IMPLEMENTATION OF SIMULATION-BASED LABORATORY EXPERIMENT USING MATLAB SIMULINK TOOL FOR PULSE CODE MODULATION (PCM) IN DIGITAL COMMUNICATION COURSE

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Abstract

Most engineering students have been having difficulties in understanding the fundamentals of engineering courses in classroom. To tackle this problem, the use of simulation-based lab was introduced in teaching and learning process. This paper discusses the implementation of simulation-based laboratory experiment using Matlab Simulink Tool for Pulse Code Modulation (PCM) in Digital Communication course, in order to give them clearer understanding of the theoretical concept that they have learned in class for practical application. Matlab Simulink is used to help the engineering students in having good understanding of basic PCM. To demonstrate the capability of the tool, the block diagram of PCM is constructed and simulated by using Matlab Simulink. The process involved to design PCM via MATLAB Simulink is composed of Simulink simulator block set. Simulink simulator block set includes input sources, scope, sample and hold circuit, quantizer and multiplexing .There are three important steps of PCM processes including sampling, quantizing and encoding. Each characteristic of PCM process in Matlab Simulink is analyzed and then compared with the theory. It is shown that these theoretical results coincide with the simulation results and it achieved 100% accuracy.

Keywords: Simulation based lab; PCM; Simulink block sets; Sample and Hold Circuit; Quantizer;

1.0   INTRODUCTION

Digital communication is a compulsory course offered to students who choose the field of communication engineering in Diploma of Electrical Engineering in UiTM Terengganu. This course runs in semester 5. The course deals with the basic concepts of digital transmission and modulation in communication system. The emphasis will be on Pulse Code Modulation (PCM) and coding. As an outcome of this course, the students are expected to be able to understand and explain the fundamental concepts of Pulse Code Modulation (PCM). To achieve this objective, implementation of simulation based laboratory experiment using Matlab Simulink tool has been introduced to students.

Pulse Code Modulation (PCM) is a method that is used to convert an analog signal into a digital signal, so that the modified analog signal can be transmitted through the digital communication network. Digital signals (PCM) are more reliable and accurate than analog signal because it is more resistant to interference. Moreover, probability of error occurrence will be reduced by the use of

appropriate coding methods. PCM is used in most telecommunications applications like Telkom (wireless and wireline telecommunication) system, CD laser disks, digital audio recording, digitized video special effects, digital video and voice mail (Xue & Chen, 2013). It is also widely used in Radio Control Units where radio transmitter and receiver is used for remote controlled cars, planes and boats/ships.

Matlab is one of the most widely used computational tools in science and engineering. This is because Matlab is the most powerful software package that has many built-in tools for solving problems and for graphical illustrations (Yi, Jian & Chun, 2005). Moreover it is ideal software that integrates computation, visualization and programming (Ertugrul, 2000). Typically it is used for control systems, communication and most importantly signals and image processing. It is widely used in universities, laboratories and also at private companies. Most academicians use Matlab software in the curriculum to replace the traditional programming languages such as FORTRAN, C, Basic and Pascal (Elliot, Vijayakumar, Zink & Hansen, 2007).

Simulink is a graphical extension tool in MATLAB for designing and simulation of systems easily without using hardware devices (Koprda, Turcani & Balogh, 2012) It is basically a graphical block diagramming tool comprising customizable set of block libraries. It uses a drag and drop system for component simulation, and the lines are used to connect between these components. Typically Simulink is widely used in control theory and digital signal processing for simulation and design. It is because Simulink enables rapid construction of virtual prototypes to explore design concepts and helps to analyze the result of the model.

Matlab Simulink is very useful for developing algorithms, GUI assisted creation of block diagrams and realization of interactive simulation based design (Ibrahim, 2016). MATLAB simulation is the most preferable and best way to bring out the idealistic reality to a model-based design environment. MATLAB simulation can make the project more expressive and understandable due to its availability of tool, toolboxes, advanced functionalities and simulators. Since MATLAB Simulink is a high-performance language for technical computing, it is very useful to allow people to solve many technical computing problems, especially for algorithm development like Pulse Code Modulation design system. Other than that, many researchers used simulation-based laboratory experiment like PCM-based digital communication system using LabVIEW (Gupta, 2016), a survey of virtual laboratories for teaching/learning tools and future trends (Beucher & Weeks, 2006) and also used automation and measurement (William & Palm, 2009; Hill, 2013).

The approach taken here is learning how to use Matlab Simulink as a platform to plan, design, simulate, test and analyse the result. For instance PCM is designed by using MATLAB Simulink tools. The goal of this paper is to provide an easy way platform to understand the real concept of basic PCM. In addition, the use of Matlab Simulink as a simulation tool to solve engineering problem also can make the learning process becomes more interesting.

