DigiPoints Volume 1

Leader Guide

Module 3 – Analog-to-Digital Conversion

Summary

As we know, digital data is composed of 1s and 0s. We can transmit analog signals, such as voice and video, via digital signals. This module covers how the analog-to-digital-to-analog conversion is accomplished. In addition, the basic concepts of transmitting digital information is covered to include asynchronous and synchronous systems, coding schemes, parallel and serial modes, as well as simplex, half duplex, and full duplex systems.

Outcomes

The purpose of this module is to describe the analog-to-digital conversion process. The student will learn how a continuously varying analog signal is encoded into a binary digital signal and then recovered. Covered in this section will be the Nyquist Frequency, the concepts of sampling, quantizing, and encoding, as well as the distortion that results, the PAM and PCM signals created, and the importance of the synchronization in a digital network. The purpose of this module is also to describe basic concepts of digital transmission. The student will learn about basic coding schemes and the origination of this concept. Also to be learned is the concept of parallel versus serial transmission techniques and where those are commonly found. Synchronous and asynchronous transmission techniques will be covered as well as basic variations. Finally, the concept of simplex, half duplex, and full duplex will be covered.

Objectives

Upon successful completion of this module, the student should be able to:

- Describe the Nyquist Frequency and explain its importance.
- Find the Nyquist Frequency for a given analog signal.
- Explain what a CODEC does.
- Explain how an analog signal is converted into a digital signal. This explanation must include each of the following items:

– Nyquist Frequency
– Sampling
– PAM Signal
– Quantizing and Distortion
– Encoding

– μ-Law Standard Scale
– PCM Signal
– Decoding
– Clock
– The peculiarities of the μ-Law Standard Scale

- Describe the importance of coding and know the basic differences between:

– Morse Code
– Baudot Code
– BCDIC (Binary Coded Decimal Interchange Code)
– EBCDIC (Extended Binary Coded Decimal Interchange Code)
– ASCII

- Describe the difference between parallel and serial transmission techniques.
- Compare asynchronous transmission with synchronous transmission and explain the key characteristics of each.
- Explain how simplex, half duplex, and full duplex differ.

Prerequisites

Students should have read Chapter 3 of *DigiPoints, Volume 1*.

Length

2 – 2 ½ hours

Materials/Preparation for Instructor

- One workbook per student
- Visual Aids
- Instructor should read Chapter 3 of *DigiPoints, Volume 1*.

Supplies/Equipment

- Dry erase board with markers and eraser
- Easel flip chart
- Masking tape
- Pointing tool, e.g., laser or pointer
- Tent cards for students' names

Audience

The intended audience will be mid- to senior-level technicians or other associates who are seeking an understanding of digital basics.

Module Outline

This is an introductory level module that will provide a review of the following topics:

Objectives 1
Introduction 2
Analog-to-Digital Conversion 3
Basic Concepts of Digital Transmission 17
Control Codes and Format Effectors 28
Mode of Transmission 29
Synchronous and Asynchronous Transmission 32
Summary 42
Appendix 43

Objectives

EXPLAIN

REFER TO WB 3.1 AND WB 3.2

Tell students that when they have completed this module, they will be able to accomplish these objectives.

- Describe the Nyquist Frequency and explain its importance.
- Find the Nyquist Frequency for a given analog signal.
- Explain what a CODEC does.
- Explain how an analog signal is converted into a digital signal. This explanation must include each of the following items:
    - ◊ Nyquist Frequency
    - ◊ Sampling
    - ◊ PAM Signal
    - ◊ Quantizing and Distortion
    - ◊ Encoding
    - ◊ μ-Law Standard Scale
    - ◊ PCM Signal
    - ◊ Decoding
    - ◊ Clock
    - ◊ The peculiarities of the μ-Law Standard Scale
- Describe the importance of coding and know the basic differences between:
    - ◊ Morse Code
    - ◊ Baudot Code
    - ◊ BCDIC (Binary Coded Decimal Interchange Code)
    - ◊ EBCDIC (Extended Binary Coded Decimal Interchange Code)
    - ◊ ASCII
- Describe difference between parallel and serial transmission techniques.
- Compare asynchronous transmission with synchronous transmission and explain the key characteristics of each.
- Explain how simplex, half duplex, and full duplex differ.

Introduction

DISCUSS VA 3.1
REFER TO WB 3.3

- Analog signals are continuously varying signals.
- ALL analog signals can be broken down into their component sine waves, each with a specific frequency and amplitude.
- There are 5 sine waves in VA 3.1.

ASK

What are the differences between these sine waves?

Answer:

◊ *Differing frequencies and/or amplitudes*

ASK

What type of information is carried on sine waves?

Answer:

◊ *Speech, whistles, tones, TV, RF/Radio, Light, and X-rays among others.*

DISCUSS VA 3.2
REFER TO WB 3.4

We are going to learn about these three functions and their role in A/D/A conversion.

A/D/A is analog-to-digital-to-analog conversion

- The equipment used is known as a coder/decoder (CODEC).
  - ◊ The coder converts analog signals to digital binary bits.
  - ◊ The decoder converts digital binary bits to analog signals…sine waves.

