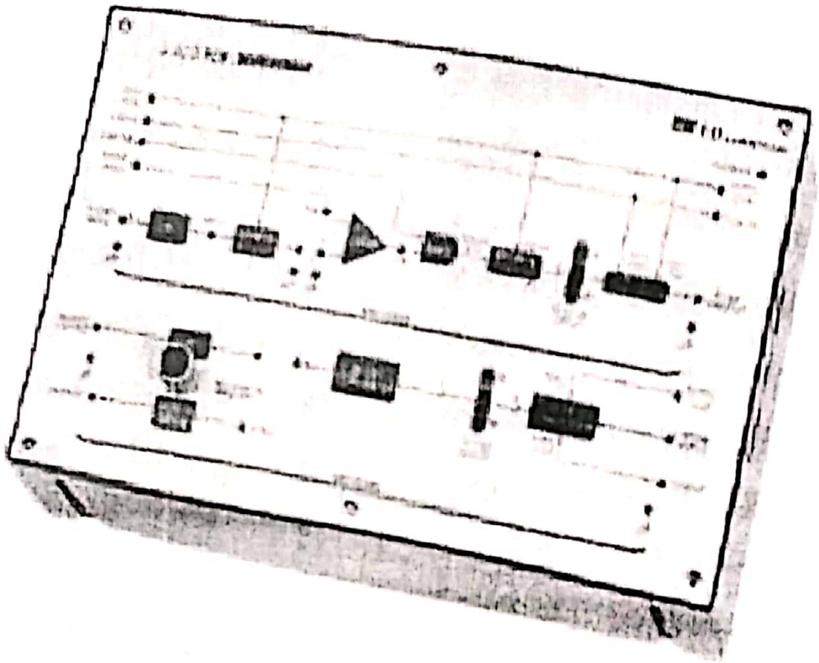
1603023 – 1603030

Chapter 5 Uniform PCM I (Counter type)



In this experiment, we will understand the conversion process of both counter type A/D converter and parallel D/A converter using uniform PCM method. Also we will discuss general cause of noise and distortion within time domain and determine Nyquist rate against message signal based on sampling theory.

This experiment can demonstrate how the number of quantizing interval effects on quantizing noise within time domain. Also it can explain the effect of low-bandwidth filtering in quantizing error signal. We can measure signal-to-quantizing noise ratio and understand resolution against quantizing noise and effect on message signal amplitude.

Experiment 5-1. A/D & D/A Conversion

1. Objectives of Experiment

1. To understand converting process of Analog-Digital and Digital-Analo
2. To understand the method of counter type A/D conversion.
3. To understand the method of parallel D/A conversion

2. Requiring Equipments

(1) Power Supply(U-2920A)

(2) Signal Source(U 2920B)

(3) Pulse Code Modulation 1(Counter-Type)(U-2920E)

(4) Digital Storage Oscilloscope (2-CH, 60[MHz])

(5) Digital Multimeter(EDM-4760)

3. Excrement Procedures

(1) Prepare module and measuring equipment as following figure 5-6. Set all ADJ control terminals to MIN respectively and provide the power to all devices.

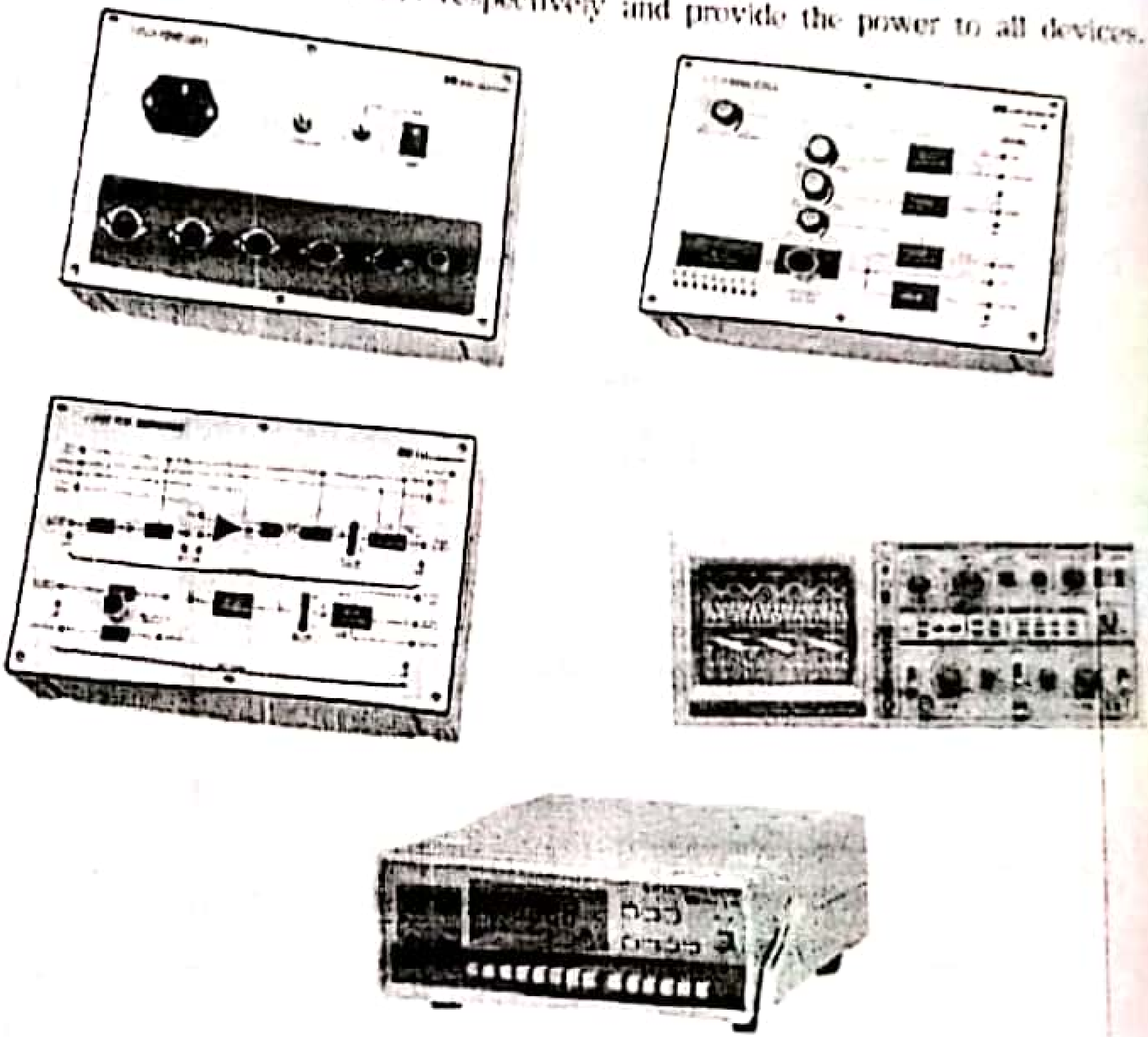


Figure 5-6 Test module & measuring equipments for experiment

(2) Set frequency selector in Signal source to 8[kHz].

