM_{DSBSC} = 1$

$FOM_{LSBSC} = 1$

$FOM_{FM} = \frac{3}{2}D^2 = \frac{3}{2}\beta^2 = 6$

(2) $SNR_{O,AM} = \frac{A_c^2 k_a^2 P_{av,m}}{2WN_0}$

$SNR_{O,DSB\text{-}SC} = \frac{c^2 A_c^2 P_{av,m}}{2N_0W}$

$SNR_{O,LSBSC} = \frac{c^2 A_c^2 P_{av,m}}{4N_0W}$

$SNR_{O,FM} = \frac{3A_c^2 k_f^2 P_{av,m}}{2N_0W^3}$

(3) $B_{t,AM} = 2W$ (Hz)

$B_{t,DSBSC} = 2W$ (Hz)

$B_{t,LSBSC} = W$ (Hz)

$B_{t,FM} = 2(W + \Delta f) = 2W(\beta+1) = 6W$ Hz

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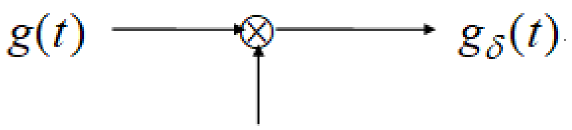
課後問答10

Q1

If the bandwidth of analog signal g(t) is W Hz, the Nyquist sampling rate is used to get PAM signal.

(1) Write the spectrum equation of $G_\delta(f)$ in terms of G(f).



$$s_\delta(t) = \sum_{n=-\infty}^{\infty} \delta(t - nT_s)$$

$$g_\delta(t) = g(t)s_\delta(t) = \sum_{n=-\infty}^{\infty} g(nT_s)\delta(t - nT_s)$$

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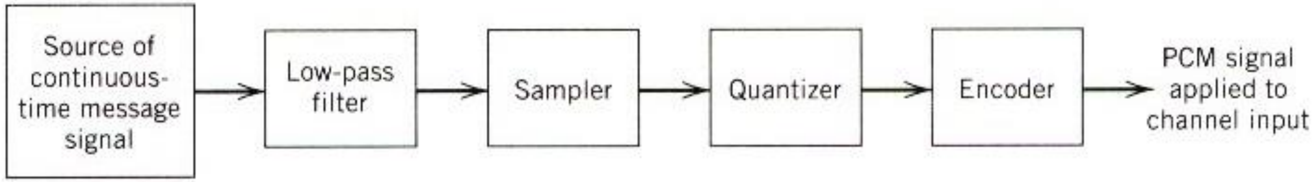
$$G_\delta(f) = f_s \sum_{m=-\infty}^{\infty} G(f - mf_s)$$

= 2wG(f+2w) + 2wG(f) + 2wG(f-2w) + ...

(2) Please draw the block diagram of a PCM transmitter.



(a) Transmitter

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(3) Determine the frequency transfer function of the LPF.

$H(f) = \frac{1}{f_s} \, \mathrm{rect}\left(\frac{f}{2w}\right) = \frac{1}{f_s}, \ -w \le f \le w$

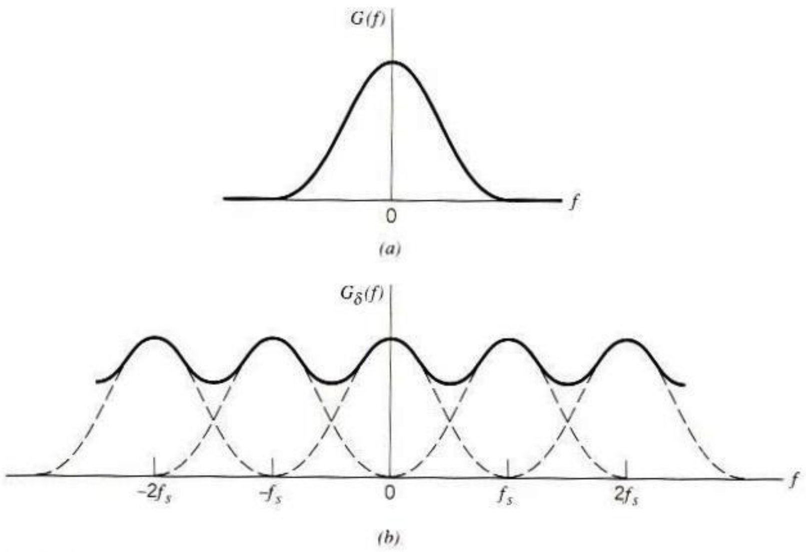
$h(t) = \mathrm{sinc}(2wt)$

Q2

(1) How do you avoid the aliasing?

