EFFECTS OF NOISE IN PULSE MODULATION TRANSMISSION (Optional)

Performance Objectives

A. Demonstrate the affect that noise has on a PAM signal in a communications channel.
B. Demonstrate the affect that noise has on a detected PAM signal using a synchronizer in a communications channel.
C. Demonstrate the effect that noise has on a PWM signal in a communications channel.

Basic Concepts

1. Electrical noise is unwanted energy that interferes with the reception and reproduction of intelligence signals.
2. Noise is usually random and can be divided into external channel noise and noise generated inside a transmitter or receiver.
3. Noise in a communications channel will deteriorate a signal.
4. The presence of noise in a communications channel can distort the true signal at a receiver and prevent the receiver from providing an accurate replica of the transmitted information.
5. Signal-to-noise ratio (SNR) is used to compare the noise to the signal in a communications system.
6. PAM signals are greatly affected by noise; PWM signals are less affected by noise.

Introductory Information

A signal will deteriorate during transmission and reception due to modulation and demodulation distortion or because of noise being introduced into the communication channel as shown in Figure 6-1. (The term "channel" referred to in this laboratory exercise is a single path for transmitting signals.) The noise is superimposed on the transmitted signal causing distortion.

Noise is a familiar topic in communications that must be considered. Noise is always present and limits the performance of a communications system. Noise is random unwanted energy that has the greatest effect on a signal in a channel where the signal is the weakest. Noise in a channel or at the input to a receiver is the most noticeable. Noise is received with the signal and if severe enough it will distort the signal making it unintelligible and useless.

A common method used to determine if the noise in a communications system is excessive is to measure the signal-to-noise ratio. The signal-to-noise ratio is a measure of the signal power to the noise power. Signal-to-noise ratio (SNR) can be expressed mathematically as:

\[
\frac{S}{N} = \frac{\text{SIGNAL POWER}}{\text{NOISE POWER}} = \frac{P_s}{P_n}
\]

at any given point in a communications system. A high SNR is necessary to achieve minimum errors in signal detection. Three different SNR's are shown in Figure 6-2. With an SNR of 1 the signal cannot be recognized.
With an SNR of 2 the signal can be recognized but the noise is one-half the amplitude of the signal. With an SNR of 5 the amplitude of the noise is only one-fifth the amplitude of the signal. As the signal increases in amplitude it is less affected by the noise.

The SNR is also expressed in decibel form as:

\[
\text{decibel} = \text{dB} = 10 \log \frac{P_s}{P_n}
\]

A decibel (dB) equals one-tenth of a bel. A bel is the fundamental unit in a logarithmic scale for expressing the ratio of two amounts of power. The bel is seldom used because it is considered too large a unit. The decibel is used as the practical indicator of a power ratio. For example:

\[
P_s = 120W, P_n = 10W
\]

\[
\text{dB} = 10 \log \frac{120}{10} = 10 \log 12 = 10.8\text{dB}
\]

Therefore, if the noise power is 1/12 the signal power, the SNR is equal to 10.8dB. An SNR of 30dB ensures virtually error free signal detection in a receiver. An SNR of 30dB corresponds to a noise power of 1/1000 of signal power. See appendix B for more information on logarithms and decibels.

Modulation systems such as PAM and PWM are affected by noise. Noise can change the amplitude or width of a pulse. It may also cause receiver synchronizer instability in synchronizing with the received signals. The intelligence of the PAM signal is in its amplitude and is affected more by noise than a PWM signal. It is important that the amplitude of a received PAM signal be a true representation of the original transmitted level. The effect that added noise has on a PAM signal (Figure 6-3), depends on factors such as the strength of the signal, the distance the signal travels, and the environment the signal passes through. The SNR characteristic of a PAM signal is similar to that of amplitude modulation (AM). Because a PAM signal is most affected by noise, it is not used as often as other forms of pulse modulation such as PWM.

The intelligence of a PWM signal is in the pulse width. PWM signals, unlike PAM signals, are not affected by noise changing the amplitude of the signals. But, a PWM signal can be affected by noise superimposing itself on the edges of the PWM pulses if the edges are not vertical. The PWM signal can be input to an amplitude clipper or limiter to improve the SNR by removing the noise superimposed on top of the pulse.