(3) Connect CLK, RAMP, SINE terminal output of signal source to CLK, RAMP, AUDIO INPUT terminal of PCM 1 module.

(4) Connect 32[kHz] of signal generator from signal source to CLK×4 terminal and connect 128[kHz] to CLK×16 terminal of PCM 1 module.

(5) Set oscilloscope as followings:

TIME/DIV 0.2[ms]

CH-1 VOLT/DIV	5 [V]
CH-2 VOLT/DIV	5 [V]
TRIGGER MODE	AUTO
TRIGGER SOURCE	CH 1
VERTICAL MODE	DUAL
INPUT COUPLING	DC
SLOPE	•

(6) Connect CH-1 input probe of oscilloscope to TP1 of PCM 1, set the frequency to 1[kHz] by adjusting frequency ADJ. control terminal of audio generator and set amplitude to 8[Vp-p] by adjusting Amplitude ADJ. control terminal.

(7) Connect CH-1 input probe of oscilloscope to TP2 of PCM 1, set ramp voltage to 9[Vp-p] by adjusting Amplitude ADJ. control terminal in ramp generator.

(8) If CH-1, 2 input probe of oscilloscope would be connected to TP1 and J1 of PCM module, two wave forms would be appeared as figure 5-7.

□ What's the name of two wave forms appeared in figure 5-7?

□ How many times of sampling and size of phase within one cycle of instantaneous sampling wave form indicated in figure 5-7?

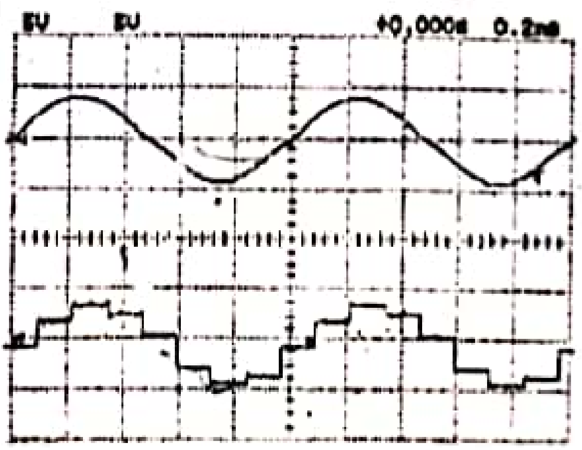


Figure 5-7. Message Signal(above) and Sample-Hold output(below)

(9) Remove CH-1, 2 input probe of oscilloscope connected to TP1 and J1 terminal of PCM I module and connect J1 terminal and J2 terminal.

(10) Check whether wave form of oscilloscope as figure 5-8 appears on the screen or not, when input probe of oscilloscope CH-1 would be connected to TP3 of PCM I module. At that time, set TIME/DIV of oscilloscope to 0.1[ms].

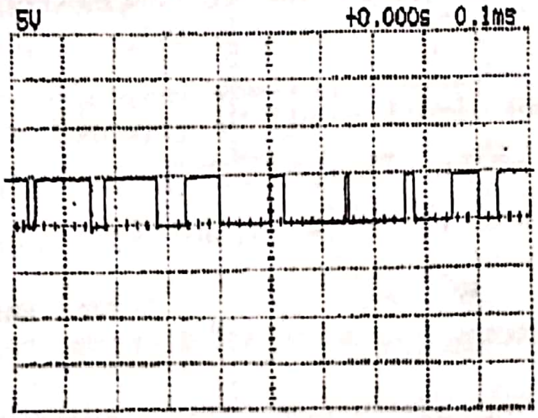


Figure 5-8. TP3's wave form

□ How message signal would be modulated into this wave form?

(11) If input probe of oscilloscope CH-1, 2 would be connected to SYNC, CLK and PCM OUTPUT terminal of PCM I module, wave form of oscilloscope as figure 5-9 will be appeared. At that time, set TIME/DIV of oscilloscope to 50[μs].

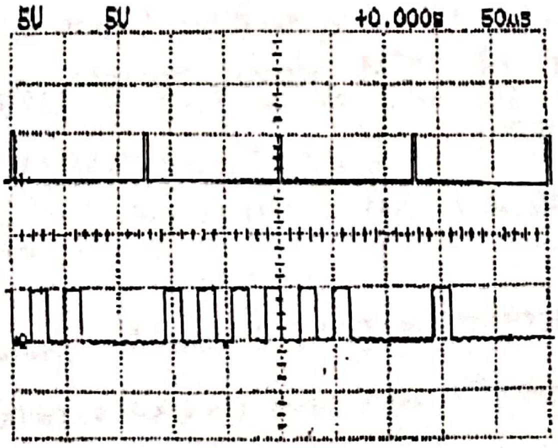


Figure 5-9. Clock signal(above) and PCM direct signal(below)

¤ Check how many number of pulse wave form of CH-2 would be included during CH 1 input wave form of oscilloscope. Enter 4 bit codes. 1101

(12) If input probe of oscilloscope CH 1, 2 would be connected to J1 and PCM OUTPUT terminal of PCM 1 module, wave form of oscilloscope as figure 5-10 will be appeared. At that time, adjust TIME/DIV to 50[μs] for making the size of quantization phase to appear on the oscilloscope screen with about four pieces.

But PCM direct output signal would be appeared with delay as much as one cycle of quantization phase. That is to say, we can realize that it would be appeared by delaying with one cycle toward right side in oscilloscope.

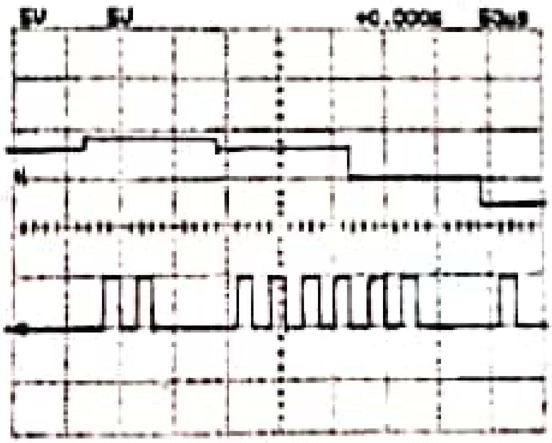


Figure 5-10 Phase size of Instantaneous sampling(above) & PCM direct signal (below)

¤ How many pulse of PCM signal against maximum phase size of instantaneous sampling wave form?

¤ Please explain scaling A/D conversion process?

(13) Remove AUDIO INPUT of PCM 1 module connected to SINE input of SIGNAL SOURCE temporarily and also remove connection line connecting J1 terminal and J2 terminal temporarily.

(14) Connect DC VOLTAGE +5[V] output terminal of POWER SUPPLY to J2

(18) If we set INPUT COUPLING of oscilloscope CH-1, 2 to AC and connect each probe to TP1 and J3 terminal of PCM I, wave form of figure 5-11 would be appeared in oscilloscope screen. At that time, set TIME/DIV of oscilloscope to 50[μs].