取樣頻率要大於兩倍 Nyquist rate $$f_s \geq 2W$$

(2) Draw the sampled spectrum with aliasing error.



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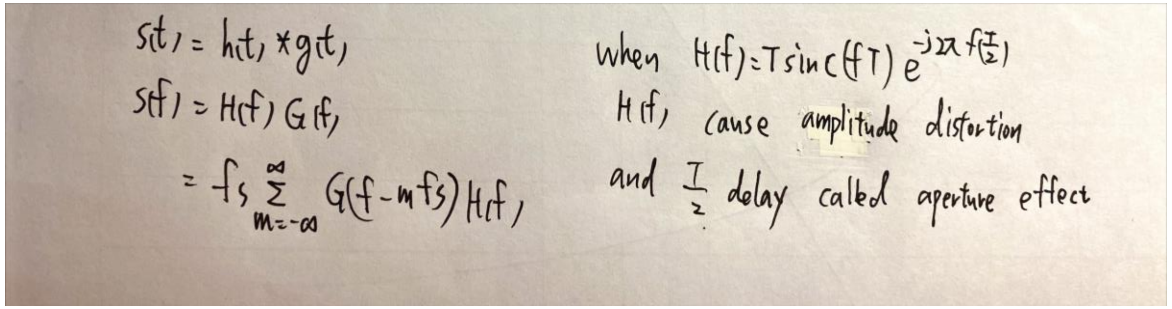
Q3

(1) If the impulse response of zero order hold circuit is $h(t)=1,\ 0 \leq t \leq T$, please use the transfer function explain the aperture effect.



$s(t) = h(t) * g(t)$

$S(f) = H(f)\,G(f)$

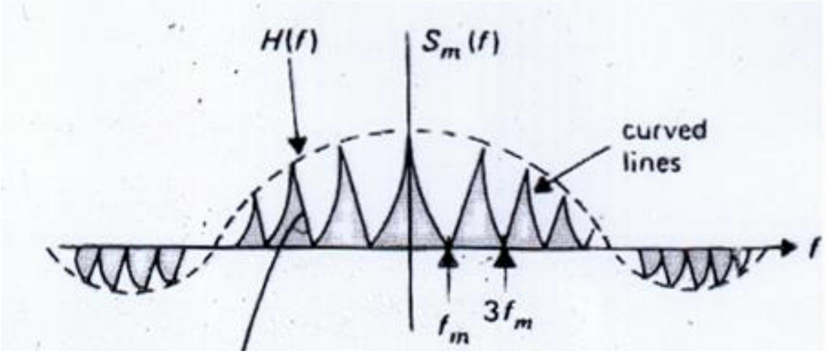
$= f_s \sum_{m=-\infty}^{\infty} G(f - m f_s)\,H(f)$

when $H(f) = T\,\mathrm{sinc}(fT)\,e^{-j2\pi f(\frac{T}{2})}$

$H(f)$ cause amplitude distortion

and $\frac{T}{2}$ delay called aperture effect

(2) Draw the spectrum of a sampled signal $g_\delta(t)$ with aperture effect 孔徑效應.



aperture effect 孔徑效應:

zero order hold 所造成，導致取樣頻譜的振幅失真和相位失真

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(3) Why do you need zero order hold circuit ?

使訊號穩定，避免訊號產生氣泡

所以使用**zero order hold** 把訊號**hold**住一段時間

Q4

(1) For a sinusoidal signal $g(t) = A_m \sin 2\pi ft$, the quantized sample is encoded with R bits, derive the output signal to noise ratio of A/D.

