Department of Electrical Engineering and Computer Science

Faculty Member: Dr. Huma Ghafoor Dated: 9/05/2023

Semester: 6th Section: BEE 12C

EE-351 Communication Systems

Lab 11: Pulse Amplitude Modultion

Group Members

Name	Reg. No	Viva / Quiz / Lab Performance	Teamwork	Ethics	Software Tool Usage	Analysis of data in Lab Report
		5 Marks	5 Marks	5 Marks	5 Marks	5 Marks
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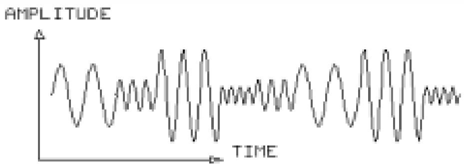
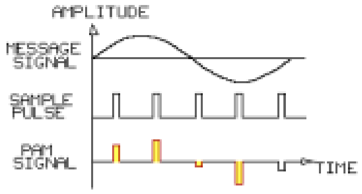
2 Pulse Amplitude Modulation

2.1 Introduction



An analog message signal, representing voice for example, has continuous amplitude and frequency values that vary with time.

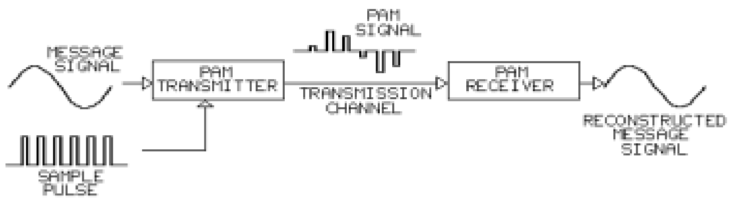
Analog communications systems transmit the complete analog waveform.



Instead of transmitting the analog waveform, it is possible to transmit pulses that represent the message signal's waveform.

Samples of the analog message signal can be taken at regular intervals.

In pulse-amplitude modulation (PAM), the amplitude of each pulse sample is proportional to the amplitude of the message signal at the time of sampling.



The PAM signal, rather than the analog message signal, is transmitted to a receiver.

The PAM receiver demodulates (reconstructs or recovers) the PAM signal into the original analog message signal.

2.2 Advantages:

Two advantages of transmitting PAM signals rather than complete analog signals are: If the duration of the PAM pulse is small, the energy required to transmit the pulses is much less than the energy required to transmit the analog signal.

The time interval between the PAM pulses may be filled with samples of other messages, which allows several messages to be transmitted simultaneously on one channel; this technique is called time-division multiplexing (TDM).

2.3 Lab Report Instructions

All questions should be answered precisely to get maximum credit. Lab report must ensure following items:

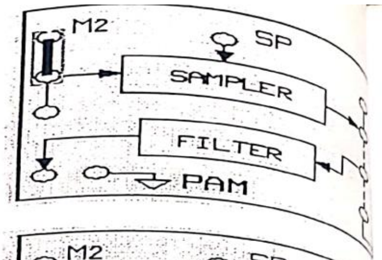
- Lab objective
- Results (screen shots) duly commented and discussed.
- Conclusion

3 Lab Procedure

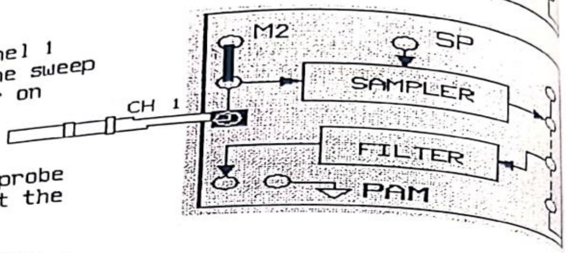
3.1 Modulation

Signal Generation

1. On the PAM circuit block insert a two-post connector between the message signal terminal M2 and the SAMPLER's input.



2. Set oscilloscope channel 1 to 2 V/DIV, and set the sweep to 0.1 ms/DIV. Trigger on channel 1.



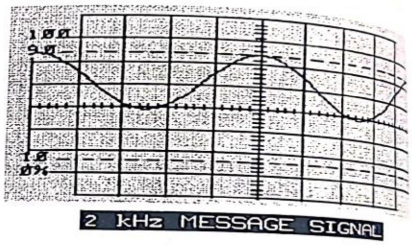
Connect the channel 1 probe to the test terminal at the SAMPLER's M2 input.

Is the message signal (M2) a 5 Vpk-pk, 2 kHz signal?