An example of this method is shown in Figure 6-4 in which an output portion of the pulse which is not affected by noise is the result. The clipper or limiter selects the amplitude range between two horizontal lines A and B and removes all the effects of noise. Noise will have no affect on PWM pulses with vertical edges unless the noise peaks are so large that they can be mistaken for pulses, or so large negatively that they distort the original pulse. However, the transmitted pulses in a practical system cannot have perfect vertical edges. This will affect the PWM signal but not nearly as much as an amplitude change affects a PAM signal. Increased bandwidth is required in receivers used to detect PWM signals with steep vertical edges. The SNR characteristics of a PWM signal is similar to that of frequency modulation (FM).

In this laboratory exercise you will become familiar with the effects of noise in pulse modulation reception by using a CHANNEL SIMULATOR TRAINER along with the PULSE MODULATION TRAINER. The CHANNEL SIMULATOR TRAINER will simulate what may happen to a pulse-modulated signal between a transmitter and receiver. The trainer requires +15Vdc and -15Vdc for operation and consists of 8 functional
circuits. Three circuits will be used and discussed in this laboratory exercise.

The NOISE SOURCE circuit shown in Figure 6-5 outputs noise at jacks J3 and J4. The noise output at J4 is the direct output from a random sequence generator. The noise output at J3 is a filtered output from the random sequence generator and can be attenuated to 1/2 amplitude by the ATTEN SELECT switch.

![Figure 6-5](image)

The lower section of the CHANNEL circuit shown in Figure 6-6 has a selectable bandwidth and signal-to-noise ratio (SNR).

![Figure 6-6](image)

The signal is input at J8 and applied to a circuit with a bandwidth of 4, 20, 40, or 200kHz which is selected by the BANDWIDTH SELECT (kHz) DIP switch. Noise is input at J9 and summed with the signal input at J8 to produce a signal output at J10 with a SNR of 5, 10, 15, or 20dB. The SNR ratio is selected by the SNR SELECT (dB) DIP switch.

The NOTCH FILTER/SPKR AMP circuit is shown in Figure 6-7. The audio signal to be amplified by the SPKR AMP section of the circuit is input at J25. The amplified audio signal is output at J26. The amplification to the signal input at J25 is adjustable by the VOL ADJ potentiometer.

![Figure 6-7](image)

Additional Reading

See bibliography at the back of this manual for additional reading material related to this subject.

Equipment and Materials

- Power Source: +15Vdc power supply, 200mA (No speaker used)
- 500mA (Maximum with speaker)
- Power Source: -15Vdc power supply, 150ma

Pulse Modulation Trainer
Channel Simulator Trainer
AF Generator
Dual Trace Oscilloscope
Frequency Counter
Speaker

Exercise Procedure

Objective A. Demonstrate the effect that noise has on a PAM signal in a communications channel.

Preparatory Information

A modulation system such as PAM is affected by noise in the communications channel as shown in Figure 6-8.

Since the intelligibility of the PAM signal is in its amplitude, any noise superimposed on the pulses can change the amplitude of the original transmitted pulses in the channel. As a result, the signal output
from the PAM demodulator is distorted and the reconstructed intelligence output from the filter is distorted. Noise added to the pulses in the transmission of the PAM signal causes reconstruction errors. Reconstruction errors are errors that cause the amplitude of the reconstructed signal to differ from the original amplitude of the transmitted signal. A noise free PAM signal and a PAM signal with reconstruction errors due to noise are shown in Figure 6-9.

![Figure 6-9](image)

The added noise may add to or subtract from the original amplitude of the PAM signal. This changes the average dc level of the signal and the SNR for each pulse.

The higher the amplitude of the pulse, the higher the SNR and the less the pulse is effected by noise.

The added noise superimposed on the pulses also cause the PAM signal to have vertical jitter or bounce as shown in Figure 6-10a by the dashed lines. The noise is not shown in the figure for simplicity. The vertical jitter of the PAM signal input to the demodulator causes the PAM samples output from the PAM demodulator to have vertical jitter as shown in Figure 6-10b. Consequently, the reconstructed intelligence will have vertical jitter.