Analog-to-Digital Conversion

Sampling

- SAMPLING is the first step in the conversion process.
- The question is how many times must an analog signal be sampled in order to get all the information contained in the signal.
  - ◊ A Bell Labs scientist, Harry Nyquist, produced a mathematical proof in the 1920s that PROVED that the full information content of any continuous signal can be recovered if the signal is measured and coded at a rate that is twice the frequency of the HIGHEST sinusoidal component of that signal.
  - ◊ Multiply the highest frequency by two (2); that will give you the number of samples per second needed to capture all the information required to recover the original signal.

ASK

What are the three (3) steps in converting an analog signal to a digital signal?

Answer:

- ◊ *Sampling, Quantizing, and Encoding*

Write on board:
Sampling
Quantizing
Encoding

ASK

What is a Codec?

Answer:

- ◊ *Coder/Decoder for Analog-to-Digital-to-Analog conversion.*

ASK

What is the Nyquist Frequency?

Answer:

- ◊ *The Nyquist Frequency is the sampling rate, which is twice the highest frequency of a given signal.*

DISCUSS VA 3.3
REFER TO WB 3.5

- Voice over telephony is ~100 – 3300 Hz.
- The early systems were designed to pass up to 4,000 Hz.
  - ◊ Thus, the highest frequency expected was 4,000 Hz.
  - ◊ The sample rate would be twice the highest frequency or 2 x 4000 Hz
  - ◊ The Nyquist frequency is then 8000 times per second,
  - ◊ A sample is taken every 0.000125 seconds or each 125 µsec (micro-second)

t = 1/f
t = 1/8000
t = .000125

ASK

If the highest frequency for a video signal is 4 MHz, what is the Nyquist Frequency?

Answer:

ASK

- ◊ *8,000,000 times per second*

What is the sampling interval?

ASK

Answer:

- ◊ *1/8,000,000 or .000000125 seconds. 0.125 msec*

What type of device is implied here?

Hint: We are measuring time.

Answer:

- ◊ *The implied device is a clock. Something that indicates something occurring at regular intervals in time, such as every 125 msec.*

EXPLAIN VA 3.4
REFER TO WB 3.6

- At regular intervals, a sample is taken.
  - ◊ NOTICE that the time to take the sample is significantly less then the interval time.
  - ◊ If the sample time = the interval time, this would be a 100% sample.
- At regular intervals, therefore, a "snap shot" of the signal being sampled is taken.
- This sample has a value, amplitude, which must be recorded and kept track of so that the original signal can be recovered.
- The sampled signals are called PAM signals:
  - ◊ Pulse Amplitude Modulation.
  - ◊ The PAM signal has the amplitude of the analog signal at the moment of measurement.

ASK

How often is a voice channel sample being taken, in seconds?

Answer:

- ◊ *.000125 sec*

ASK

How "long" is the sample period?

Answer:

- ◊ *It is a "snap shoot" and is considered instantaneous.*

ASK

What are these sample signals called?

Answer:

- ◊ *PAM or Pulse Amplitude Modulation signal.*

EXPLAIN VA 3.5
REFER TO WB 3.7

REVIEW THE APPENDIX IN THE LEADER GUIDE FIRST.
EXPLAIN USING THE EASEL FOR DRAWING

CONTINUE EXPLANATION OF VA 3. 5
AND WB 3.7

Quantizing

Quantizing the PAM signal is the next step.

- That is, establishing a discrete value for this sample based on an established set of values. We do it every day.
- What is Quantizing?
- You might call it rounding.
  - ◊ The CODEC takes the sample of the analog signal at a point in time.
  - ◊ This sample, known as a PAM signal, has an amplitude.
  - ◊ This amplitude is put against a predetermined scale.
  - ◊ The PAM signal is then given a fixed value.
- This means that the signal will round up or down depending on a set of rules that are programmed in the equipment.
- When this rounding takes effect, there is a certain amount of insignificant error introduced into the process.
- This is known as "Quantizing Error" or "Distortion".
  - ◊ How is that problem overcome?
  - ◊ By setting up the values and the algorithm (the rules) such that this "error" is not detectable to the receiving equipment or people.
  - ◊ In other words, the amount of quantizing error is too small to make a difference.
- Remember our pies. You cut that pie into 1/3s. Nobody really cares if the cut is .333 or .33333333; it is not significant.

Write on board:
>Sampling

>Quantizing
Encoding

Draw PIEs from Appendix

Write on board:
>Sampling

>Quantizing
PAM

Encoding

ASK

What is a PAM signal?

Answer:

- ◊ *A sample of the analog signal at a point in time.*

What is Quantizing Error?

Answer:

ASK

◊ *The PAM signal (amplitude of the analog signal) is put against a predetermined scale. It is then given a fixed value.*

Why does it happen?

Answer:

ASK

◊ *The signal will round up or down depending on a set of rules that are programmed into the equipment.*

How does that impact the information being sampled?

ASK

Answer:

◊ *It should not impact the information at all. By setting up the values and the algorithm (the rules) such that this "error" is not detectable to the receiving equipment or people. In other words, the amount of quantizing error is too small to make a difference.*

Why?

ASK

Answer:

◊ *By sampling at the Nyquist Frequency, enough data is available to reconstruct the original information.*

EXPLAIN VA 3.6
REFER TO WB 3.8

Encoding

How are we going to encode this PAM signal?