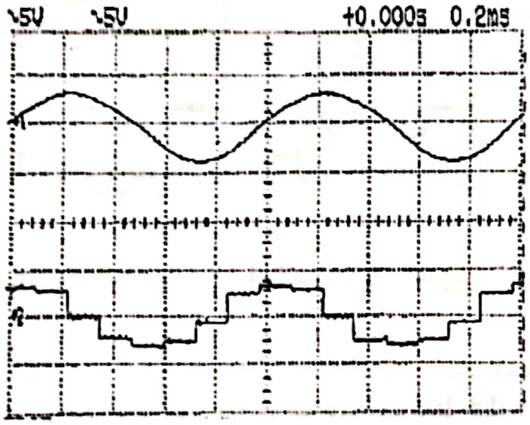


Figure 5-11. Message Signal(above) & D/A conversion demodulation output(below)

□ Please explain the form of demodulation message signal processed with D/A conversion.

□ When we measure amplitude of input message signal and demodulation message signal, what is difference?

(19) Compare and observe input message signal and demodulation message signal by connecting CH-1 input probe of oscilloscope to AUDIO OUTPUT of PCM I module.

□ These two signals are similar?

(20) Connect CH-2 input probe of oscilloscope to J3 terminal of PCM I module.

(21) Make the ramp voltage to 6[Vp-p] by adjusting Amplitude ADJ. control terminal of RAMP GENERATOR from PCM I. At that time, oscilloscope would be appeared as figure 5-12.

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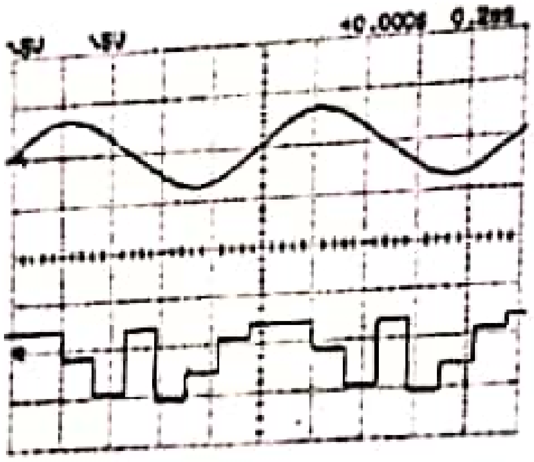


Figure 5-12. Message signal(Above) & Clipping D/A conversion output(below)

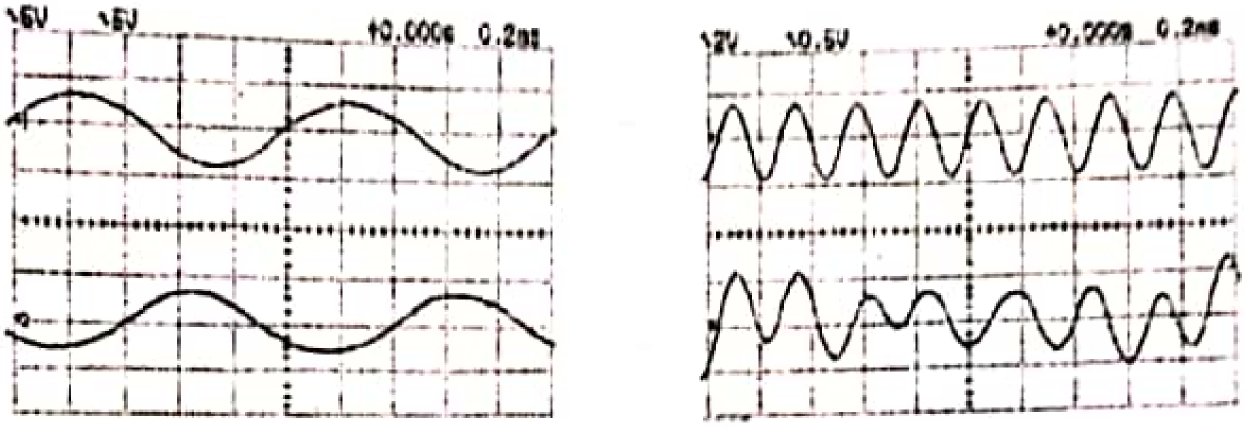
- Why distortion would be occurred in recovered message signal?
- What is the name of this kind of distortion?

(22) Adjust ramp voltage to 9[Vp-p] by adjusting Amplitude ADJ. control terminal of RAMP GENERATOR again.

If we connect CH-2 input probe of oscilloscope to AUDIO OUTPUT of PCM I, wave form like as figure 5-13(a) would be appeared.

(23) Adjust frequency to 4[kHz] by adjusting Frequency ADJ. control terminal of AUDIO GENERATOR in SIGNAL SOURCE.

If we connect CH-2 input probe of oscilloscope to AUDIO OUTPUT of PCM I, wave form like as figure 5-13(b) would be appeared.



(a) Status without Aliasing (b) Status with Aliasing

Figure 5-13. Message signal(Above) & Demodulation message signal(below)

- Why distortion would be occurred in demodulation message signal?
- What is the name of this kind of distortion?

(24) Adjust frequency to 1[kHz] by adjusting Frequency ADJ. control terminal of AUDIO GENERATOR in SIGNAL SOURCE.