![Figure 6-10a](image)

In the detection process of a PAM signal, the PAM demodulator only samples the input pulses during the time of a PAM pulse. Therefore, the noise between the pulses is removed and the SNR of the signal is improved.

PAM receivers must have sufficient bandwidth to pass PAM pulses or pulse amplitude distortion will result and the SNR will decrease. With insufficient bandwidth, many frequency components of the pulses are not passed, the pulses change shape and decrease in amplitude as shown in Figure 6-11. As the amplitude of the pulses decrease, the SNR decreases.

![Figure 6-11](image)

A diagram of the circuitry used in the trainers to demonstrate the affect that noise has on a PAM signal in a communications channel is shown in Figure 6-12.

The sampler, clock, sample/hold, and low-pass filter blocks are identical to the circuitry used in previous laboratory exercises with the Pulse Modulation Trainer. A complete schematic diagram of the noise circuit, and a partial schematic of the CHANNEL and NOTCH FILTER SPKR AMP used on the Channel Simulator Trainer is shown.

The intelligence signal is input to the sampler at J6. A PAM pulse is output from the sampler at J8 on the trailing edge of each clock input to the sampler at J7.

The clock PRR determines the sampling period. The PAM signal from the sampler is input to the channel circuit at J8 in the Channel Simulator Trainer, through R18, to pin 2 of U13A. Inverting operational amplifier U13A, in conjunction with R18, R19, C9 through C12, and BANDWIDTH SELECT switch S2 form four different low-pass filters to select one of four different bandwidths. Input resistor R18 and feedback resistor R19 determine the gain of the circuit along with any capacitor placed in parallel with R19 by switch S2. With all the contacts of switch S2 open as shown, the gain of the circuit is unity for a wide band of frequencies. With this condition the bandwidth is limited only by the internal characteristics of the op amp. Low-pass filtering action takes place when switch S2 is used to place one of four capacitors in parallel with R19 making the bandwidth 4, 20, 40, or 200kHz. The PAM signal output from
U13A is developed across R20 and input to U13B at pin 6.

Another signal is input to U13B at pin 6 from the noise source circuit. The noise source circuit in the Channel Simulator Trainer consists of a random sequence generator U2, an active op amp filter U3A, and an op amp buffer U3B. With +12V on pin 3 and pin 4 tied to ground, U2 operates as a random sequence generator and outputs a sequence of random digital pulses at pin 1. The digital pulses are available at J4 and coupled by capacitor C3 to the input of U3A and its associated components. Op amp U3A and its associated components operate as a low-pass filter circuit tuned to 7.15kHz. The gain of the circuit is unity and is set by feedback resistor R5 and input resistor R4. Resistors R4, R6, and capacitor C4 operate together as a passive low-pass filter. Frequencies above 7.15kHz are shunted to ground through C4. Capacitor C5 operates like a low-pass filter. At frequencies above 7.15kHz, the reactance of C5 decreases which increases the negative feedback and lowers the gain of the op amp. The filtered output of U3A at pin 1 is a random series of analog pulses (noise). The noise output from U3A at pin 1 is input to a voltage divider consisting of resistors R7 and R8 and the input of U3B at pin 5. With the ATTN SELECT switch open the switch is in the X1 position allowing all noise from U3A to be input to U3B. With the ATTN SELECT switch closed (X1/2 position), R8 is placed in the circuit and drops 1/2 the noise signal from U3A.

The signal developed across R8 is input to U3B at pin 5. Op amp U3B operates as a buffer between U3A and the output of the noise source circuit at J3. With pins 6 and 7 connected together, U3B operates as a unity gain voltage-follower. The output of the noise circuit at J3 is input to the channel circuit at J9.