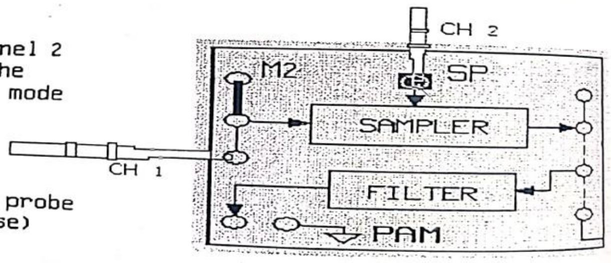
a. yes b. no

3. For a 2 kHz message signal, what is the Nyquist rate for the sample pulse signal?

Nyquist rate = _____ kHz



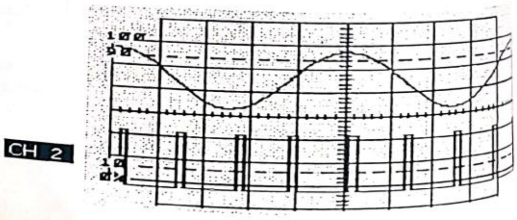
4. Set oscilloscope channel 2 to 2 V/DIV, and set the oscilloscope vertical mode to ALT (or DUAL).



Connect the channel 2 probe to the SP (sample pulse) input to the SAMPLER.

5. What are you observing on channel 2?

a. PAM signals
b. sample pulse signals

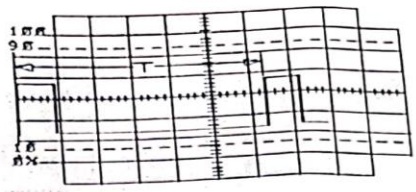


EXERCISE 2-1

6. Set the oscilloscope sweep to 20 μs/DIV.

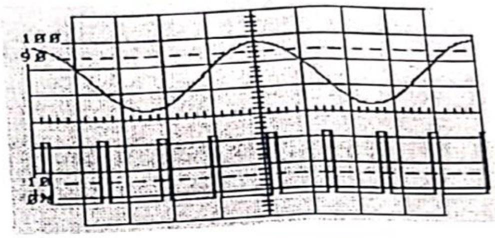
   Measure the period (T) of the sample pulses on channel 2.

   T = _____ ms



7. From the period T = 0.1250 ms, calculate the frequency of the sample pulse.

   $f_S = 1/T$
   $= \_\_\_\_\_$ kHz

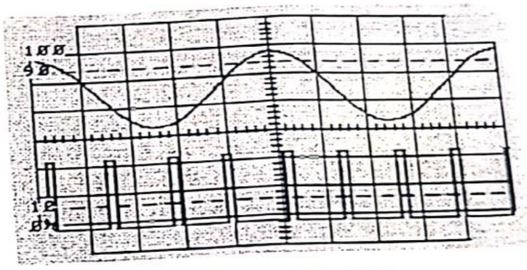


T = 0.1250 ms

8. You determined that the Nyquist rate for a 2 kHz message signal is 4 kHz.

   Is the 8.0 kHz sample pulse adequate to form a PAM signal that represents the message signal?

   a. yes b. no

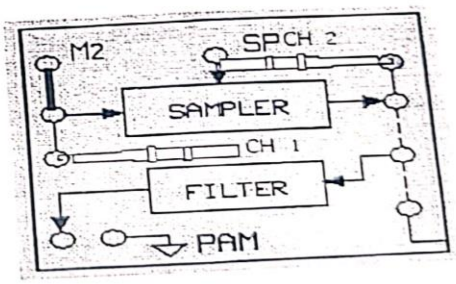


f = 8.0 kHz

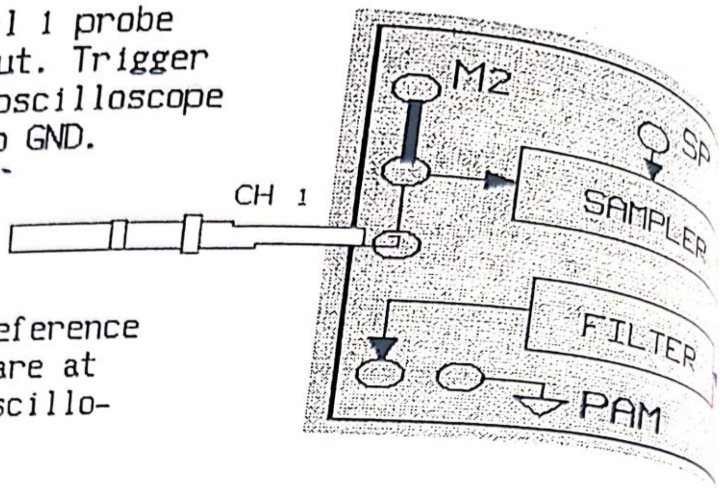
9. Set the oscilloscope sweep to 0.1 ms/DIV. Connect the channel 2 probe to the SAMPLER's output. Adjust the oscilloscope for clear signals with the LEVEL control knob.