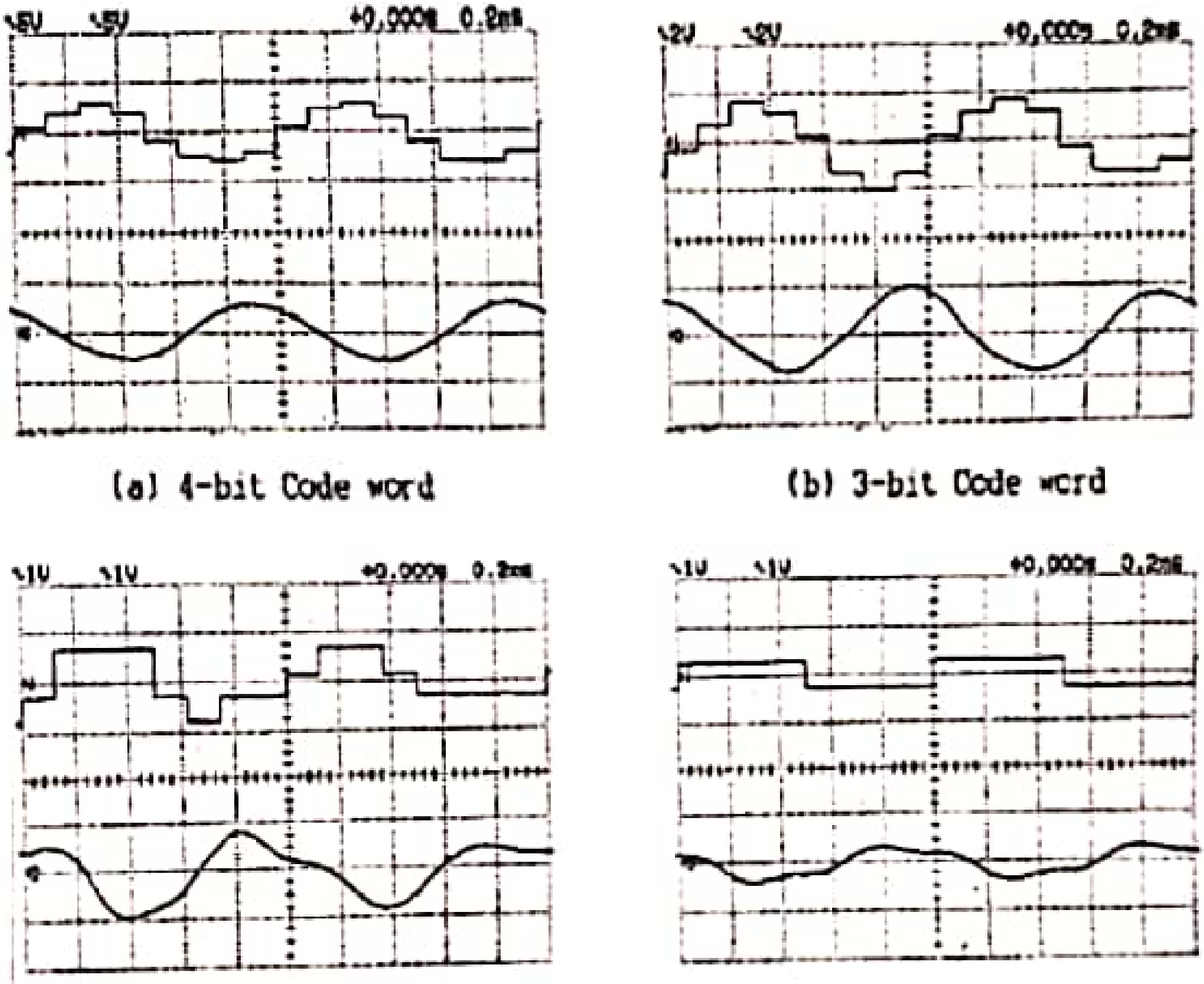
(25) If we connect CH 1, 2 Input probe of oscilloscope to J3 terminal and AUDIO OUTPUT of PCM I module, wave form like as figure 5-14(a) would be appeared in the screen.

(26) Make 3 bit code word by connecting 128[kHz] of SIGNAL GENERATOR connected to CLK × 16 terminal of PCM I module to 64[kHz]. If we set VOLT/DIV of oscilloscope to 2[V], the result would be indicated like as figure 5-14(b).

(27) Make 2-bit code word by connecting CLK × 16 terminal of SIGNAL GENERATOR to 32[kHz]. If we set VOLT/DIV of oscilloscope to 1[V], the result would be indicated like as figure 5-14(c).

(28) Make 1-bit code word by connecting CLK × 16 terminal of PCM I module to 16[kHz] of SIGNAL GENERATOR.

The screen of oscilloscope appears like as figure 5-14(d).



(a) 4-bit Code word

(b) 3-bit Code word

(c) 2-bit Code word

(d) 1-bit Code word

Figure 5-14. Lowpass Filtering Effect against the length of code word

o Is recovered message similar to original message signal?

o What's the reason for distortion occurred in recovered signal? Also is there any method for protecting distortion?

(28) Connect CLK×16 terminal of PCM 1 module and 128[kHz] output terminal of SIGNAL GENERATOR again for driving 4-bit code word.

(29) Remove AUDIO INPUT terminal of PCM 1 module connected with SINE output of SIGNAL SOURCE and then remove connection line between J1 terminal and J2 terminal.

(30) Connect DC VOLTAGE (5[V]) output terminal of POWER SUPPLY to J2 terminal of PCM 1.

(31) Set FUNCTION of Digital Multimeter to DC V and RANGE to 20[V] respectively.

(32) Make lighting status of ENCODER DISPLAY Diode to equal with table 5-3 by adjusting DC VOLTAGE ADJ control terminal.

At that time, measure the J3 terminal voltage by using Digital Multimeter and record it into table 5-3.

In Digital Multimeter, (+) measuring terminal would be connected to GND and (-) measuring terminal would be connected to J3 terminal.

Because signal would be reversed by internal amplifier.

Table 5-3. 4-bit D/A conversion's output voltage

DECODE DISPLAY				Output Voltage [V]
D3	D2	D1	D0	
ON	ON	ON	ON	
ON	ON	ON	OFF	
ON	ON	OFF	ON	
ON	ON	OFF	OFF	
ON	OFF	ON	ON	
ON	OFF	ON	OFF	
ON	OFF	OFF	ON	
ON	OFF	OFF	OFF	
OFF	ON	ON	ON	
OFF	ON	ON	OFF	
OFF	ON	OFF	ON	
OFF	ON	OFF	OFF	
OFF	OFF	ON	ON	
OFF	OFF	ON	OFF	
OFF	OFF	OFF	ON	
OFF	OFF	OFF	OFF	

□ What is step size of D/A conversion?

(32) Set all power switches to OFF and remove all connection lines.

4. self-check

1. Explain the principle of A/D and D/A conversion.

2. What is minimum size of clock frequency needed for converting analog input signal having frequency characteristics of 1[kHz]?

3. What is code word from output of A/D conversion?

4. How the length of code word and resolution within given voltage rage?

5. What is the interval of quantization of 8-bit D/A conversion having input range of ±10 V?

Experiment 5-2. Characteristics & Measurement of Quantization

1. Objectives of Experiment

1. To understand the influence of the number of quantization's interval on quantization noise.
2. To understand the effect of low-pass filtering in quantization error signal.
3. To be able to measure signal to quantization ratio.
4. To understand the influence of resolution and message signal amplitude on quantization noise.

2. Excrement Procedures

(1) Prepare module and measuring equipment like as figure 5-18. Set all ADJ. control terminals to MIN and provide power to all devices.

(2) Set FREQUENCY SELECTOR of SIGNAL SOURCE to 8[kHz].

(3) Connect CLK, RAMP, SINE terminal output of SIGNAL SOURCE to CLK, RAMP, AUDIO INPUT terminal of PCM-1 module.

(4) Connect 4 32[kHz] of SIGNAL GENERATOR in SIGNAL SOURCE to CLK×4 terminal and connect 128[kHz] to CLK×16 terminal of PCM-1 module.

(5) Connect SYNC, CLK, CLK×4, and PCM OUTPUT to SYNC, CLK, CLK×4, and PCM INPUT of DECODER respectively.

(6) Connect J1 and J2 terminal and J3 terminal and NOTCH FILTER INPUT terminal.