Op amp U13B in the channel circuit is a summing amplifier and sums the PAM signal from U13A with the noise input at J9 from the noise source circuit. The two signals are summed at U13B pin 6. The SNR SELECT (dB) switch S3 selects a SNR of 5, 10, 15, or 20dB by closing contacts C1 through C4 which selects resistors R21 through R24 respectively. The larger the input resistor, the lower the gain of U13B to the noise signal and the higher the SNR at J10. Once the SNR is selected, the PAM and noise signals are summed and output at J10.
The output of U13B at J10 is input to the sample/hold circuit at J14 in the Pulse Modulation Trainer. At the trailing edge of each clock pulse input at J15, the sample/hold circuit output at J16 is an instantaneous sample of the PAM signal and noise input. The sample/hold circuit holds the PAM sample at J16 until the trailing edge of the next clock pulse input at J15. The PAM samples output from the sample/hold circuit at J16 is a staircase signal. Because the PAM signal is only sampled during the time of a PAM pulse, the noise between the pulses is not present at J16 and the S/N is improved. The only remaining noise is the noise superimposed on the PAM sample.

The staircase signal from J16 is input to the low-pass filter at J34. The reconstructed intelligence signal with noise is output from a second low-pass filter at J37 and input to the SPKR AMP circuit at J25 in the Channel Simulator Trainer.

The speaker amplifier circuit inputs the reconstructed intelligence and noise at J25. Capacitor C22 is a coupling capacitor. The intelligence signal is developed across a voltage divider consisting of R42 and VOL ADJ potentiometer R43. The value of the intelligence signal selected by the VOL ADJ at terminal 2 of R43 is input to U10 at pin 2. Amplifier U10 is a low-voltage audio power amplifier and its gain is set internally to 20. Capacitors C24 and C26 are used for circuit stability. Capacitor C23 is a decoupling capacitor for the +12V source. Capacitor C25 is used to block the dc voltage at U10 pin 5 from reaching the speaker connected to J26. Resistor R44 is used to protect U10 and the speaker from large transients that could be generated in the event that the speaker was connected after the circuit was energized with a signal input at J25. The intelligence signal and noise are output at J26 to the speaker.

1. a) With the power off, connect the circuit shown in Figure 6-13. Apply power to the trainers, AF generator, oscilloscope, and frequency counter.

1. b) Set the AF generator frequency to 400Hz and adjust the AF level control to output a 5Vp-p sine wave at J6. Adjust the FREQ ADJ potentiometer on the clock circuit to indicate 12kHz on the frequency counter. Set all DIP switches on the channel circuit to off. Set the ATTEN SELECT switch on the noise source circuit to X1/2. Adjust the VOL ADJ on the speaker amplifier circuit to a comfortable listening level. Move the channel 1 probe connected at J6 to J10 on the Channel Simulator Trainer. Is any noise visible on the PAM signals or audible from the speaker? Explain.

1. c) Set the SNR SELECT (dB) switch on the channel circuit to 20dB. Set the oscilloscope sweep speed to 0.5 milliseconds. With a SNR of 20dB, are the PAM signals clearly visible above the noise?

1. d) Change the oscilloscope sweep speed to 50 microseconds and adjust the oscilloscope trigger level control for stable positive pulses. Is the SNR the same for all pulses observed? Explain.

Figure 6-13
e) Alternately change the SNR SELECT switch on the channel circuit from 20dB to 5dB. Are the PAM signals clearly visible for all dB switch settings? Explain.

f) Set the oscilloscope sweep speed to 0.5 milliseconds and the SNR SELECT switch on the channel circuit to 20dB. Change the oscilloscope sweep speed if necessary and explain the presence of the solid horizontal line of noise observed on the screen.

g) Connect the oscilloscope channel 2 probe to J16. Set the oscilloscope sweep speed to 0.5 milliseconds. Explain the missing solid horizontal line of noise at J16 that is observed at J14.

h) Set the oscilloscope sweep speed to 50 microseconds and the SNR SELECT switch on the channel circuit to 20dB. Alternately change the BANDWIDTH SELECT switch on the channel circuit from 200kHz down to 4kHz. Describe the effect that the decreasing bandwidth has on the PAM pulses and noise level seen on channel 1.

i) Set all the channel circuit DIP switches to off. Move the channel 1 probe connected at J10 on the Channel Simulator Trainer to J37 on the Pulse Modulator Trainer and the channel 2 probe from J16 to J6. Trigger the oscilloscope on channel 2. Alternately change the SNR from 20dB down to 5dB. Describe the effects that the decreasing SNR has on the intelligence signal and speaker noise level.
j) Set the channel circuit SNR SELECT switch for a SNR of 4dB. Alternately change the channel bandwidth from 200kHz to 4kHz. Describe the effect that the decreasing bandwidth has on the reconstructed intelligence and the noise level heard from the speaker.

k) Turn off power to all equipment.