1.1 DIGITAL MODULATION

1.2 Pulse Code Modulation (PCM)

Pulse Code Modulation (PCM) is a process of converting an analog signal into a digital signal (A/D conversion) for digital transmission system. The signals in PCM are binary value represented by only two possible states, either with logic 1 (high) and logic 0 (low). PCM modulation occurs in a PCM transmitter. It involves three main processes which include sampling, quantization and encoding. First process is sampling. It is the process of taking samples of the analog input signal at a rate of Nyquist sampling frequency as $fs \geq 2fm_{(max)}$ (Skalar, 2001). The sampling process in a PCM transmitter is to periodically sample the analog input and convert those samples to a multilevel Pulse Amplitude Modulation (PAM) signal. Then, the second process is quantization. Quantization is representing the

sampled values of the amplitude by a finite number, which is the process of converting continuous amplitude sample into a discrete signal.

The last process is encoding. Encoding is the process of converting the discrete signal (voltage or current levels) to represent **1 (high)** and **0 (low)** of the digital signals on the transmission path. Basically, in PCM encoding, each sample is represented as one in the set of eight bit binary words. All three processes which occur in the PCM transmitter is shown in Figure 2.1.
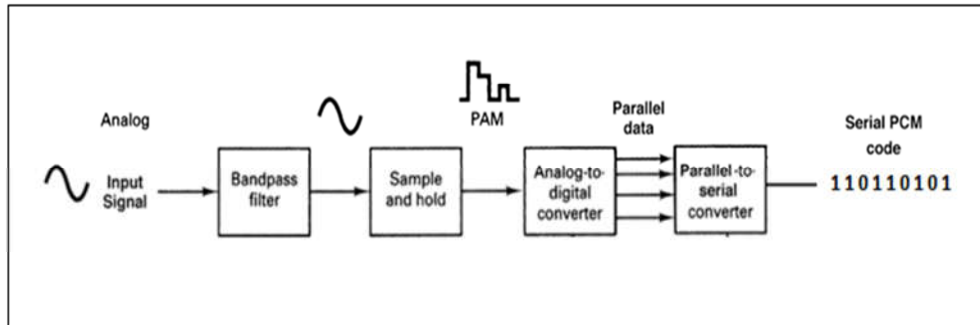

Figure 2.1 PCM transmitter of block diagram system.

Figure 2.1 shows a PCM transmitter of block diagram system. PCM transmitter consists of bandpass filter, sample and hold circuit, analog to digital converter and parallel to serial converter. The function of each block in the PCM transmitter system is shown in Table 2.1 below.

Table 2.1 The function of each block in the PCM transmitter system.

Block PCM	Function
Bandpass filter	Limits the input analog signal to the standard voice-band frequency range (300 Hz to 3000 Hz) such as to remove high frequency components that affect the signal shape and the sampling rate.
Sample-and-hold	A circuit that converts those samples to a multilevel PAM signal.
Analog-to-digital converter (ADC)	Converts the PAM samples to parallel PCM codes. This signal is converted to binary data in a serial-to-parallel converter series and then proceeds to the transmission line as a series of digital pulses.
Parallel-to-serial converter	Converts parallel PCM codes received from the transmission line to serial pulses.

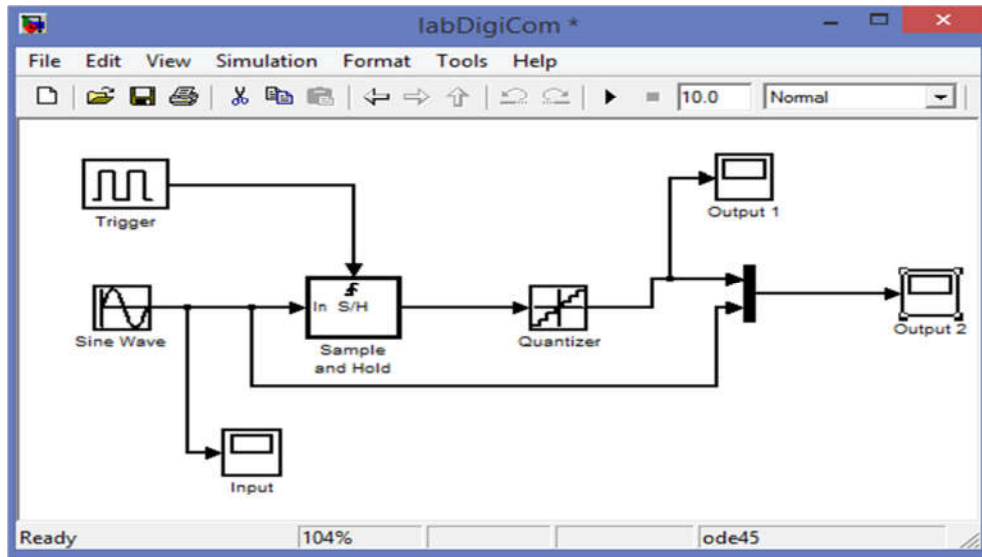**DESIGN AND SIMULATION BY MATLAB SIMULINK TOOL**