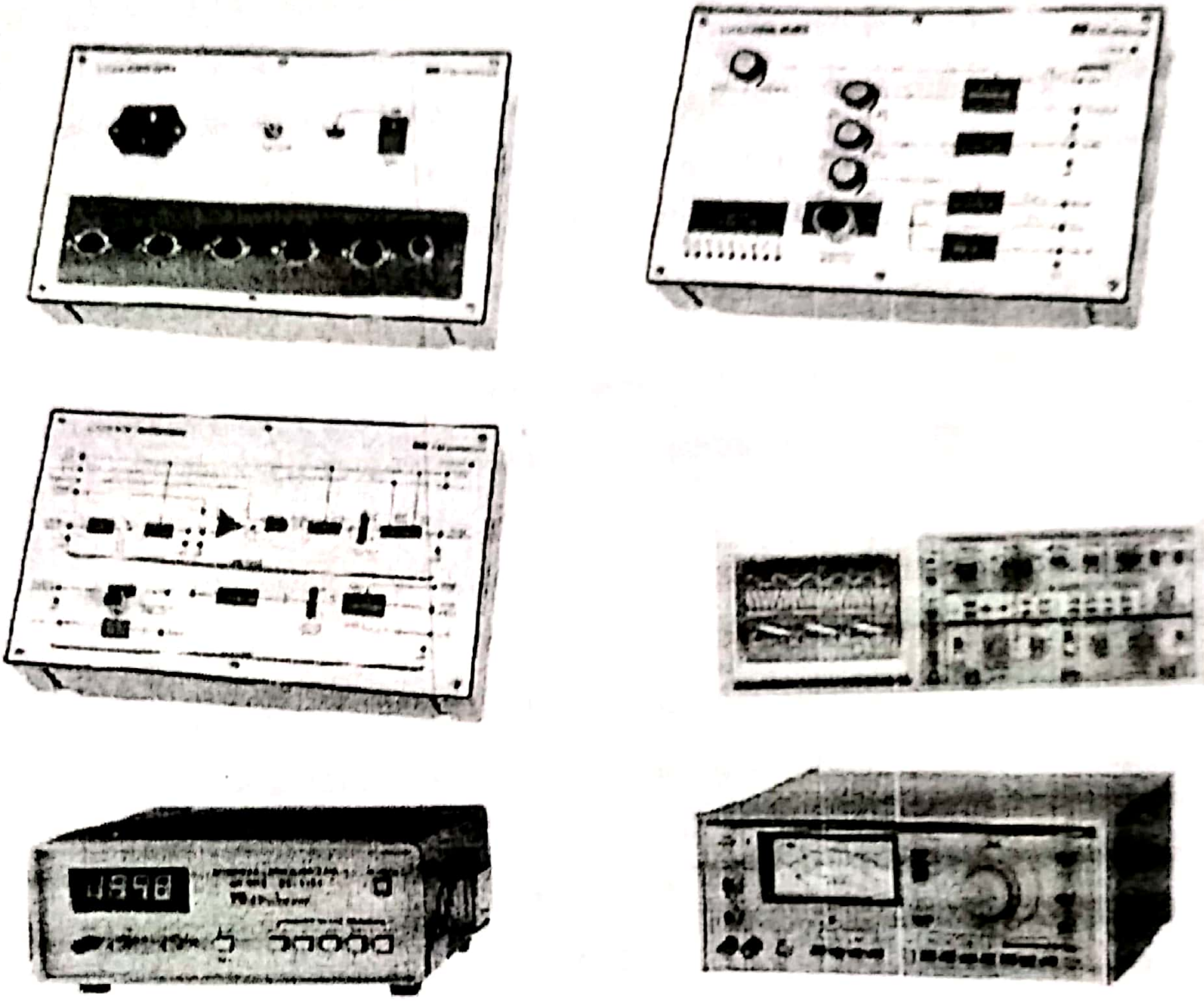


Figure 5-18. Test module & measuring equipments for experiment

(7) Set oscilloscope as followings:

TIME/DIV	0.2[ms]
CH 1 VOLT/DIV	5 [V]
CH 2 VOLT/DIV	5 [V]
TRIGGER MODE	AUTO
TRIGGER SOURCE	CH-1
VERTICAL MODE	DUAL
INPUT COUPLING	AC

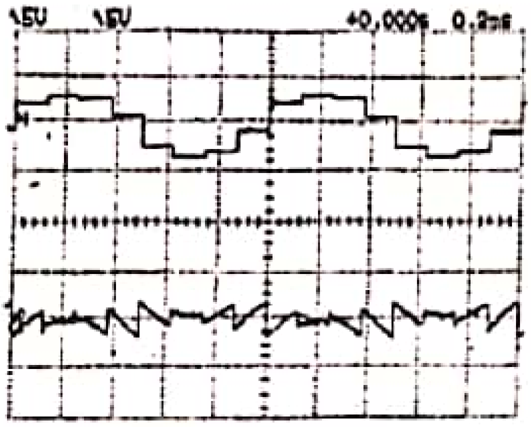
(8) Connect CH 1 input probe of oscilloscope to RAMP terminal of PCM I, set amplitude to 9[V_{P-P}] by adjusting Amplitude ADJ. control terminal of RAMP

GENERATOR.

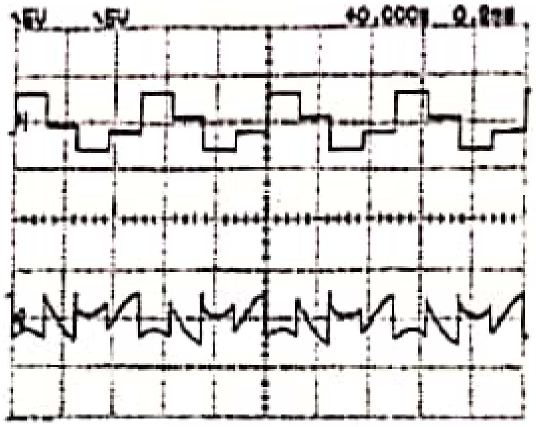
(9) Connect CH 1 input probe of oscilloscope to RAMP terminal of PCM I and set ramp voltage to $9[V_{p-p}]$ by adjusting Amplitude ADJ. control terminal in ramp generator.

(10) Connect CH-1, 2 input probe of oscilloscope to J3 terminal and NOTCH FILTER OUTPUT of PCM I. Adjust RESONANCE FREQ. ADJ. control terminal to amplitude of oscilloscope CH-2 wave form be minimum. And then two wave forms like as figure 5-19 would be appeared in the oscilloscope screen.

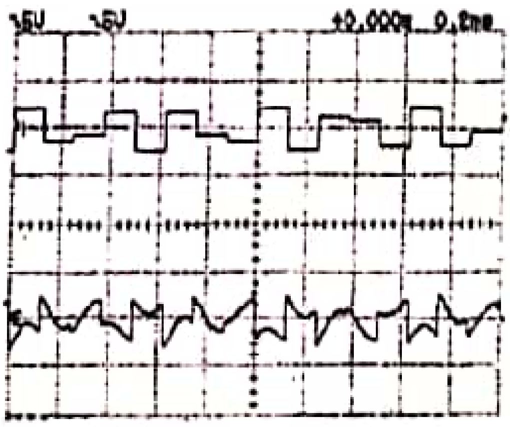
(11) If performs the experimental procedure (10) after setting the frequency of input message signal to 2[kHz] and 3[kHz] respectively, figure 5-19(b) and (c) would be appeared on the screen.