Objective B. Demonstrate the affect that noise has on a detected PAM signal using a synchronizer in a communications channel.

Preparatory Information
One of the effects of noise in a communications channel on a detected PAM signal is vertical jitter or bounce. An additional effect that is produced when a synchronizer is used in the detection of a PAM signal with noise superimposed on the signal is horizontal jitter. As shown in Figure 6-14, the input to the synchronizer is the PAM signal with noise, that has vertical jitter or bounce indicated by the dashed lines in Figure 6-15a.

The synchronizer must generate clock pulses synchronous with the input PAM signal. The synchronous clock pulses from the synchronizer are used in the PAM demodulator for pulse sampling. The vertical jitter of the PAM signal input to the synchronizer causes the output clock pulses to have horizontal phase jitter and occasionally lose synchronization with the PAM signal as shown in Figure 6-15b. With a high SNR synchronization is maintained. As the SNR decreases, the horizontal phase jitter increases until the synchronizer is out of synchronization more than it is in synchronization with the PAM signal. The combined effect of the PAM signal with vertical jitter and the synchronizer clock pulses with horizontal phase jitter input to the PAM demodulator is shown in Figure 6-15c. The PAM samples output from the demodulator have vertical and horizontal phase jitter. This combined effect can be seen on the reconstructed intelligence signal shown in Figure 6-15d.
A block diagram of the circuitry used on the trainers to demonstrate the effect that noise has on a detected PAM signal using a synchronizer in a communications channel is shown in Figure 6-16. A 2-channel TDM PAM signal is used for synchronizer stability, but only one channel is demodulated for demonstration purposes.

The intelligence signal is input to samplers A and B at J6 and J10 respectively. Each sampler samples its intelligence signal input at a different time at the trailing edge of each clock pulse input at J7 and J11. A PAM pulse is output from samplers A and B at J8 and J12 and input to the adder circuit at J24 and J25.

The PAM pulses input to the adder at J24 and J25 are added together and output at J27. The output signal from the adder at J27 is a 2-channel TDM PAM signal with each channel carrying the same intelligence signal. The TDM PAM signal at J27 is input to the channel circuit at J8 on the Channel Simulator Trainer.

The TDM PAM signal input to the channel circuit at J8 is added to the noise input to the channel circuit at J9 from the noise source circuit. An SNR of 5, 10, 15, or 20dB is selected by closing the appropriate switch on the SNR SELECT (dB) DIP switch on the channel circuit. A bandwidth of 4, 20, 40, or 200kHz is selected for the TDM PAM signal input at J8 by closing the appropriate switch on the BANDWIDTH SELECT (kHz) DIP switch on the channel circuit. The TDM PAM signal with noise is output from the channel circuit at J10 with a specific SNR and input to the sample/hold circuit at J14 and synchronizer at J38.

The TDM PAM signal is input to the synchronizer circuit at J38 and into a full-wave rectifier to invert any negative PAM pulses to positive. The PAM pulses are output from the rectifier at J43 after rectification. The positive PAM pulses at J43 are input to a band-pass filter which outputs a sine wave at J44. The sine-wave at J44 is input to a phase-locked loop which outputs pulses at J45. The pulses at J45 are input to another phase-locked loop which outputs its pulses into a divide-by-two counter. The output of the divide-by-two counter at J39 is a pulse train of clock pulses synchronized with the pulses output from the clock circuit at J1. The synchronized clock pulses at J39 are input to the sample/hold circuit at J15.

