Experiment #3 – Pulse Code Modulation (PCM)

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# **Experiment Objective**

Introduction of basic concepts of Delta Modulation (DM) system with simulation and hardware implementation.

# **2.0 About Laboratory Day and Equipment List**

# The laboratory session took place on the Thursday section between 9:00am and 11:50am on February 15th, 2024. My lab partner was Isiah. The equipment for the is experiment is listed below,

1. MATLAB
2. Rohde & Schwarz RTM 3034 Oscilloscope
3. CD4013
4. CD4016
5. LM741

# **3.0 Simulation**



See section 5.0 for MATLAB code.

# **4.0 Implementation**

A diagram of a circuit

Description automatically generated

Check the waveforms at the output of the flip-flop and the sampler. Compare the output of the integrator mr(t) with the input waveform m(t) by superimposing both signals. Plot all waveforms and measure the step size. Explain your observations. Vary the following parameters and observe the changes in the reconstructed signal. Record the waveforms for each case.

1. Vary the message frequency between 50 Hz and 1 KHz.

For all the signals, the demodulated signal has a higher voltage amplitude compared to the input. As the frequency increases, the demodulated signal has fewer rapid variations. The rapid variations are useful because when they’re averaged by a low pass filter it can get closer to the original signal (lower SQNR). Also, when the frequency is much higher, there appears to be a phase shift in the output signal and changes in the output signal become more linearly (the slope of the sine wave has become straight).

A screenshot of a computer

Description automatically generated

Flip Flop Output (Modulated Signal)

A screen shot of a graph

Description automatically generated

Delta Modulation Output with 50 Hz Sine Input

A screen shot of a graph

Description automatically generated

Delta Modulation Output with 100 Hz Sine Input

A screen shot of a graph

Description automatically generated

Delta Modulation Output with 200 Hz Sine Input

A screen shot of a graph

Description automatically generated

Delta Modulation Output with 500 Hz Sine Input

A screen shot of a graph

Description automatically generated

Delta Modulation Output with 1000 Hz Sine Input

2) Vary the message amplitude between 0 and 2Vpp.

As the Vpp rises the closer the output signal peak to peak matches the input signal. Also there are smaller changes in output signal when the voltage is higher.

A graph on a black background

Description automatically generated

Input vs Output with Input

A screen shot of a computer

Description automatically generated

Input vs Output with Input

3) Vary the sampling frequency between 400Hz and 100 KHz

As the sampling frequency is increased, the output signal has more “levels” and matches the input signal more closely. However, after 50 kHz there does not seem to be an improvement to output signal with any additional increase to the sampling frequency.

A screen shot of a graph

Description automatically generated

Output Signal vs Modulated Signal, Sampling frequency of 400 Hz

A screen shot of a graph

Description automatically generated

Output Signal vs Modulated Signal, Sampling frequency of 1.4 kHz

A screen shot of a computer

Description automatically generated

Output Signal vs Modulated Signal, Sample frequency of 50 kHz

A screen shot of a computer

Description automatically generated

Output Signal vs Modulated Signal, Sample frequency of 100 kHz

# **4.5 Questions and Results**

Delta modulation is special case of Differential PCM where each sample is represented by just 1 bit – explain.

Delta modulation is the approach as DPCM, however, were limited by 2 levels of information. Delta modulation still transmits the difference between the predicted difference vs actual difference of signal but at a much higher frequency. Since the quantization level is only 2 levels, we must compensate with higher sampling frequency. At the higher frequency the demodulator takes smaller steps which allows a more accurate reproduction of the message signal. A benefit the Delta modulation has over DPCM is that the implementation is much simpler but at the cost of higher sampling frequency requirement (also higher bandwidth).

# **5.0 MATLAB Code**

Used to generate figure(s)

clear all

close all

clc

fs = 2000;

ts = 1/fs;

tn = 0:ts:1/25;

StepSize = 1/15;

m = 0.5 .\* sin(2\*pi\*50\*tn);

s = DM\_Encod(m, StepSize);

So = LowPassFilter(100, 0.1, s);

subplot(3,1,1);

plot(tn, m);

title("Message Signal");

subplot(3,1,2);

plot(tn, s);

title("Modulated Signal");

subplot(3,1,3);

plot(tn, So \* 0.5);

title("Demodulated Signal");

function s = DM\_Encod(m, stepsize)

xlen = length(m);

accum = 0;

s = zeros(1, xlen);

for i=1:1:xlen

if m(i) > accum

s(i) = 1;

accum = accum + stepsize;

else

s(i) = -1;

accum = accum - stepsize;

end

end

end

function So = LowPassFilter(fod, cf, Si)

b = fir1(fod, cf);

So = conv2(Si, b, 'same');

end

# **6.0 Learned Objectives**

* Delta Modulation
* DPCM Demodulation
* MATLAB Simulation

# **7.0 Conclusion**

In conclusion, the experiment on Pulse Code Modulation (PCM) and Delta Modulation (DM) provided valuable insights into signal encoding. It revealed the impact of varying parameters on the output signal, emphasizing the trade-offs involved in modulation techniques. The experiment enhanced understanding of Delta Modulation's simplicity and its demand for higher sampling frequencies, crucial for designing efficient communication systems.