(a) $f_m = 1$ [kHz]



(b) $f_m = 2$ [kHz]



(c) $f_m = 3$ [kHz]

Figure 5-19. D/A Conversion demodulation output(above) and quantization error wave form(below)

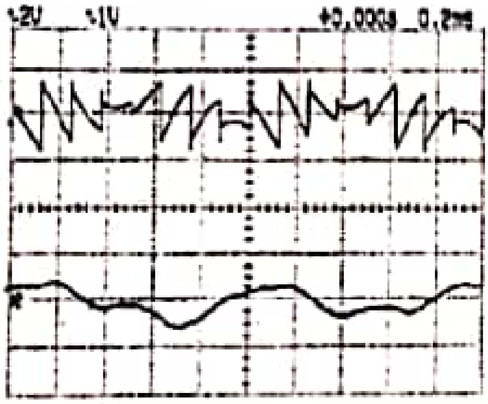
□ What is influence of quantization error depending on relationship between signal frequency of message signal and sampling rate?

(12) Connect CH-1 Input probe of oscilloscope to TP 1 again and set frequency to 1[kHz] by adjusting Frequency ADJ. control terminal of AUDIO GENERATOR.

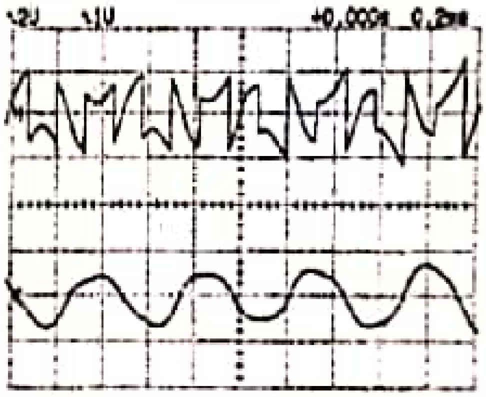
(13) Connect NOTCH FILTER OUTPUT terminal to J4 terminal.

(14) Connect CH-1 and 2 Input probe of oscilloscope to J4 terminal and AUDIO OUTPUT respectively. Adjust RESONANCE FREQ. ADJ. control terminal to amplitude of CH-1 wave form in oscilloscope be minimum. And then two wave forms would be appeared like as figure 5-20(a).

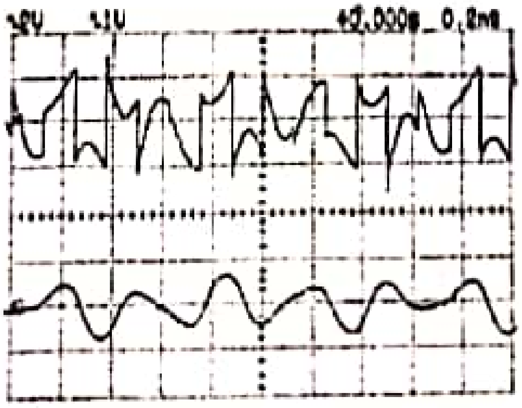
(15) If you performs experiment procedure No. 14 after setting frequency of input message signal to 2[kHz] and 3[kHz], figure 5-20(b) and (c) would be appeared on the screen.



(a) $f_m = 1$ [kHz]



(b) $f_m = 2$ [kHz]



(c) $f_m = 3$ [kHz]

Figure 5-20. quantization error wave form(above)&quantization signal after LPF filtering (below)

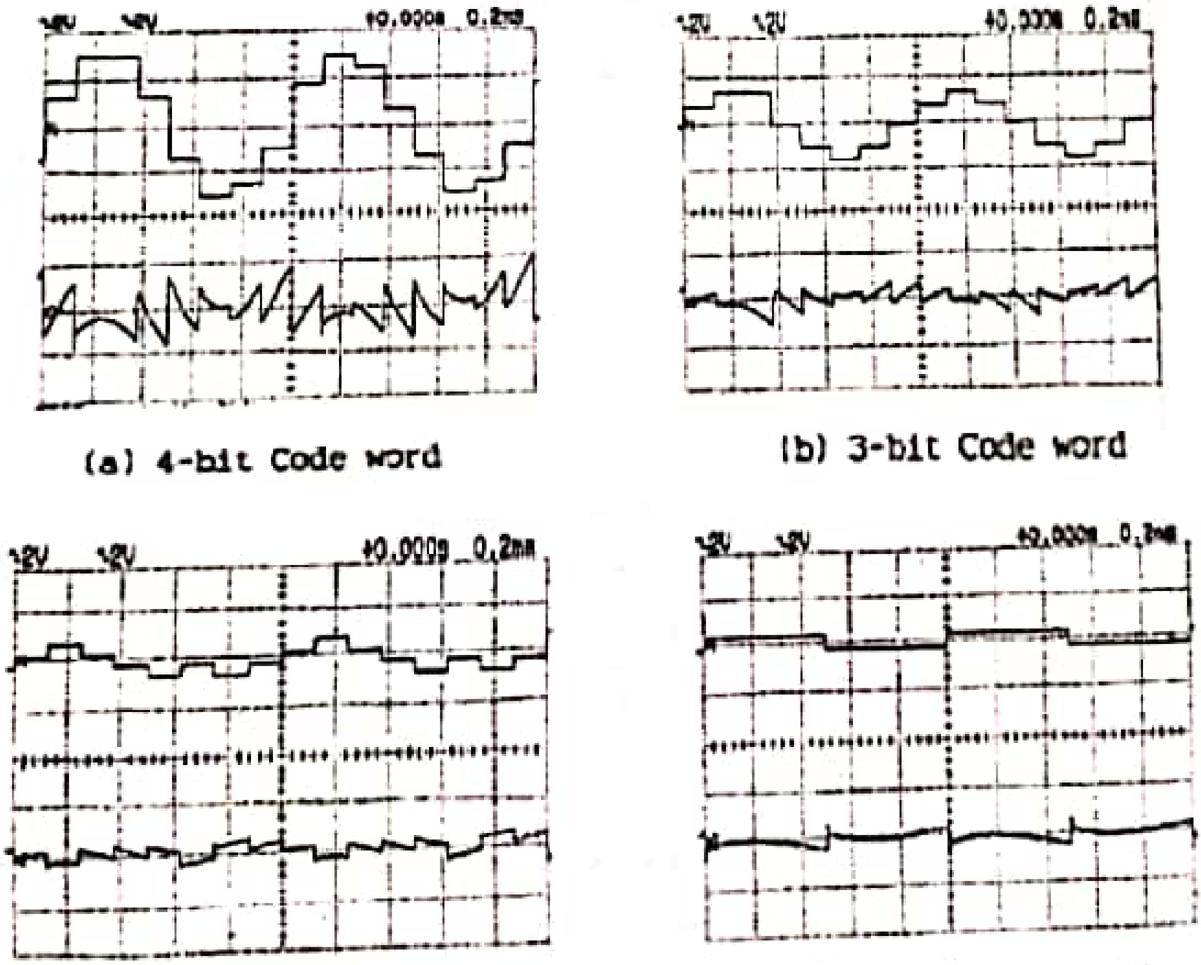
o Can low-pass filter get rid of quantization noise completely?