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$g(t) = A_m \sin 2\pi ft$

$M_{max} = A_m$

$\Rightarrow \Delta = \frac{2A_m}{2^R}$

$\sigma_q^2 = \frac{1}{3} M_{max}^2 \, 2^{-2R} = \frac{1}{3} A_m^2 \, 2^{-2R}$

$$(SNR)_o = \frac{P}{\sigma_p^2} = \left(\frac{3P}{M_{max}^2}\right) 2^{2R}$$

$$= \left(\frac{3P}{A_m^2}\right) 2^{2R} = \frac{3}{2}\, 2^{2R}$$

$\therefore 10\log(SNR)_o = 1.8 + 6R$ (dB)

$\boxed{\text{公式}}$

$$\Delta = \frac{2M_{max}}{2^R}$$

$$\sigma_q^2 = \frac{\Delta^2}{12} = \frac{1}{3} M_{max}^2 \, 2^{-2R}$$

$$SNR_o = \frac{P}{\sigma_p^2} = \left(\frac{3P}{M_{max}^2}\right) 2^{2R}$$

(2) If R=8 bits, what is the gain of A/D.

$R = 8$ bits $\Rightarrow 10\log(SNR)_o = 1.8 + 6 \times 8$

$= 49.8$ (dB)

(3) What is the function of oversampling? Please state the reasons.

oversampling A/D $\Rightarrow f_s \gg 2W$

(取樣頻率大於2倍頻寬)

量化雜訊平均分佈在 $(-\frac{f_s}{2}, \frac{f_s}{2})$，所以雜訊在

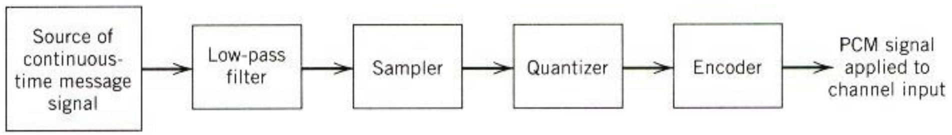
$W < |f| < \frac{f_s}{2}$ 可被低通濾波器濾除 ($f_s \uparrow$, $\sigma_q^2 \downarrow$)

$\Rightarrow$ 目的：降低雜訊

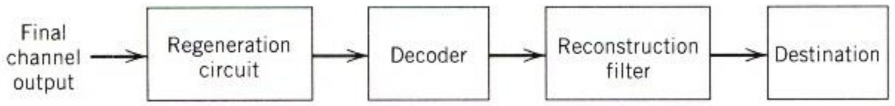
Q5

Please draw the block diagram of a PCM transmitter and receiver.

 # should add one blocks respectively.



(a) Transmitter



(c) Receiver

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Write the impulse response equation $h_i(t)$ of ideal reconstruction filter.

$$h_i(t) = \mathrm{sinc}(2Wt)$$

Write the output equation of ideal reconstruction filter. If the bandwidth of analog signal g(t) is W Hz, the Nyquist sampling rate is used to get PAM signal.

$$g(t) = g_\delta(t) * h_i(t)$$

$$= \sum_{n=-\infty}^{\infty} g(nT_s)\,\delta(t-nT_s) * h_i(t)$$

$$= \sum_{n=-\infty}^{\infty} g(nT_s)\,h_i(t-nT_s)$$

$$= \sum_{n=-\infty}^{\infty} g(nT_s)\,\sin(2W(t-nT_s))$$

By teacher's note

Q6

A TDM (分時多工) is used for four users, which have bandwidth of $w_1=w_2=10\text{k Hz}$, $w_3=20\text{k Hz}$, $w_4=40\text{k Hz}$