- Consider the Encoding scale on VA 3.1.6.
  - ◊ The signal is between 0.00 mv and –4.00 mv.
  - ◊ Set up a scale divided into 0.50 mv intervals.
  - ◊ There are 9 discrete points between 0 and – 4 in .50 increments.
  - ◊ Between those 9 discrete points, are 8 intervals.
  - ◊ Recall, that 2^3 is 8, therefore, 3 binary digits will be all that are required to define these intervals.
  - ◊ Discrete binary numbers from 000 (-4.00 to –3.50 mv) to 111 (-0.50 to 0.00 mv) are assigned.
  - ◊ For a PAM signal of –2.72 the discrete number 010 is picked for encoding.
  - ◊ Since this is the range of –3.00 to –2.50 mv, the PRECISE value of the PAM sample is not encoded.

Write on board:
>Sampling
>Quantizing
PAM

> Encoding

2^3 = 8 is covered in Module 1

Read VA 3.6 from the bottom up

000 is the binary number for the range –4.00 to –3.50 mv

-0.76 mv is in the range from –1.0 to –0.50 mv or 110.

ASK

What type of error has been introduced?

Answer:

- ◊ *Quantization error.*

ASK

What is the encoded value of a PAM signal of –2.1 mv?

Answers:

- ◊ *011*
- ◊ *The PAM signal is between 0 and 0.5 mv. Cannot determine the exact value of the PAM signal.*

ASK

What is the encoded signal of -2.92 mv?

Answer:

- ◊ *010*

ASK

What is the encoded signal of – 2.51 mv?

Answer:

◊ *010*

ASK AND ANSWER THIS

What happens if the voltage is exactly at a division point, e.g. –1.0 mv.

Answer:

◊ *It depends on the algorithm, the rules, as to which interval will be assigned. For example it may be a function of which direction it is going!*

EXPLAIN VA 3.7
REFER TO WB 3.9 AND WB 3.10

PCM Signal

- The analog signal is sampled.
- That sampled signal is called a PAM signal.
- The PAM signal is quantized.
- That quantized signal is encoded into Marks and Spaces, 1s and 0s.
- The output encoded signal is called a PCM signal, Pulse Code Modulation.
- THAT process of encoding the PAM signal into binary digits is called PCM.
- PCM is Pulse Code Modulation. This binary signal is referred to as a PCM Signal, a Binary Word, or a Time Slot.

ASK

What are the 3 steps required to convert an analog signal to a digital signal?

Answer:

◊ *Sampling, Quantizing, Encoding.*

Write the student answers on the easel.

ASK

How fast do we have to sample an analog signal in order to insure that we get all the information of that signal?

Answer:

◊ *Twice the highest sinusoidal frequency.*

ASK

What is the sampling rate called?

Answer:

◊ *Nyquist Frequency*

ASK

What is the sampled signal known as?

Answer:

◊ *PAM Signal*

ASK

What types of errors are introduced in our process?

Answer:

◊ *Quantizing Errors*

ASK

Why?

Answer:

◊ *The PAM signal is the instantaneous amplitude sample of a continuously varying analog signal. When it is quantized, a discrete binary number is being assigned; this binary number is an approximation of the actual amplitude.*

ASK

Why are they not considered a problem?

Answer:

◊ *In a properly designed and engineered system, these distortions are not significant.*

ASK

What is the outputted encoded signal called?

Answer:

◊ *PCM Signal, Word, or Time Slot.*

©SCTE

- This is the basic method of converting an analog signal to a digital signal.
  - ◊ In the example above, the signal was assigned to 1 of 8 discrete intervals or binary numbers.
  - ◊ The switched telephony network needs more than 8 intervals to provide quality encoding and transmission of the signal.

REVIEW VA 3.8
REFER TO WB 3.11

The telephony encoding system was designed to use 8 digits. You may recall we used 8 digits in Module 1 to discuss binary numbers.

Review the section on converting to and from binary numbers in Module 1 only if necessary

ASK

What is the value of 1111 1111?

Answer:

- ◊ *255*

ASK

- ◊ *And, if you include "0000 0000", you have 256 discrete points.*

ASK

Which is the most significant bit on this table?

Answer:

- ◊ *The bit representing 2^7*

The least significant bit?

Answer:

- ◊ *The bit representing 2^0*

- In the telephone system the most significant bit is set to 1 for positive voltages and 0 for negative voltages.
    - ◊ On VA 3.1.8 this is represented as digit position 1
- Digits Positions 2, 3, and 4 divide the signal into 7 maxi-intervals or segments. (111)
- Digit Positions 5, 6, 7, & 8 gives us 16 mini-intervals. (1111)
    - ◊ Each mini-interval contains 16 mini-intervals.

111 = 7

1111 = 15

EXPLAIN VA 3.9
REFER TO WB 3.12 AND WB 3.13

Look at the 7 Maxi-Intervals

- The 7 maxi-intervals are not the same size.
  - ◊ Starting at the maximum voltage "V", the interval or segment sizes decrease by ½ each time.
  - ◊ Thus, Interval 7 starts at V/2 and ends at V.
  - ◊ Interval 7 is ½ the entire scale.
  - ◊ Interval 6 begins at V/4 and ends at V/2;
  - ◊ Interval 6 is ¼ of the entire scale.
  - ◊ This continues until Interval 1 is 0 to V/64.