   What is the signal on channel 2?

   ✓ a. PAM signal
   b. SP signal
   c. M2 message signal

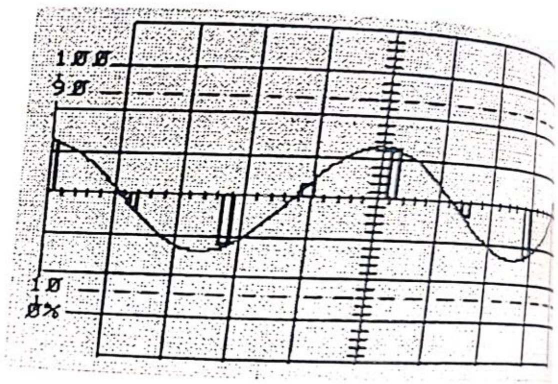


Connect the channel 1 probe to the SAMPLER input. Trigger on channel 1. Set oscilloscope channels 1 and 2 to GND.



Adjust the ground reference lines so that they are at the center of the oscilloscope screen.

. Set channels 1 and 2 to AC. The message signal should overlay the PAM signals, as shown.



Compare the PAM signal with the message signal. Does the amplitude of the PAM signals match the amplitude of the message signal?

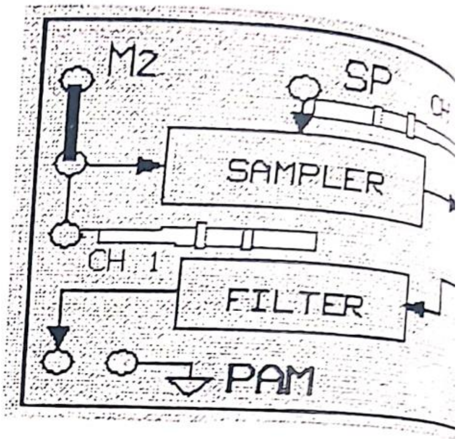
a. yes b. no

In the following PROCEDURE steps, you will calculate the power of PAM signal formed from a 5 V_{pk-pk}, 2 kHz message signal with an 8 sample pulse.

19. Connect the circuit and oscilloscope probes as shown.

    Set channels 1 and 2 to 2 V/DIV, and set the sweep to 0.1 ms/DIV. Set the vertical mode to ALT (or DUAL), and trigger on channel 1.

    The message signal (CH 1) and the PAM signal (CH 2) should appear as shown in the help window.

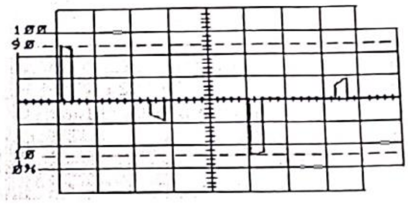


EXERCISE 2-1

20. Set the vertical mode to channel 2 so that only the PAM signal appears.

    Set channel 2 to 1 V/DIV and the sweep to 50 µs/DIV.

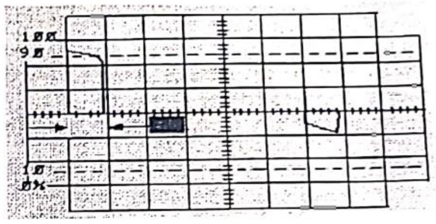
    Adjust the oscilloscope so that the PAM signal appears as shown.



21. Set the oscilloscope to a sweep of 20 µs/DIV. The PAM signal should appear as shown.

    Measure the pulse width (PW) of a PAM signal. 1.5×10^{-5}

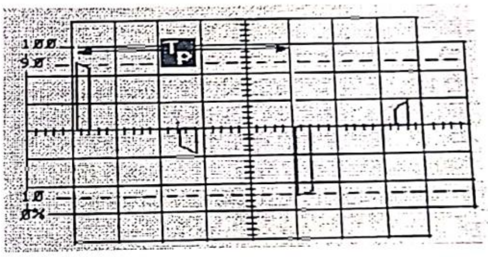
    PW = _____ ms



22. Set the oscilloscope to a sweep of 50 µs/DIV. The PAM signal should appear as shown.

    Measure the period (T_P) of PAM pulse P1, which is 2 times the 8 kHz SP signal period.