(1) What is the maximum sample interval ? (用戶最取頻寬去求得最大取樣區間)

$$\boxed{T=\frac{1}{2W}}$$

$$W_1 = 10k(Hz) \Rightarrow \frac{1}{20k} = T_1$$

$$W_2 = 10k(Hz) \Rightarrow \frac{1}{20k} = T_2$$

$$W_3 = 20k(Hz) \Rightarrow \frac{1}{40k} = T_3$$

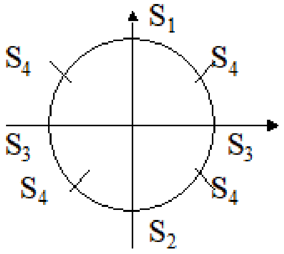
$$W_4 = 40k(Hz) \Rightarrow \frac{1}{80k} = T_4$$

$$\therefore T_s = \frac{1}{20k} \ (sec)$$

(2) Determine the number of samples per sampling interval. (每個取樣區間的樣本)

$$n_s = \frac{T_s}{T_1} + \frac{T_s}{T_2} + \frac{T_s}{T_3} + \frac{T_s}{T_4}$$

$$= \frac{\frac{1}{20}}{\frac{1}{20}} + \frac{\frac{1}{20}}{\frac{1}{20}} + \frac{\frac{1}{20}}{\frac{1}{40}} + \frac{\frac{1}{20}}{\frac{1}{80}} = 1+1+2+4 = 8$$



$S_1S_4S_3S_4S_2S_4S_3S_4S_1S_4S_3S_4S_2S_4S_3S_4$

← one period →

(3) Determine the data rate for 8 bits PCM modulation.