Point out how the size increases from 1 to 7.

Or, how it decreases from 7 to 1.

DISCUSS

Why do the maxi-intervals change in size by a factor of 2?

- To get the best quality possible with 8 bits, it is necessary to capture as much information at the lower frequencies as possible.
  - ◊ Recall the lower frequencies are changing at a slower rate, so the change in amplitude between samples is less with lower frequencies at the lower power levels.
  - ◊ This quantizing method captures information better at the lower intervals.

Look at the mini level divisions

- The mini-intervals are 16 evenly divided segments.
- 16 segments or mini-intervals are found in EACH maxi-interval.
- At the lowest maxi intervals, the mini intervals provide more intervals for capturing amplitude information.
    - ◊ Thus, low level signal variations are captured with more precision by having more intervals in which to assign these samples.
    - ◊ It allows for a better quality of service.
    - ◊ The scale being used to assign binary codes to the PAM signal is called the μ-Law Encoding Scale.

"m" is pronounced "mu"

ASK

Why do the maxi intervals change in size by a factor of 2?

Answer:

- ◊ *It provides for more discrete intervals for low the lower frequencies of the voice. It is these lower frequencies where the vowels are made and it is where the "power" of the voice signal resides. The end result is a better quality signal.*

ASK

How do you convert a PCM signal back to an analog signal?

Answer:

ASK

- ◊ *Just reverse the process.*

ASK

How many bits are in the 'word' that is being used to transmit voice grade analog signals?

Answer:

- ◊ *8 bits in the PCM signal, word, time slot.*

What will it create with these 8 bits?

ASK

Answer:

- ◊ *It will create a voltage of the same polarity and within the range of the original analog signal.*
- ◊ *After that, an "integrator" will connect these voltages into a smooth sinusoidal waveform.*

How will this wave differ from the original?

ASK

Answer:

Quantizing error is in this signal, so there is some variance. However, the sampling rate and the m-Law Encoding Scale that are used is designed so that neither the equipment nor the human interface will notice any difference.

How does this encoding scheme handle low amplitudes?

Answer:

- ◊ *By having the maxi intervals decreasing in size by a factor of 2, and the mini intervals always having 16 evenly spaced intervals, the lowest amplitudes are more finely measured than are the higher amplitudes. That means that the lower frequency waves are being measured better at their lower amplitudes. This is important for quality voice service.*

DISPLAY VA 3.10
REFER TO WB 3.14

There are other methods used to encode analog into digital signals.

Not going to discuss. Just make them aware that there are other methods.

Basic Concepts of Digital Transmission

DISCUSS VA 3.11
REFER TO WB 3.15

Coding Schemes

- Morse Code is NOT one of the encoding schemes used to transmit digital data. People have long used different methods to communicate: drums, smoke signals, semaphore, horns, etc.
- Samuel Morse, the inventor of the telegraph, wanted to send letters (as in A,B,C…Z) out across wires.
    - ◊ He had a voltage he could control; either it was on or off.
    - ◊ When on, it could be on for a long time and represent a DASH or a short time to represent a DOT.
    - ◊ When off, it was off.
- Morse wanted a system to transmit messages FAST, using the least dots and dashes possible. He learned that "E" is the most used letter in the English language.

ASK

How do you transmit an "E" in Morse Code?

Answer:

- ◊ *One, and only one, DOT*

ASK

What is the second most used letter?

Answer:

- ◊ *"T" is one DASH…that may be the 2nd most used letter; or "I" with two DOTS.*

- Based on Morse's desire to transmit messages as quickly as possible, what appears to be the least used letter in English?
    - ◊ "Q" Dash Dash Dot Dash.
- So, some letters have one symbol, others two, and others three or four. Then there are the numbers and other symbols.

ASK

What type of receiver was used to decode these transmissions?

Answer:

◊ *An intelligent receiver…a human being. This receiver did the error correction on the spot.*

DISCUSS VA 3.12
REFER TO WB 3.16

Baudot Code

- Emil Baudot originated the Baudot code for use on the French telegraph system.
  - ◊ It was standardized as CCITT International Alphabet No. 1.
- Today when referring to Baudot coding, the reference is to CCITT International Alphabet No. 2.
- The Baudot code uses 5 bits to represent a character.

ASK

How many different characters can be represented with 5 bits, that is, 2^5?

Answer:

- ◊ $2^5=2*2*2*2*2= 32$

- The table shows 26 letters being used AND 26 numbers/symbols being sent.

The Baudot character set uses two five bit characters to indicate either letters or figures, that is lower case or upper case.

- 11111 are the bits for the lower case, that is the letters
- 11011 are the bits for uppercase, that is the figures and other symbols.
  - ◊ Once one of these control characters is sent, all characters following are either letters (or figures) until the other control character is sent.
- The Baudot code is sent at a steady 10 characters per second or 50 bits per second.
  - ◊ This is teletype speed.
- This method of sending messages allows a machine to send and receive the code.
  - ◊ A keyboard can be set up with the shift keys allowing a change from Letter to Figure.
  - ◊ Humans are still needed to request retransmission if things go wrong.
  - ◊ Since a machine could send…and receive the bits/characters automatically, specially trained telegraphers are not needed.