    T_P = _____ ms

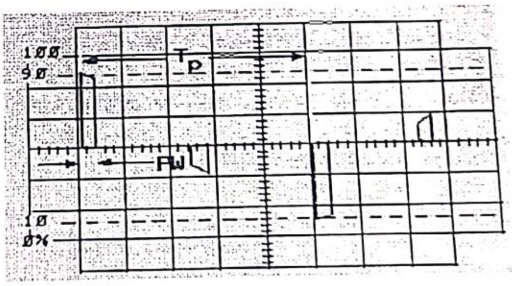


23. Calculate the pulse duty cycle fraction (PW/T_P).

    Pulses P1 and P2 have equal PW/T_P ratios.

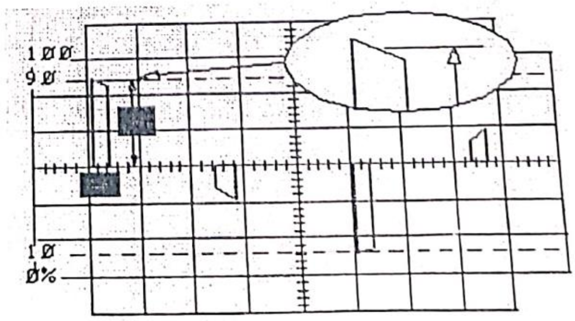
    $$PW/T_P = \frac{0.01600}{0.25000}$$ 3/25

    PW/T_P = _____ ~~ms~~



24. Measure the voltage of PAM pulse P1, as shown.

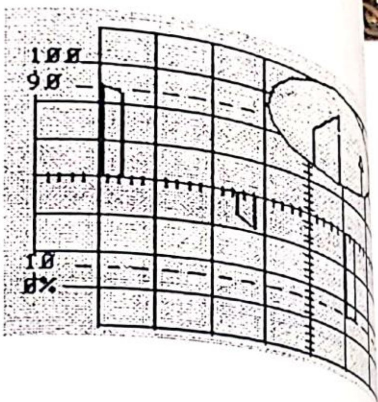
    V1 = _____ V

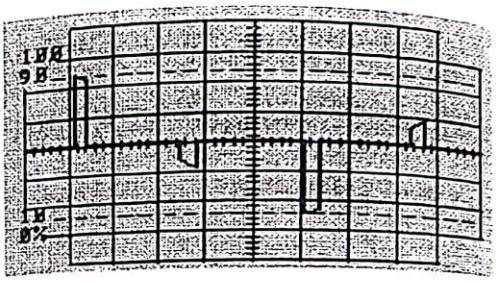


ignal Generation

25. Measure the voltage of PAM pulse P2, as shown.

V2 = ____ V





26. $V_{rms(p)} = \sqrt{V^2_{rms(p1)} + V^2_{rms(p2)}}$

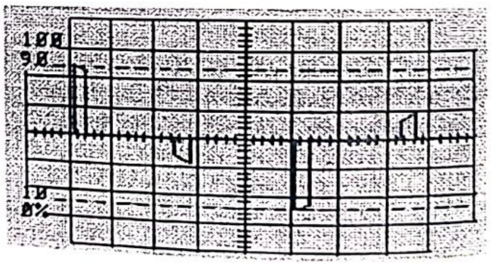
$= \sqrt{(V1 \times \sqrt{PW/T})^2 + (V2 \times \sqrt{PW/T})^2}$

$= \sqrt{PW/T_p \times (V1^2 + V2^2)}$

$=$ ____ V_{rms} $V_{rms} = 0.665\ V_{rms}$

$.6 \times \sqrt{(0.0688 \times 10^{-3})}^2$

$+ 0.8 \times \sqrt{(0.0688 \times 10^{-3})}^2$

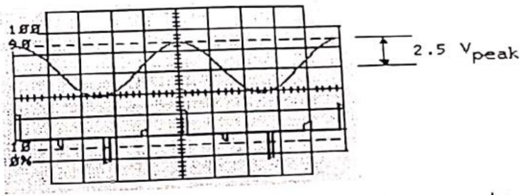


27. Calculate the power of the PAM signal across a 1 kΩ impedance

$P_p = \frac{V^2_{rms(p)}}{2}$

$=$ ____ mW

EXERCISE 2-1



28. Set channel 1 to 2 V/DIV, the mode to DUAL, and the sweep to Ø.1 ms/DIV. The peak voltage of the 2 kHz sine wave is 2.5 V_{peak}. Calculate the power of the sine wave message signal across a 1 kΩ impedance.