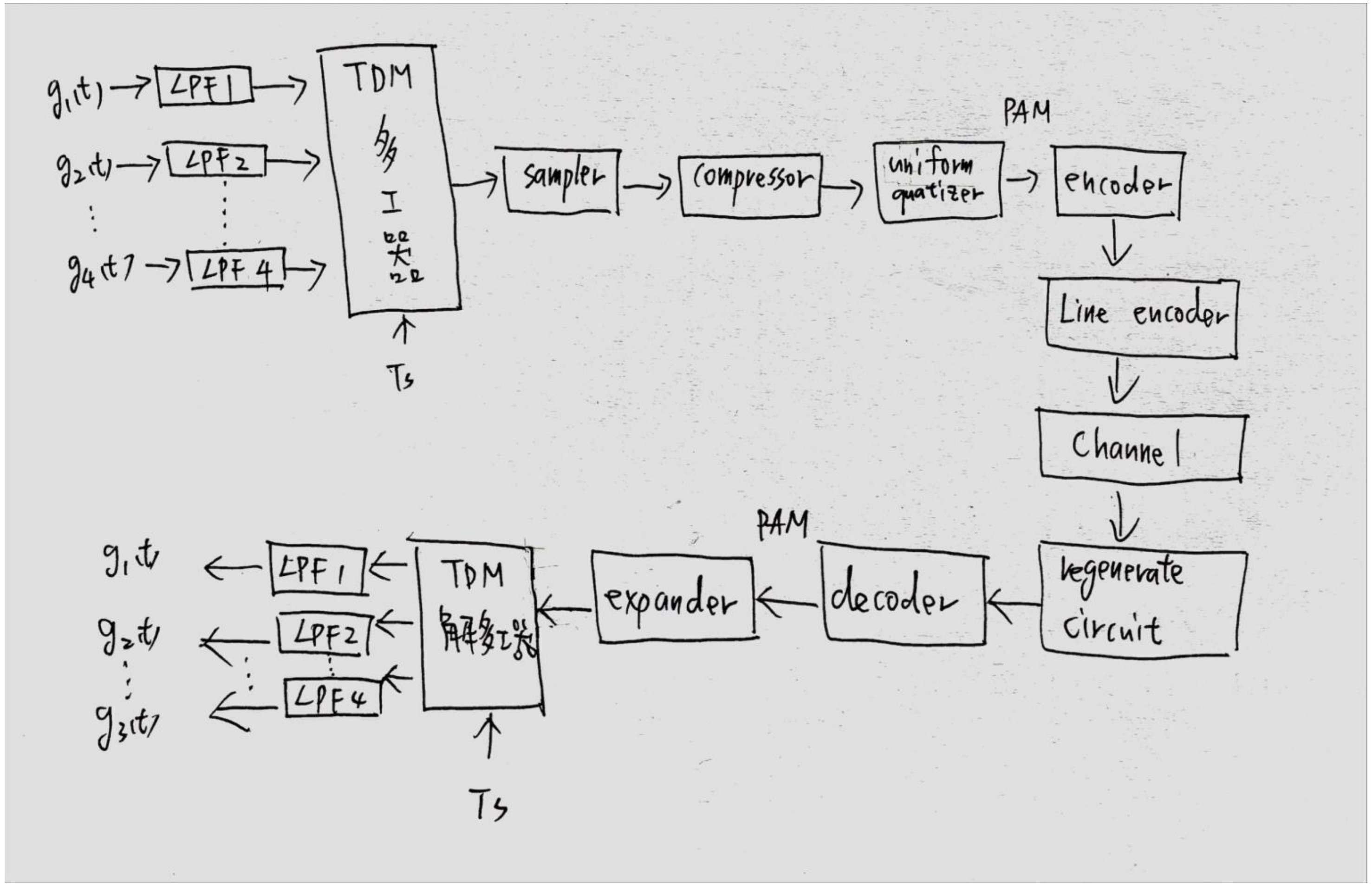
$$R_b = \frac{n_s \times bit}{T_s}$$

$$R_b = \frac{8 \times 8}{T_s} = \frac{8 \times 8}{\frac{1}{20k}}$$

$$= 1280k \ \text{bit/sec}$$

Q7

Please draw the block diagram of a PCM transmitter and receiver, where TDM accommodates 4 voice channel and the compander can get high resolution for small speech signal



What is the type of compression law used in T1 modem?

μ-law , $u=255$, 15 piecewise-linear segment

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What is the physical meaning of 8 bit PCM codeward at the decoding output of T1?

B1 => sign bit
B2~B4 => identify the segment number
B5~B8 => identify the quantization level in each segment

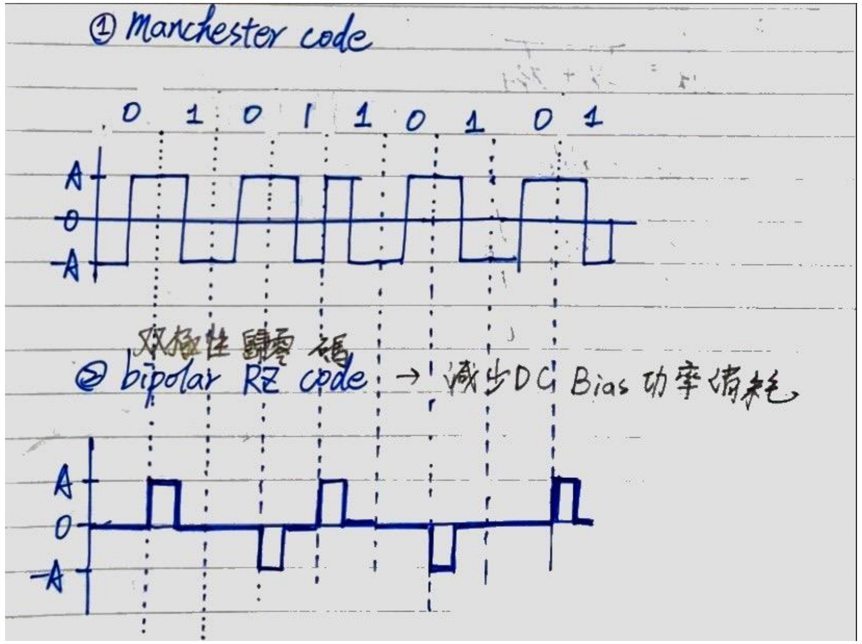
If the PCM codeward is 01100110, what is sign, segment and quantization level for the decoding output of T1 modem?

sign : 0 正 segment = 110 → 7 quantization level: 0110 2+4+1=7

Q8

Draw the linear code waveform of 010110101 using

(1) Manchester code, bipolar RZ code with the reference bit of 1.



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Please write the formula of the differential encoding if bk is the current bit and dk-1 is the previous difference bit and write the truth table

$$d_k = \overline{b_k \oplus d_{k-1}}$$

b_k	d_{k-1}	d_k
0	0	1
0	1	0
1	0	0
1	1	1