Baudot's code was a major advancement in communications.

ASK

How can the Baudot code be used to send 52 different characters when only 5 bits are available?

Answer:

◊ *The use of the shift key indicates if what follows is letter or figures and symbols.*

BCD

- As digital computers were developed, a way was needed to hold, move, and manipulate data.
- These machines were developed to crunch numbers.
    - ◊ Such as producing tables for artillery
    - ◊ Breaking secret military and diplomatic codes
- These early machines used an internal code named Binary Coded Decimal (BCD).
- The problem is communicating with a machine.
    - ◊ As new applications for computers developed, it was observed that it would be more efficient if the computer and the people interfacing with the computer could interface via a printer.
    - ◊ Although humans use numbers, they like to read things too.

DISCUSS VA 3.13
REFER TO WB 3.17

BCDIC

- ◊ A new code was developed: Binary Coded Decimal Interchange Code (BCDIC). This code, like Baudot code, had no error detection capability.
- ◊ BCDIC has 6 bits

Write on board:

BCDIC

ASK

How many bits are used in the BCDIC coding scheme?

Answer:

- ◊ *6 bits*

ASK

How many characters can be represented?

Answer:

- ◊ *6 bits offers a total of 64 possible characters.*

ASK

For what type of equipment was the BCDIC code developed?

Answer:

- ◊ *Digital Computers*

EBCD

- IBM developed EBCD (Extended Binary Coded Decimal) for its IBM Selectric typewriter.
  - ◊ EBCD has error detection capability. It has a parity bit making the EBCD code work as a 7 bit character.
  - ◊ EBCD was also known as PTTC – Paper Tape Transmission Code

ASK

- What did this add to data communications?

  Answer:
  - ◊ *The parity bit was added so that ALL characters would be either odd or even in terms of 1 bits. Consider the* far left *bit the parity bit. For the information character "001011"*
  - ◊ *A '1' is added for even parity and a '0' for odd parity.*
  - ◊ *If correct parity is not received, it can be assumed the character is received in error.*
- EBCD still requires shift characters to indicate if LETTERS or FIGURES are being transmitted.
  - ◊ This is not efficient.

Write on board:

EBCD

Bits	***Parity***	***Info***
EVEN:	***1***	***001011***
ODD :	***0***	***001011***

DISCUSS VA 3.14
REFER TO WB 3.18 AND WB 3.19

Write on board: EBCDIC

EBCDIC

- Then next development was EBCDIC: Extended Binary Coded Decimal Interchange Code.
  - ◊ This is an 8 bit code.
  - ◊ With 8 bits, there are $2^8 = 256$ possibilities or combinations.
  - ◊ That covers letter, numbers, punctuation characters, etc.
  - ◊ This includes upper and lower case letters.
  - ◊ There is no need for a shift key; that reduces overhead.
- It is efficient. EBCDIC is one of the two most widely codes used.

ASK

Why is this code more efficient than Baudot, BCD, or EBCD?

Answer:

- ◊ *There is no need to have a shift key transmitted.*

ASK

What do we NOT have with EBCDIC?

Answer:

- ◊ *There is no parity bit; there is NO error detection.*

- To handle error checking, IBM developed another method called Block Check Character or CheckSum.
  - ◊ Here, a number of characters are transmitted in a block, and
  - ◊ A checksum number is provided to determine if there are any errors.
  - ◊ This Checksum number is the total number of 1 bits in a block of data.
  - ◊ If the system detects errors, then the block that had errors in it is retransmitted.

ASK

What is a “checksum”?

Answer:

◊ *Error checking method used to determine if a BLOCK of data is in error. The total number of 1 bits is summed; that number is the checksum. The software can determine if there are any errors in the block of data transmitted.*

ASK

How would the errors be corrected?

Answer:

◊ *This would require retransmission of the entire block in which the error was found.*

DISCUSS VA 3.15
REFER TO WB 3.20 AND WB 3.21

Write on board:

ASCII

ASCII

- The most widely used code is ASCII: American Standard Code for Information Interchange
  - ◊ This is a 7-bit code, and $2^7 = 128$ characters.
  - ◊ An 8th bit can be added as a DATA bit or as a PARITY bit.
  - ◊ If it is a Data bit, there are now an additional 128 characters.
  - ◊ Some of these characters can be defined by the programmer
  - ◊ Two vendors may use ASCII and have some different character sets defined.
  - ◊ Equipment from two different vendors may work together, but not be fully compatible.
  - ◊ The ASCII code allows the programmer to easily sort both numbers and alpha characters. Since the codes for numbers precede the capital letters, and the capital letters precede the small letters, and it is all in ascending order, ASCII makes the sorting of items very efficient.
  - ◊ International equivalent is CCITT International Alphabet No. 5.

DISCUSS

ASK

If different programmers can define certain characters differently, what does that mean with respect to interoperability of equipment?

Answer:

- ◊ *Equipment from two different vendors may not be fully compatible.*
- ◊ *EBCDIC also has characters that programmers can use. Thus, different vendors can mean slightly different codes.*

- How do you read the ASCII code? If we read from left to right, and define the bit positions as " 7 6 5 4 3 2 1"

ASK

ASK

What is the ASCII code for "P"?