The 2-channel TDM PAM signal with noise, input to the sample/hold circuit at J14, is sampled by the synchronized clock pulses at J15. The output of the sample/hold circuit at J16 is an instantaneous sample with noise from one of the 2-channel TDM PAM signals input at J14. The sample/hold circuit holds the PAM sample at J16 until the next synchronized clock pulse at J15. The PAM samples with noise output from the sample/hold circuit at J16 is a staircase signal and is input to a low-pass filter at J34.

The reconstructed intelligence signal with noise superimposed on it is output from a second low-pass filter at J37. The reconstructed intelligence signal at J37 is input to the speaker amp circuit at J25 on the Channel Simulator Trainer.
The output to the speaker at J26 is an amplified version of the input. The amount of amplification is set by the VOL ADJ potentiometer on the speaker amplifier circuit.

- a) With the power off, connect the circuit shown in Figure 6-17. Apply power to the trainers, AF generator and oscilloscope.

- b) Set up the oscilloscope for dual-trace operation with a sweep speed of 20 microseconds and trigger the oscilloscope on channel 1. Adjust the FREQ ADJ potentiometer on the clock circuit for a 90 degree phase difference between the pulses at J1 (displayed on channel 1) and the pulses at J45 (displayed on channel 2).

Note: A 90 degree phase difference is achieved when the transitions of the 12kHz signals on channel 2 occur in the middle of the 24kHz signals on channel 1.

Is the 12kHz signal on channel 2 leading or lagging the 24kHz signal on channel 1?

- c) Move the channel 2 probe connected at J45 to J39. Superimpose the two signals and adjust the PHASE ADJ potentiometer on the synchronizer circuit for zero degree phase difference. (If the two signals are 180 degrees out of phase, turn the PHASE ADJ potentiometer clockwise then counterclockwise to bring the signals in phase. Repeat if necessary.) What is the frequency of the clock pulses output from the synchronizer at J39?

\[ f_{39} \quad \text{kHz} \]

- d) Set the AF generator frequency to 400Hz and adjust the AF level control to output a 5Vp-p sine wave at J6. Set all DIP switches on the channel circuit to off. Set the ATTEN SEL switch on the noise source circuit to X1/2. Adjust the VOL ADJ on the speaker amplifier circuit to a comfortable listening level. Move the channel 2 probe connected at J45 to J38 and trigger the oscilloscope on channel 1. What type of signal is observed at J38 and what is its frequency?

\[ f_{38} \quad \text{kHz} \]

Figure 6-17
e) Alternately change the SNR SELECT (dB) switches on the channel circuit from 20dB to 5dB and back to their off position. Describe the effect that the noise has on the PAM signals.

f) Move the channel 2 probe connected at J38 to J43 which is the output of the full-wave rectifier in the synchronizer. Repeat step "e" for the rectified PAM signals.

g) Move the channel 2 probe connected at J43 to J44 which is the output of the band-pass filter in the synchronizer. Repeat step "e" for the sine waves.

h) Move the channel 2 probe connected at J44 to J45 which is the output of the first PLL in the synchronizer. Repeat step "e" for the pulses.

i) Set the oscilloscope sweep speed to 0.1 milliseconds. Move the channel 2 probe connected at J45 to J39. Alternately set the SNR SELECT (dB) switches on the channel circuit from 20dB to 5dB and back to their OFF position. Describe the effect that the noise has on the synchronizer output clock pulses.

j) Set the oscilloscope for channel 1 viewing and trigger the oscilloscope on channel 1. Move the channel 2 probe connected at J39 to J37. Move the channel 1 probe connected at J1 to J6. Set the oscilloscope sweep speed to 0.5 milliseconds. Alternately set the SNR SELECT (dB) switches on the channel circuit from 20dB to 5dB and back to 20dB. Describe two effects that the noise has on the reconstructed intelligence when using the synchronizer.

k) Remove the connector at J39 and connect it to J1 to replace the synchronizer with the clock. How is the noise now affecting the reconstructed intelligence?

l) Turn off power to all equipment.
Objective C. Demonstrate the affect that noise has on a PWM signal in a communications channel.