Figure 3.0 PCM transmitter block diagram

Figure 3.0 illustrates the blocks needed to design PCM using Matlab Simulink. The blocks used for studying PCM include input sources (sine wave and trigger), sample and hold circuit, quantizer, multiplexer and scope (input and output). For the first step, it needs to select and drag blocks from library and arrange according to required model. The scope blocks are used to view the inputs, check or analyze output and rectify accordingly. Table 3.0 shows the function of each block in PCM block diagram by Matlab Simulink.

Table 3.0 The function of each block in PCM transmitter system.

Blocks	Specifications
Sine wave	Used as modulating signal.
Trigger	Used as pulse carrier signal.
Sample and hold	Samples and hold at certain amplitudes.
Quantizer	The sampled amplitudes are rounded to nearest values.
Mux	Used as multiplexing.
Scope	Used as screen to display result.

Figure 3.0 shows the block diagram of the PCM transmitter system. The sample pulse carrier signals (trigger) in addition with the modulating signal (sine wave) are applied to sample & hold circuit. Sample & hold circuit will sample the input signal during on period of the clock signal and will hold the sampled output till next pulse comes. Then, these sampled signals are quantized to the nearest value which gives us our required step signal input. Each quantized sample is encoded into several bit code words. This process is illustrated in Figure 3.1 below.
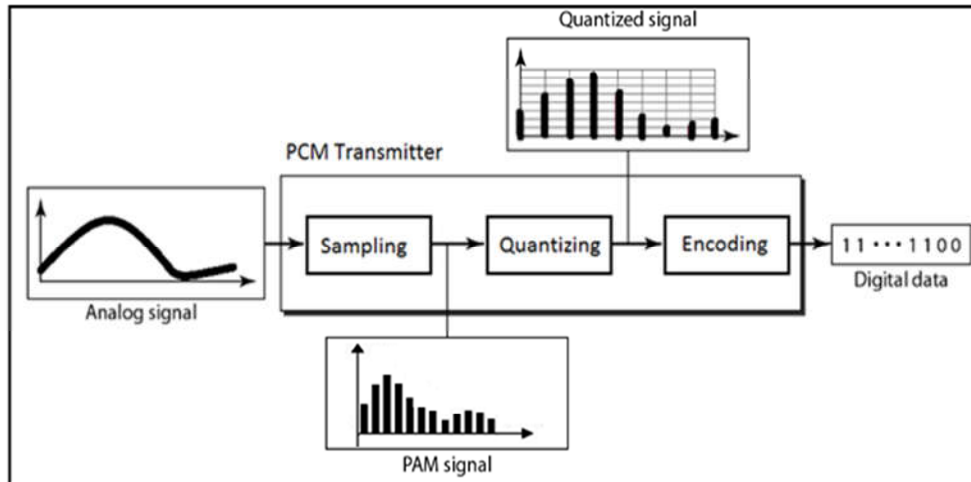
Figure 3.1 Sampling, quantizing and encoding process in PCM transmitter.

2.0   RESULT AND DISCUSSION

From a setup for PCM block diagram done in Matlab Simulink Software, the first input scope is shown in Figure 4.0. The result shows that the input analog signal is a sine wave pattern. Amplitude and frequency are set to 5V and 1rad/sec respectively.
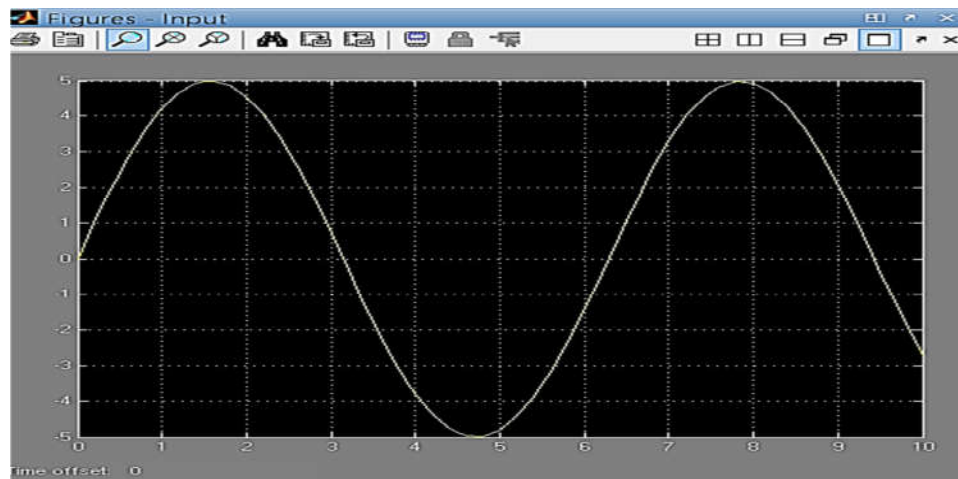