(16) Set frequency of message signal to 1[kHz] again and connect CH 1, 2

Input probes of oscilloscope to J3 terminal and NOTCH FILTER OUTPUT. Adjust RESONANCE FREQ. ADJ control terminal of NOTCH FILTER to appeared CH-2 wave form in oscilloscope be minimized. And then two wave forms would be appeared like as figure 5-21(a)

(17) If you connect CLK×16 terminal to 64[kHz] of SIGNAL GENERATOR and activate it with 3 bit code word, and adjust RESONANCE FREQ. ADJ of NOTCH FILTER like as experiment procedure No. 16, figure 5-21(b) would be appeared on oscilloscope screen.

(18) If you connect CLK×16 terminal to 32[kHz] and 16[kHz] of SIGNAL GENERATOR and activate it with 2-bit and 1-bit code word and adjust RESONANCE FREQ. ADJ. of NOTCH FILTER like as experiment procedure No. 16, figure 5-21(c) and 5-21(d) would be appeared on oscilloscope screen.



(a) 4-bit Code word

(b) 3-bit Code word

(c) 2-bit Code word

(d) 1-bit Code word

Figure 5-21. D/A demodulation output against the length of code word(above) &

quantization noise(below)

¤ Explain the influence on quantization noise when the number of quantization's interval decreases.

(19) Make 4-bit code word by connecting CLK×1 terminal to 16[kHz] of SIGNAL GENERATOR and CLOCK×16 terminal to 64[kHz] of SIGNAL GENERATOR.

(20) Remove the connection between J3 terminal and NOTCH FILTER INPUT and between J4 terminal and NOTCH FILTER OUTPUT and then connect J3 terminal and J4 terminal.

(21) Connect CH-1 Input probe of oscilloscope to RAMP terminal of PCM-I module and set RAMP Voltage to be 6[Vp-p] by adjusting Amplitude ADJ. control terminal of RAMP GENERATOR

(22) Connect CH-1, 2 Input probe of oscilloscope to J3 terminal and AUDIO OUTPUT respectively. The wave form like as figure 5-22 would be appeared on oscilloscope screen.

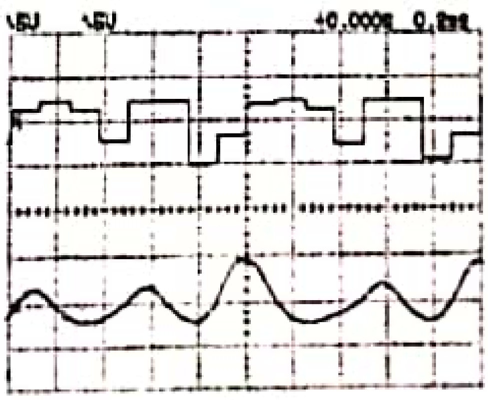


Figure 5-22. Clipping D/A Conversion Demodulation Output(above) & Demodulation message output(below)

¤ What's reason for occurring distortion of demodulation message output wave form and the name of this kind of distortion?

(23) Connect CH-1 Input probe of oscilloscope to RAMP terminal of PCM-I

module again and set RAMP voltage to be $0[V_{P-P}]$ by adjusting Amplitude ADJ. control terminal of RAMP GENERATOR.

- From now on, we will perform the experiment to measure signal-to-quantization noise ratio in PCM system.

(24) Connect CH-1 probe of oscilloscope to TP1, adjust Frequency Adj. terminal to display 1[kHz] and then set Amplitude ADJ. control terminal to the center.

(25) Remove the connection between J1 terminal and J2 terminal and between J3 terminal and J4 terminal.

(26) To get minimized amplitude, adjust RESONANCE FREQ. ADJ. control terminal after connecting TP1 terminal to NOTCH FILTER INPUT and also connecting CH 1 Input probe to NOTCH FILTER OUTPUT. This is the step for setting resonance frequency of NOTCH FILTER to 1[kHz].

(27) Connect AUDIO OUTPUT to NOTCH FILTER INPUT after connection line of TP1 terminal connected to NOTCH FILTER INPUT. And then connect 600 [Ω] load to NOTCH FILTER OUTPUT.

(28) To obtain $1[V_{rms}]$ signal voltage, adjust Amplitude ADJ. control terminal by selecting RANGE of Distortion Meter to 3[V] and connecting to TP1 terminal.

(29) Remove Distortion Meter from TP1 terminal and then connect J1 terminal and J2 terminal and J3 terminal and J4 terminal.

(30) Measure and record quantization noise(V_Q) in table 5-4when 4-bit code word by connecting Distortion Meter to NOTCH FILTER OUTPUT.

(31) Measure quantization noise voltage when 3-bit code word by connecting CLK×16 terminal to 64[kHz] of SIGNAL GENERATOR and also measure quantization noise value when 2-bit code word by connecting CLK×16 terminal to 32[kHz]of SIGNAL GENERATOR and then record measured value into table 5-4.

(32) Remove Distortion Meter connected to NOTCH FILTER OUTPUT and

connect to AUDIO OUTPUT. Read the 2-bit total value that Distortion Meter indicates and then record that value into table 5-4.

(33) Measure 3-bit total output voltage (V_o) by connecting CLK×16 terminal to 64[kHz] of SIGNAL GENERATOR and then record that value into table 5-4.

(34) Measure 4-bit total output voltage (V_o) by connecting CLK×16 terminal to 128[kHz] of SIGNAL GENERATOR and then record that value into table 5-4.

Bit Number	Quantization Noise Voltage V_Q [mV]	Total Output Voltage V_o [mV]	Signal Voltage $V_s=\sqrt{V_o^2-V_Q^2}$ [mV]	signal-to-quantization noise ratio (SN_QR)[dB]	
				Measuring value $20\log(V_s/V_Q)$	Theoretical value $1.8+6N$
4					
3					
2					

Table 5-4. Determination of signal-to-quantization noise ratio(SN_QR)

(35) Complete the table by calculating signal voltage, measuring and theoretical signal-to-quantization noise ratio provided in table 5-4.

- Explain whether the measuring and theoretical SN_QR value against number of bit in table 5-4 are correspond each other or not.
- If the number of code word bit would be increased, how it is effect on SN_QR?

(36) Draw the signal-to-quantization ratio (measuring and theoretical value) on the number of word bits provided in table 5-4 into figure 5-23.