$P_S = (0.707 \times V_{peak})^2/Z$
$= \_\_\_\_\_$ mW

P_{PAM}

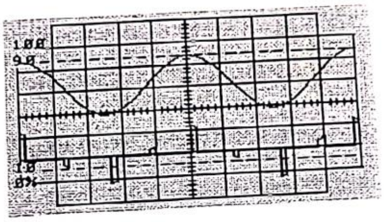
$\boxed{V_{pp} \times 0.3535}$

$V_{peak} \times 0.71$

$\frac{V_{rms}^2}{R}$. P_m

P_S = 3.124 mW

P_p = Ø.399 mW

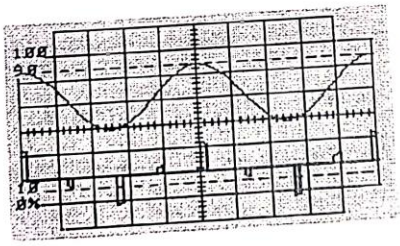


29. Calculate the ratio of the PAM signal power to the sine wave message signal power.

Power ratio = PAM power/sine wave power
$= P_p/P_s$
$= \_\_\_\_\_$

$\frac{P_{PAM}}{P_{SM}}$

$\times \frac{PW}{T}$



P_S = 3.124 mW

PW = Ø.Ø16 ms

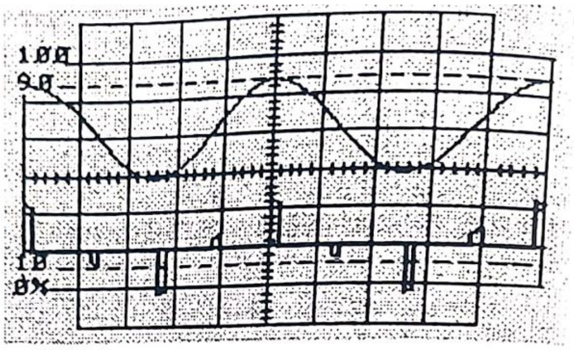
T = Ø.125 ms

30. Calculate the theoretical power of the PAM signal from the sine wave power (P_S). The PAM signals period (T) is Ø.125 ms, which is half T_p.

$P_p = PW/T \times P_S$
$= \_\_\_\_\_$ mW

$P_{PAM} = P_S \times$

2-27



31. Is your calculated theoretical PAM signal power about equa to the PAM signal power calculated from the measured pulse amplitudes and PW/T_p?

a. yes b. no

3.2 Demodulation

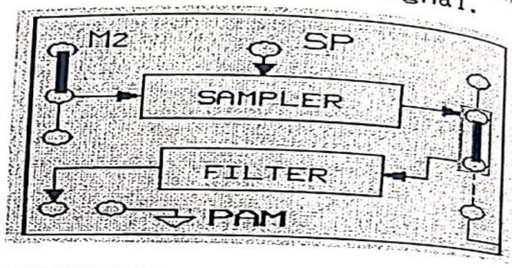
PROCEDURE

In this PROCEDURE, you will reconstruct a message signal from a PAM signal by using a low pass filter.

You will observe the effect of the PAM signal's frequency spectrum and the filter's cutoff frequency on the reconstructed message signal.

1. On the PAM circuit block, insert a two-post connector between M2 and the SAMPLER input.

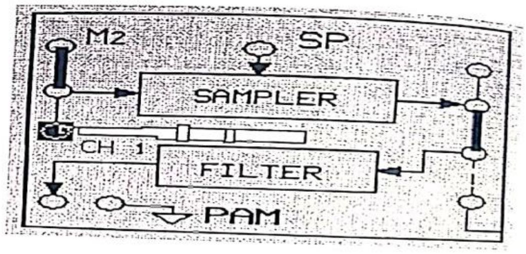
   Insert a two-post connector between the SAMPLER and the FILTER.



2. Set the oscilloscope channel 1 to 2 V/DIV, and set the sweep to 0.1 ms/DIV. Trigger on channel 1.

   Connect the channel 1 probe to the test terminal at the SAMPLER message signal input.

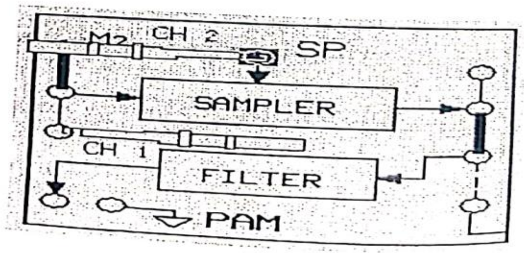
   M2 is a 5 V_{pk-pk}, 2 kHz signal.