Answer:

◊ *1010000*

ASK

What is the ASCII code for "p"?

Answer:

◊ *1110000*
◊ *"A" is 1000001*
◊ *"a" is 1100001*

- Note that the difference in each case is one 1 bit in the sixth position.

ASK

What is the advantage to the way the letters and numbers are represented by these binary digits?

Answer:

◊ *The ASCII character set allows the computer to sort numbers in the sequence "0" through "9", and letters in the sequence "A" through "Z" then "a" through "z".*

- ASCII has 128 characters
  - ◊ 96 printable characters and
  - ◊ 32 non-printable control characters.
  - ◊ The non-printable characters are in columns "000" and "001"

If the 8th bit is used as a data bit, that gives an additional 128 possible characters. Where or who defines those? What is the significance of that?

Answer:

◊ *The engineer or programmer would define those. It means that there is the possibility of equipment from 2 different vendors not being fully compatible.*

Control Codes and Format Effectors

EXPLAIN VA 3.16
REFER TO WB 3.22

- When modems were discussed in Module 2, it was pointed out that modems must do a "handshake" in order to establish the connection and transmit information.
    - ◊ This is the ASCII Control Set.
    - ◊ Terminal devices, such as printers, modems, fax machines, video terminals, etc., need to be able to talk and exchange control information.
    - ◊ These are those control characters.
    - ◊ This chart defines what each does.
- If you refer back to the EBCDIC chart, there are control characters there too.

Mode of Transmission

Serial Transmission

Write on board

How do we send the information to wherever it is going?

Serial transmission

- The bits can be sent out one after another in *SERIAL* transmission. That is:
  - ◊ Send a bit
  - ◊ Send a bit
  - ◊ Send a bit

One bit after another: 10101

- These bits can be grouped as characters, such as in
  - ◊ ASCII
  - ◊ EBCDIC
- BUT, the bits are traveling single file.

EXPLAIN VA 3.17
REFER TO WB 3.23

Parallel Transmission

- Another way that the bits can be sent is PARALLEL
- In this example, an entire 8 bit word can be sent all at once.
  - ◊ Each bit has its own path between the transmitter and the receiver.
  - ◊ It is important that all the bits leave and arrive simultaneously.
  - ◊ This requires a "clock" to insure that they all start at the same time.
- The receive end can be trickier.
  - ◊ The farther the distance, the more likely that little defects or conditions in each path will cause the bits to arrive at different times.
  - ◊ If the distance is great enough and/or the speed that bits are being sent is high enough, errors can result
  - ◊ This is a condition known as SKEW.

ASK

Where could you find parallel or serial ports?

Answer:

- ◊ *On the back of a PC.*
- ◊ *The parallel port is connected to the printer.*
- ◊ *The serial may be connected to the mouse or to a communications link.*

ASK

What is the difference between parallel and serial transmission?

Answer:

- ◊ *In parallel transmission multiple bits are sent at the same time. In serial transmission the bits are sent one after another.*

ASK

Which is faster? Why?

Answer:

◊ *Parallel is faster because multiple bits are being sent over multiple paths at the same time.*

ASK

Which is more distance sensitive? Why?

◊ *Parallel is distance sensitive because of the variances in the physical media itself. The longer the "wire" the more variables that impact transmission. It is important that all the bits that are sent down the parallel paths arrive at the same time. If these bits do not, the bits can get "mixed" in with following bits. In other words, the message gets scrambled. The effect is known as SKEW.*

- The reason PCs have to be close to their printers is the nature of the parallel transmission. When printers are a distance from the PC, other means, such as LANs are used to connect the devices.

Synchronous and Asynchronous Transmission

ASK THE FOLLOWING QUESTIONS.

How many bits in an EBCDIC character?

Answer:

◊ *8*

How many bits in an ASCII character?

Answer:

◊ *7, 8 with parity*

How many bits in the PCM signal?

Answer:

◊ *8*

Write on board:

What is another name for an 8 bit word?

Answer:

◊ *BYTE*

An 8 bit word is a byte

- What does this have to do with Asynchronous and Synchronous transmission?
  - ◊ Asynchronous systems transmit characters one at a time; these characters have start and stop bits attached in order to provide synchronization with the receiving terminal.
  - ◊ Synchronous systems transmit character after character and employ clocking techniques in order to know where the bits are in the signal.

Write on board; Asynchronous Synchronous

DESCRIBE VA 3.18
REFER TO WB 3.24

Asynchronous Transmission

- Start with asynchronous transmission.
  - ◊ It is the easiest.
  - ◊ That is why it was developed first.
- Asynchronous transmission moves the bits a character at a time.
  - ◊ The time interval between characters is not fixed.
  - ◊ Because the transmission is by character, the 8 bit character has start (1 or 2) bits and a stop bit attached.
  - ◊ The start bit indicates that the character is being transmitted. The stop bit indicates end of character.
  - ◊ A 7-bit ASCII character with 1 start, 1 stop bit and 1 parity bit has a total of 10 bits being transmitted. The overhead is 30%.
  - ◊ Overhead is defined as the bits that do not carry customer's data.