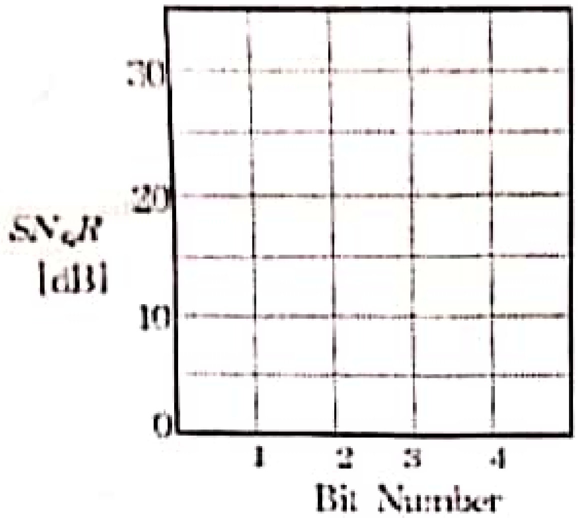


Figure 5-23. signal-to-quantization noise ratio against bit number

(37) Adjust Amplitude ADJ. terminal to be 2.828[V] by connecting Distortion Meter to TP1 or be 8[V_{p-p}] by connecting CH-1 Input probe of oscilloscope to TP1 This voltage corresponds to first row of input voltage column in table 5-5(a).

(38) Measure output voltage(V_o) by connecting Distortion Meter to AUDIO OUTPUT and then record it into table 5-5(a).

(39) Measure total output voltage(V_n) by connecting Distortion Meter to NOTCH FILTER OUTPUT and then record it into table 5 5(a).

(40) Remove the connection between J1 terminal and J2 terminal and between J3 terminal and J4 terminal. Measure residual noise voltage (V_R) from Distortion Meter connected NOTCH FILTER OUTPUT by connecting SINE terminal of SIGNAL SOURCE to J4 terminal and then record it into table 5-5(a).

(41) Remove the connection between TP1 terminal and J4 terminal and then connect J1 terminal with J2 terminal and J3 terminal with J4 terminal again.

(42) Connect Distortion Meter to TP1 terminal and adjust voltage given in table 5-5(a) by using Amplitude ADJ. control terminal of AUDIO GENERATOR Repeat experiment procedure No. 38 and 39 until table 5 5(a) is completed.

(43) Complete the table by performing calculation provided into table 5-5.

Table 5-5. The signal amplitude influence on SN_QR

Input Voltage V_i[mV]	Output Voltage V_o[mV]	Total noise Voltage V_n[mV]	Residual noise voltage V_R[mV]	Output signal voltage $V_s=\sqrt{V_o^2-V_n^2}$ [mV]	quantization noise voltage $V_Q=\sqrt{V_n^2-V_R^2}$ [mV]	signal-to-quantization noise ratio(SN_QR) $20\log(V_s/V_Q)$ [dB]	signal level $20\log(V_i/V_{max})$ V_{max}=2.828[V [dB]
2828							
1416							
708							
352							

(44) **Draw the SN_QR graph on input signal level provided into figure 5-24.**

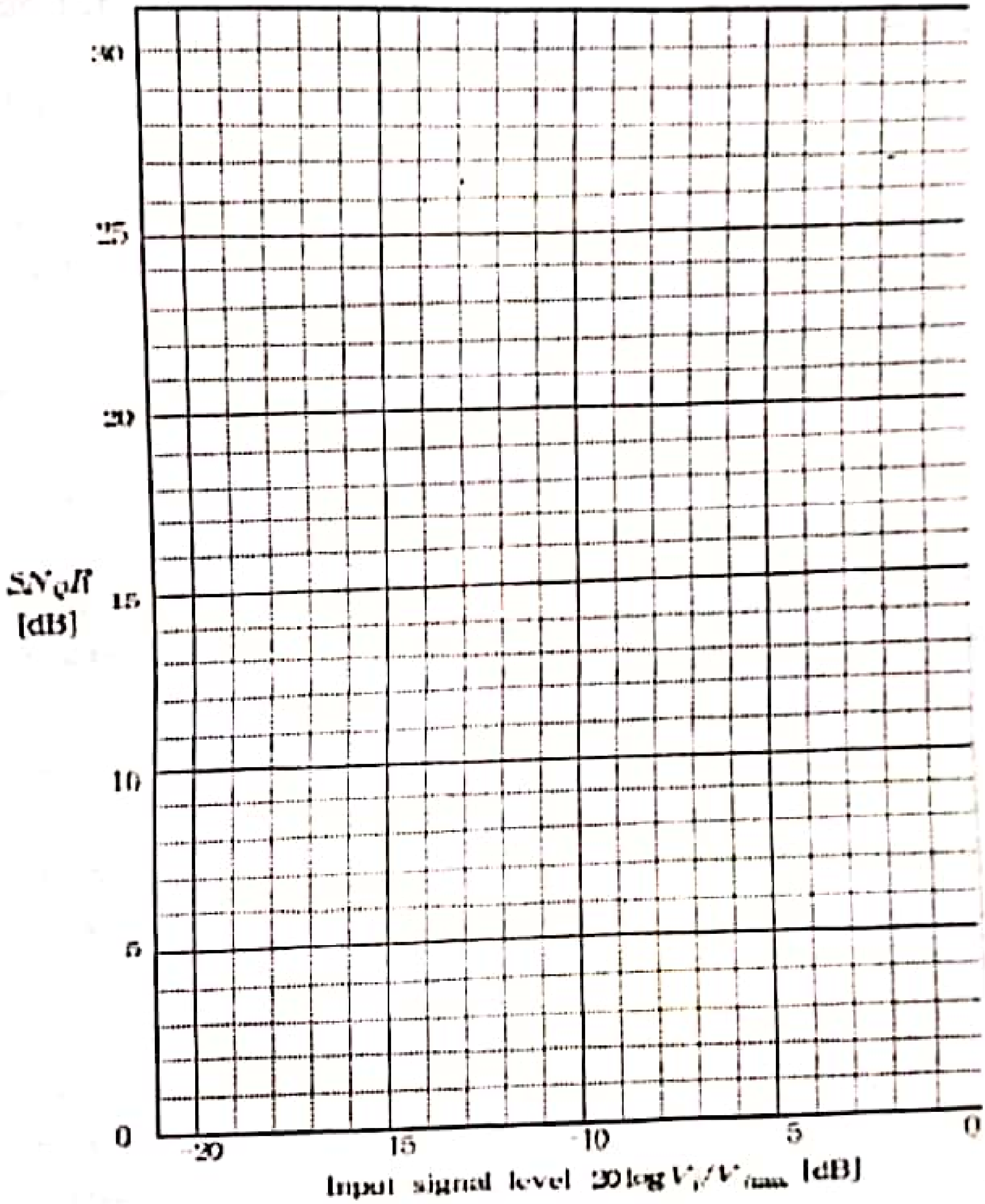


Figure 5-24. Graph of SN_QR-to-input signal level

- Explain whether this graph corresponding with expected result or not.

16) Set all power switch to OFF and remove all connection among equipments.