Preparatory Information

A PWM modulation system shown in Figure 6-18 is not affected by noise to the extent of a PAM signal. The PWM signal with the intelligence in its pulse width is not affected by reconstruction errors unless the noise peaks are extremely large. Also, the leading and trailing edges of the pulses will not be affected by the noise if the edges are vertical. However, in practical systems the edges of the pulses will not be vertical. If the bandwidth of a PWM receiver is too narrow the edges of the pulses will slope as shown in Figure 6-19.

Noise will be superimposed on the pulse and change the pulse width. If the noise on the original pulse edges add to the pulse width, the reconstructed pulse width will be wider than the desired pulse as shown in Figure 6-19a. If the noise on the original pulse edges subtracts from the pulse width, the reconstructed pulse width will be more narrow than the desired pulse as shown in Figure 6-19b.

A block diagram of the circuitry used on the trainers to demonstrate the affect that noise has on a PWM signal in a communications channel is shown in Figure 6-20.
The intelligence signal is input to the sample/hold circuit at J14 and is sampled at the trailing edge of each clock pulse input at J15. The sample/hold circuit outputs an instantaneous sample of the intelligence signal input at J14 and holds the sample at J16 until the next sampling pulse is generated. The output of the sample/hold circuit at J16 is a staircase signal which is input to the adder circuit at J25.

The sampling pulses generated in the sample/hold circuit by the clock input at J15 are output at J17 and input to the ramp generator at J22. The ramp generator outputs a linear ramp voltage at J23 with a constant ramp length and amplitude for each sampling pulse input at J22. The ramp voltage is input to the adder circuit at J24.

The ramp voltage input to the adder circuit at J24 is summed with the staircase signals input to the adder at J25. The output of the adder at J27 is a varying-height ramp voltage with an amplitude that follows the changing amplitude of the intelligence signal at J14. The varying-height ramp voltage is input to the comparator circuit at J28.

The output of the comparator at J30 is a PWM signal whose pulse width is determined by the amplitude of the varying-height ramp voltage. The PWM signal is input to the channel circuit at J8 on the Channel Simulator Trainer.

The PWM input to the channel circuit at J8 is added to the noise input to the channel circuit at J9 from the noise source circuit. A SNR ratio of 6, 10, 15, or 20dB is selected by closing the appropriate switch on the SNR SELECT (dB) DIP switch on the channel circuit. A bandwidth of 4, 20, 40, or 200kHz is selected for the PWM signal input at J8 by closing the appropriate switch on the BANDWIDTH SELECT (kHz) DIP switch on the channel circuit. The PWM signal with noise is output from the channel circuit at J10 with a specific SNR and input to a series-connected pair of low-pass filters at J34 on the Pulse Modulation Trainer.

The output of the low-pass filter at J37 is the reconstructed intelligence signal with noise. The reconstructed intelligence signal at J37 is input to the speaker amplifier circuit at J25 on the Channel Simulator Trainer.

The output from the speaker amplifier at J26 is an amplified version of its input. The amount of amplification is set by the VOL ADJ potentiometer on the speaker amplifier circuit.

☐ 3. a) With the power off, connect the circuit shown in Figure 6-21. Apply power to the trainers, AF generator, oscilloscope, and frequency counter.

☐ b) Set the AF generator frequency to 400Hz and adjust the AF level control to minimum output. Adjust the FREQ ADJ potentiometer on the clock circuit to indicate 12kHz on the frequency counter. Set all the DIP switches on the channel circuit to off. Set the ATTEN SEL switch on the noise source circuit to X1. Connect the channel 1 probe to J23. Adjust the SLOPE ADJ potentiometer on the ramp generator circuit for a 7.5Vp-p signal at J23. Move the channel 1 probe connected at J23 to J30. Adjust the THRESHOLD ADJ on the comparator circuit for a symmetrical squarewave (50% duty cycle). What do these signals at J30 represent?