3. Set oscilloscope channel 2 to 2 V/DIV, and set the vertical mode to ALT (or DUAL).

   Connect the channel 2 probe to the SP (sample pulse) terminal.

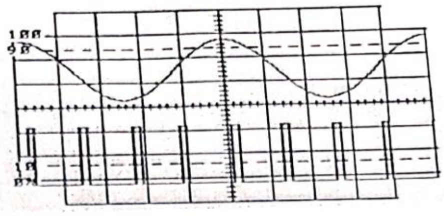
   The SP frequency (f_S) is 8 kHz.



EXERCISE 2-2

4. With a 2 kHz message signal, is the 8 kHz SP frequency greater than the Nyquist rate?

   a. yes b. no

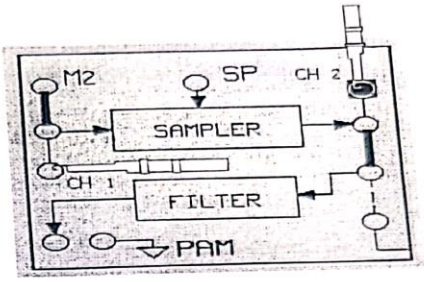


2-3

5. Connect the channel 2 probe to the SAMPLER's output to observe the PAM signal.

   Does the PAM envelope resemble the message signal waveform?

   a. yes
   b. no



NOTE

On the circuit board, the SP signals are synchronized with the 2 kHz M2 message signal. This means that the pulses always occur at the same points on the M2 waveform.

The signals are synchronized to make it convenient for you to observe the M2, SP, and PAM signals on the oscilloscope. Because the M2 and SP signals are synchronized, the reconstructed message signal may be distorted.

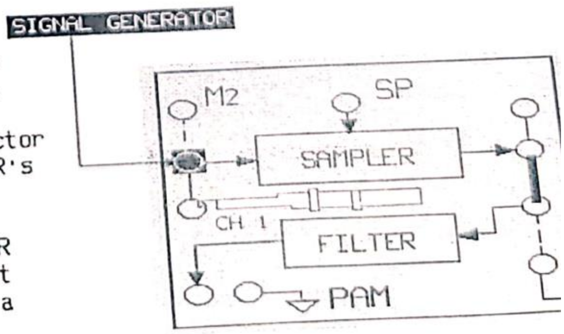
In the following PROCEDURE steps, you will use a message signal from a SIGNAL GENERATOR, which is not synchronized with the SP signal. Consequently, sampling will be random on the message signal waveform.

2-6

6. Remove the channel 2 probe from the SAMPLER's output.

   Remove the two-post connector between M2 and the SAMPLER's input.

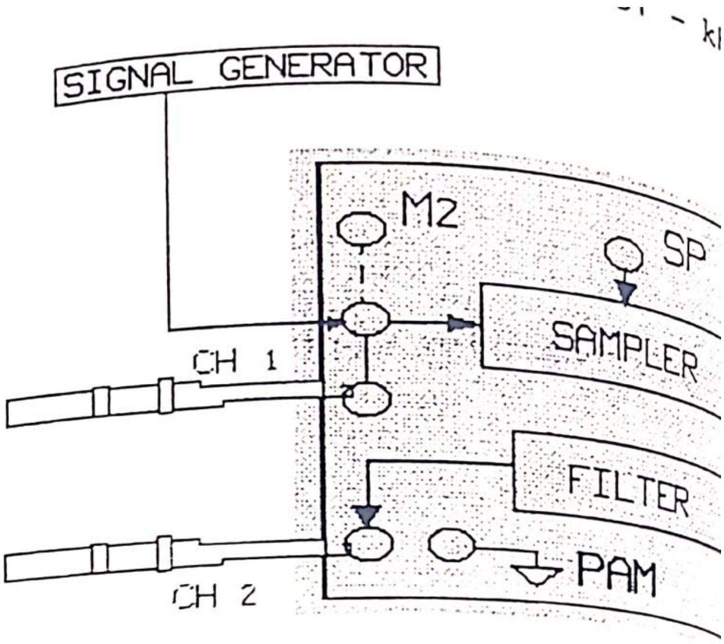
   Connect a SIGNAL GENERATOR to SAMPLER's input. Adjust the SIGNAL GENERATOR for a 2 kHz, 5 V_{pk-pk} message signal on channel 1.