Write on easel:
Mark = 1
Space = 0

- A line that is handling asynchronous transmission has two conditions:
  - ◊ Mark, a voltage level AND
  - ◊ Space, zero line voltage.
- An idle line has voltage on it;
  - ◊ This voltage is equal to the mark voltage.
  - ◊ It is there so that the equipment knows that the line is connected.
  - ◊ Then the character is transmitted with its start bit, a SPACE, to indicate a character is arriving.
  - ◊ The receiver then counts the MARKs and SPACEs.
  - ◊ It expects a set number.
  - ◊ The stop bit, a MARK, tells the receiver that this is the end of this character.
- Timing needed for this is simple.
  - ◊ The receiver needs to know the duration of each bit (Mark or Space).
  - ◊ It can determine what is coming in.
  - ◊ The START bit told it when to start counting.
  - ◊ The stop bit tells it when it is done. The stop bit may be 1.5 to 2.0 times as long as a normal Mark.
  - ◊ When it passes, the line dips to zero (space), and
  - ◊ Then returns to the idle condition (voltage).
  - ◊ The receiver waits for the next character.

- There are standards such as:
  - ◊ What is the duration of a bit (Mark or Space),
  - ◊ What is the voltage level,
  - ◊ How many bits for each character being transmitted, that is number of start, stop, and information bits.

Write on easel and record student responses

ASK

What are the advantages?

Answers:

Advantages

- ◊ *COST. It is cheap.*
- ◊ *No need for buffers;*
- ◊ *No need to store words in memory until everything OK'd.*
- ◊ *SIMPLICITY. It is one character at a time.*

ASK

What are the disadvantages?

Disadvantages

Answers:

- ◊ *SLOW SPEED. Equipment resets after each word is received.*
- ◊ *INEFFICIENT. A lot of control bits; at least 20% overhead.*

ASK

What is meant by the term, Asynchronous Transmission?

Answer:

- ◊ *The transmission of one character at a time.*

ASK

What are the advantages of asynchronous transmission?

Answer:

- ◊ *Inexpensive and simple.*

ASK

What are the disadvantages?

Answer:

◊ *Slow speed and inefficient use of bits because of overhead.*

ASK

Consider a PC-to-PC connection. If the modem being used transmits at 28.8 kbps, and the word being transmitted is 11 bits (1 start, 8 information, and 2 stop bits), what is the estimated throughput of information?

DO PROBLEM ON THE BOARD

Answer:

◊ *(8/11) * 28.8 kbps = 20.9 or 21 kbps is the estimated throughput. 27% of the bits transmitted are overhead.*

- If it is machine to machine, say a PC to another PC or a larger machine, this inefficiency can add up. On a modem with a line speed of 28.8 kbps , only 73% would be information bits…or 21 kbps information and 7.8 kbps overhead.

ASK

Give an example of overhead in the NON-cyber world.

Hint: Think post office.

Answer:

◊ *The envelope and the address on it are overhead. Your letter is the information being transmitted.*

- Overhead is not "bad" per se.
  - ◊ It is used for many things that ARE needed.
  - ◊ Excessive overhead is inefficient.
  - ◊ Overhead bits are those bits that do not carry any customer information.

EXPLAIN VA 3.19
REFER TO WB 3.25 AND WB 3.26

Synchronous Transmission

Write on board

- Synchronous transmission moves "messages" versus words.
  - Messages are groups of characters being sent one after another, like this sentence.
  - Those grouped characters, called messages, are put into Frames.
- To send entire Frames all at once, buffers are needed to hold the characters until all the characters are there to form the message that is going to be carried in the Frame.

Synchronous Messages

Frames

ASK

What makes up a Frame?

Answer:

- ◊ *Frames are made up of messages which are made up of the characters (information) to be sent.*
- ◊ *The frames consist of User information PLUS control bits/bytes.*

Write on easel

- What is going to be in a Frame?

  Answer:

  - ◊ *Synchonization characters, Start of Message Character; Control Characters; User data; Error Control & End of Message.*

Sync Characters
Start Message
Control
User Data
Error Control
End Message

- Our synchronous system can be either bit or byte oriented.
  - ◊ If it is byte oriented, all the characters (8 bits = 1 byte) are in byte format;
  - ◊ All 8 bits of a character are to be found together.
  - ◊ If the system is bit oriented, the individual bits stand alone as 1s and 0s.
  - ◊ The individual words (if there are any) are not being transmitted together as a unit.
  - ◊ There can be information in the control messages that allows the characters to be rebuilt.

Byte Oriented

Bit Oriented

Frame construction

- At the beginning is the Sync Character(s) which provide clocking, and
- Start of Message Character(s).
  - ◊ These characters form special bit patterns, and
  - ◊ Let the DCE, the modems, detect clocking, and
  - ◊ Notifies the DTE when the User Data is to begin.
- Control Characters specify the type of user information that is following.
  - ◊ Is it a mixture of code
  - ◊ Is it compressed
  - ◊ Is it facsimile
  - ◊ It also has addresses, sequence numbers, and priority indicators here.
- User data can be fixed length or variable.
  - ◊ FIXED: Example: Always 90 bytes.
  - ◊ VARIABLE: Check Control Characters to see how much is in this frame.
- Error control follows user data.
  - ◊ A common method is CRC – Cyclic Redundancy Check.
  - ◊ This is going to be covered in a later module.
  - ◊ It is a bit pattern which is based on the previous bits transmitted in the frame.
- End of Message Character. This is another unique pattern of bits that always ends the frame and lets the DTE know that the transmission of this frame has ended.