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Figure 6-21
c) Connect the channel 2 probe to J10 on the Channel Simulator Trainer. Set the oscilloscope sweep speed to 20 microseconds. Superimpose the signals at J10 and J30. Using the PWM signal at J30 as a reference, alternately change the SNR SELECT (dB) switch on the channel circuit from 20dB to 5dB while observing the pulse width and edges of the signals. Did the channel noise affect the pulse width or edges of the PWM signal at J10 in any way compared to the PWM signal at J30? Explain.

d) Set all the SNR SELECT (dB) switches to off. Set the BANDWIDTH SELECT (kHz) switch to 20kHz. Alternately turn the 15dB SNR SELECT (dB) switch on and off while observing the effect this has on the trailing edge of the PWM signal. Repeat this step using bandwidths of 40 and 20kHz and a SNR of 15dB. Describe what affect the noise has on the trailing edge of the signal with three different bandwidths.

e) Set all channel circuit DIP switches to off. Move the channel 1 probe connected at J30 to J14. Adjust the AF level control on the AF generator to output a 5Vp-p sine wave at J14. Adjust the VOL ADJ on the speaker amplifier circuit to a comfortable listening level. What do the signals at J10 represent?

f) Set the oscilloscope sweep speed to 20 microseconds. Alternately change the SNR SELECT (dB) switch on the channel circuit from 20dB to 5dB. Are the PWM signals at J10 distinguishable at all dB switch settings and is the tone from the speaker distorted by the noise?

g) Move the channel 2 probe connected at J10 to J37. Trigger the oscilloscope on channel 1. Alternately change the SNR SELECT (dB) switch on the channel circuit from 20dB to 5dB. Does the reconstructed intelligence signal on channel 2 resemble the original intelligence signal on channel 1 at all dB switch settings?

h) Turn off power to all equipment.

Summary

In this laboratory exercise you connected a circuit used to generate a PAM signal and demonstrate the affect that noise has on a PAM signal with different SNR's. You found that the noise caused the PAM signal and reconstructed intelligence signal to bounce or jitter vertically. Also, as the SNR decreased, the reconstructed intelligence signal became more distorted. You also found that as the bandwidth of the circuit that the PAM signal was input to decreased, the amplitude of the reconstructed intelligence signal decreased.

You connected a circuit in which a synchronizer was used to detect the PAM signal, and demonstrate the affect that noise has on the synchronizer and recon-
structured intelligence. You found that the vertical jitter of the PAM pulses into the synchronizer caused the output clock pulses of the synchronizer to have a horizontal phase jitter and jump in and out of sync with the input PAM pulses. You observed that as the SNR was decreased, the horizontal phase jitter of the clock pulses increased. You found that using the synchronizer caused the reconstructed intelligence to have both vertical jitter and horizontal phase jitter.

Finally, you connected a circuit to generate a PWM signal and demonstrate the affect that noise has on a PWM signal. You found that if the edges of the PWM signal were vertical, the width of the PWM signal was not affected by noise. If the edges of the PWM signal slope, noise superimposed on the edges changed the width of the PWM pulses. You also observed that the PWM signal was less affected by noise than a PAM signal because the intelligence of the PWM signal is in the pulse width and not in the amplitude.

Quiz

1. If the amplitude of a signal is increased and the noise level is held constant, the S/N ratio will
   a. increase.
   b. decrease.
   c. remain the same.
   d. first increase then decrease.

2. A PAM signal is
   a. not affected by noise.
   b. affected by noise the same as a PWM signal.
   c. affected by noise more than a PWM signal.
   d. affected by noise less than a PWM signal.

3. If the bandwidth is decreased in a PAM receiver, the
   a. SNR of the PAM signal increases.
   b. the shape of the PAM pulses are not affected.
   c. edges of the PAM pulses become more vertical.
   d. recovered intelligence signal will decrease in amplitude.

4. Using a synchronizer in the detection of a PAM signal that has a low SNR will result in
   a. a decrease in noise.
   b. removing noise from the sampled pulses.
   c. horizontal and vertical signal jitter.
   d. an improved SNR.

5. As compared to a PAM signal, a PWM signal is
   ..................................... affected by a low SNR.
   a. more
   b. less
   c. equally
   d. not

6. A PWM signal will be less affected by noise if the
   ..................................... of the PWM pulses are .....................................
   a. width / increased.
   b. width / decreased.
   c. edges / sloping.
   d. edges / vertical.