8. Connect the channel 2 probe to the FILTER's output. Set channel 2 to 200 mV/DIV.

Is the reconstructed message signal from the FILTER (CH 2) a good representation of the message signal (CH 1)?

a. yes b. no



9. On the SIGNAL GENERATOR, vary the message signal's frequency by about ±0.5 kHz, and vary its amplitude by about 0.5 Vpk-pk while observing the oscilloscope.

Did the reconstructed message signal (channel 2) vary with the message signal to the SAMPLER (channel 1)?

a. yes b. no

3.3 Deliverables

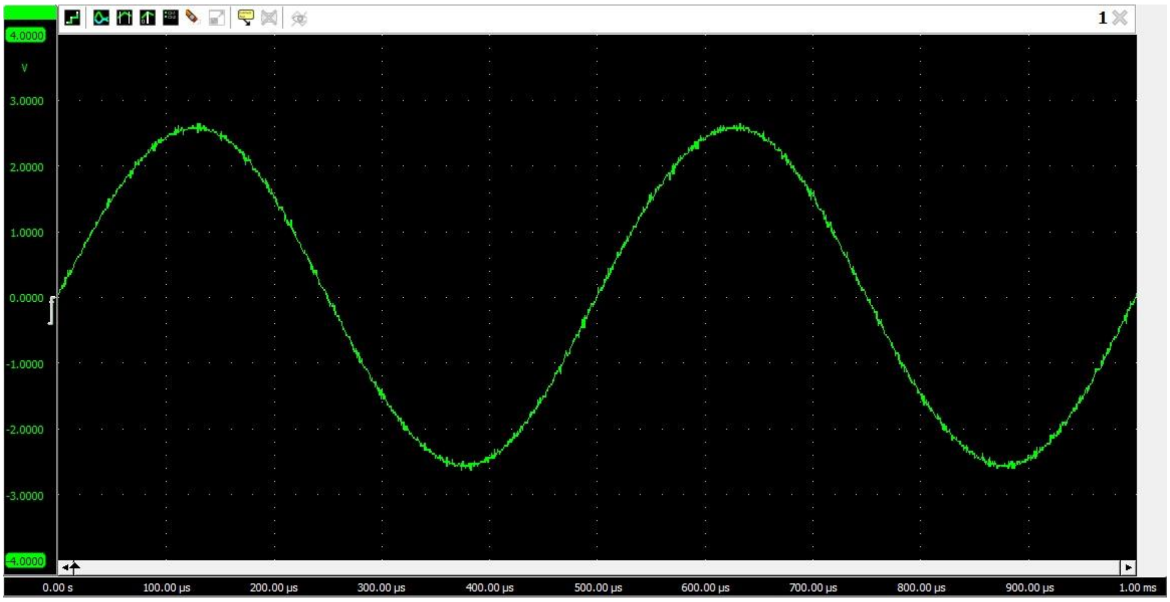
3.3.1 Signal Generation

- **Step 2**

Yes

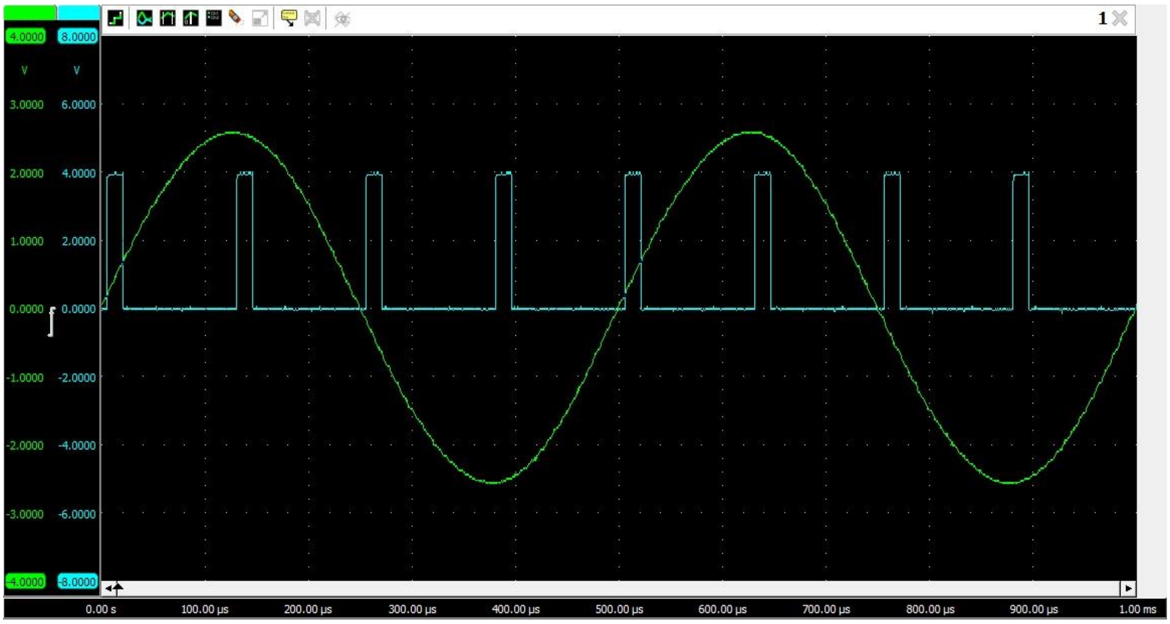
- **Step 3**

4kHz



- **Step 5**

Channel Pulse Signals



- **Step 6**

125 us

- **Step 7**

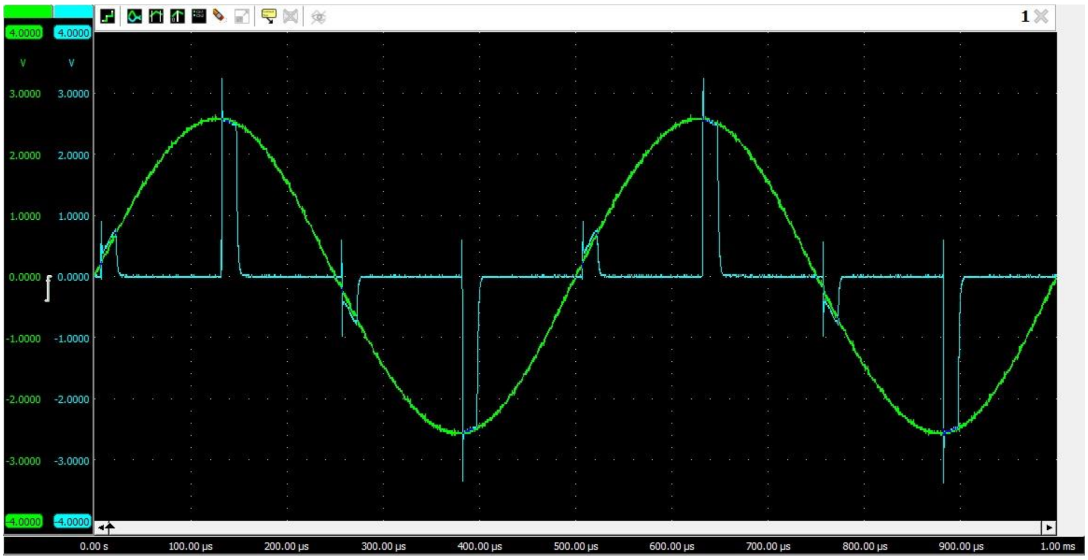
8kHz

- **Step 8**

Yes

- **Step 9**

PAM signal



- **Step 10**

Natural

- **Step 11**

Yes

- **Step 13**

Yes

- **Step 21**

16.679 us

- **Step 22**

0.25 ms

- **Step 23**

PW / Tp = 0.0667

- **Step 24**

2.53 V

- **Step 25**

0.53 V

- **Step 26**

V_{rms} = 0.667

- **Step 27**

0.445 mW

- **Step 28**

3.199 mW

- **Step 29**

0.139 W/W

- **Step 30**

0.426 mW

- **Step 31**

Yes

3.3.2 Demodulation

- **Step 4**

Yes

- **Step 5**

Yes

- **Step 8**

No

- **Step 9**

Yes

4 Conclusion

In conclusion, pulse amplitude modulation (PAM) is a digital modulation technique that represents the information to be transmitted by varying the amplitude of the transmitted pulses. PAM is a versatile modulation technique that can be used for a variety of applications, including telecommunications, data communications, and radar.

In this lab report, we investigated the characteristics of PAM by generating and analyzing PAM signals. We used a microcontroller to generate PAM signals with different pulse amplitudes and frequencies. We then used an oscilloscope to measure the amplitude and frequency of the PAM signals.

Our results showed that the amplitude of the PAM signal is proportional to the amplitude of the information signal. We also found that the frequency of the PAM signal is equal to the sum of the frequencies of the information signal and the carrier signal.