Figure 4.0 Sine wave signal display in input scope.

Second result display in Output 1 scope is as shown in Figure 4.1 below. This signal is Pulse Amplitude Signal (PAM) which signals after the sampling and quantizing processes. From the observation, it started at the trigger that limits a pulse generator signal with its amplitude and frequencies are set to 0.5V and 1rad/sec respectively. Next, this input will go through the process of sampling that functionally converts the analog to digital signal by using the sample and hold which its initial condition is set to 0. The result was also formed with the quantizer at the end. The signal would go through a quantization process that functionally measures the numerical values of the samples and gives suitable scale.
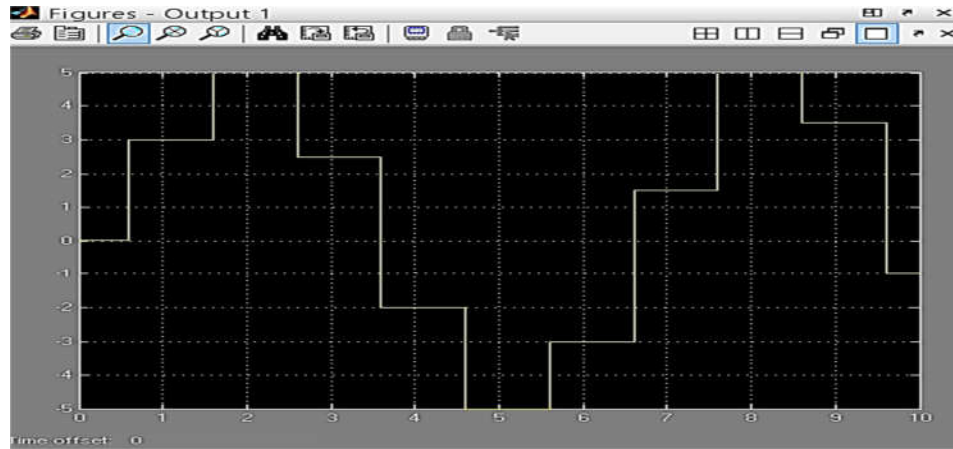
Figure 4.1 Pulse Amplitude Modulation (PAM) signal display in output 1 scope.

Figure 4.2 Combination of sine wave and PAM signal display in output 2 scope.

Figure 4.2 shows the Output 2 scope after multiplexing blocks. From the observation, this is due to usage of multiplexer as a device that has multiple inputs and shows in one output. The quantized PAM signal is converted to a serial binary code before transmission. Table 4.3 shows the sampled value (amplitudes) represented in a set of a binary number including sign bits. A set of binary numbers is encoded into fourth (including sign bits) bit code words. A set of binary numbers is also called as PCM code. The codes currently used for PCM are sign-magnitude codes, where the most significant bit (msb) is the sign bit and the remaining bits are used for magnitude. For example, the maximum voltage that can be encoded with this scheme is +5 V. 5 V amplitude is represented as a 3-bit PCM code of 101, and a + sign represents a 1 code. So the final answer to the PCM code (including the sign bit) is 1101.

Table 4.3 PCM code (including sign bits)

Time (s)	Voltage (V)	PCM Code	PCM Code (including sign bits)
0	+ 0	000	1000
2	+ 5	101	1101
4	- 4	100	0100
6	- 3	011	0011
8	+ 5	101	1101
10	- 3	011	1011

Based on the theoretical concept of PCM, it shows that the whole result of simulation Matlab Simulink has achieved 100% accuracy.

5.0   CONCLUSION

The Matlab Simulink of the PCM block diagram was studied and executed. We have successfully done performance analysis of Pulse Code Modulation and the output has been depicted in the figures above. In this work, according to the basic of PCM system, every block is implemented sequentially in Matlab Simulink. Every function of PCM system is included in a single block of Matlab Simulink, which is very helpful for the students to understand the whole PCM system.

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