ASK

Why synchronous transmission?

Answer:

- ◊ *A frame can be set up with a great deal of user data and very little overhead. EFFICIENT.*

- ◊ *Consider HDLC encoding: 1000 bits (125 bytes) of information, with only 48 bits of overhead.*

ASK

What is the overhead rate for this frame?

Answer:

- ◊ *An overhead rate of only 4.6%.*
- ◊ *48/(1000+48)=0.046*

ASK

What was the overhead on Async?

Answer:

- ◊ *Typically, 20% or more*

ASK

Explain the difference between bit oriented and byte oriented frames?

Answer:

- ◊ *In byte oriented frames, the bits of the bytes/characters are kept together.*
- ◊ *In bit oriented frames, the bits are intermingled. Thus, bit from byte 1 may be between bits from bytes 7 and 9.*

ASK

Explain the difference between fixed and variable length frames. What makes this possible?

Answer:

- ◊ *A fixed frame format is one in which each frame is the same length. A variable frame format allows the frames to vary in length.*
- ◊ *This is possible because of the information carried in the Control Characters that tell the equipment how long the frame is going to be.*

ASK

Name a method of error control?

Answer:

- ◊ *CRC. Cyclic Redundancy Check.*

ASK

How can the receiver and transmitter be synchronized if there is no central clocking device employed?

Answer:

◊ *The receiver can derive timing from the incoming signal. There are Synchronization characters and Start of Message Characters at the beginning of the frame.*

Where are priority characters and sequence numbers found in the frame?

Answer:

◊ *In the Control Characters at the beginning of the frame.*

EXPLAIN VA 3.20
REFER TO WB 3.27

Transmission Direction

There are three modes in which information can be transmitted:

- Simplex:
  - ◊ This is uni-directional.
  - ◊ Broadcast mode.
  - ◊ Kind of like talking to the dog.
- Half Duplex:
  - ◊ Communications takes place in one direction at a time.
  - ◊ This gives the receiver a chance to acknowledge receipt of message BEFORE the transmitter sends the next message.

  You talk to kids, they hear you, acknowledge what was said, and you go on.
- Full Duplex:
  - ◊ Communications takes place in both directions at the same time.
  - ◊ There are two separate paths; one for each direction of transmission.

  This resembles what happens around the dinner table.

ASK

What are the three Modes of Transmission?

Answer:

- ◊ *Simplex, Half Duplex, and Full Duplex.*

ASK

Which one requires 2 pair of wires?

Answer:

- ◊ *Trick question. None of these methods require 2 pair of wires. In fact, even the full duplex system can be handle with only one transmission path. The two paths can be separated with frequency division. Such as upstream transmission on a coaxial system.*

Summary

REFER TO WB 3.28 THROUGH WB 3.29

Have students answer the study questions at the end of Module 3. Review the answers.

Answers in Appendix

Appendix

Draw the circles shown below:

Divide one circle into thirds.

Divide the other into quarters.

What are the respective decimal equivalents?

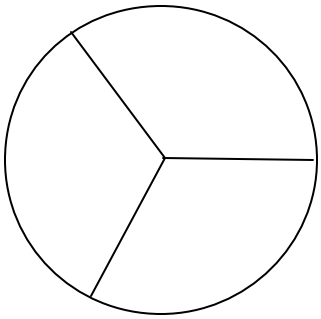
0.3333333333….or 1/3

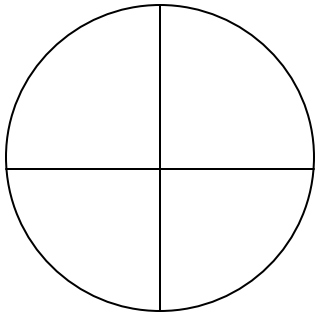
and

0.25 or 1/4

What do we call 1/3 in percent: 33.3 %. This is rounded to the nearest 1/10. It is in error, but it's not a big deal.

What do we call ¼ in percent: 25%. Do not have to round this.





Do you think these circles have been accurately divided? NO they have not. But, for quantizing purposes, let us say that they are.

Remind the students that analog signals are varying continuously (Module 1). There are virtually an infinite number of possible values for the amplitude of the signal, depending on how precise the instrumentation is. Our digital signals are discrete; the quantizing process establishes a FIXED amplitude. 33.3% vs. 33.3333333333….%

Answers to the questions at end of student workbooks.

1. What are the three steps in changing an analog signal to digital form?

   The three steps are sampling, quantizing, and encoding.

2. What is the function of a clock in digital circuits, and what are the two sources for the clock?

   The clock ensures that actions performed by different machines, or different parts of the same machine, will occur at the same time. The clock signal may be either a locally generated pulse or it may be derived from network signals.

3. What is the quantizing error, and where does it come from?

   Quantizing error is the difference between the actual value of the sampled analog signal, and the value of the voltage to which that analog sample has been assigned. It is similar to a rounding error in arithmetic calculations.

4. What was the basis for assigning a letter to a symbol in Morse code?

   In Morse code, letters are assigned to pulse strings based on their frequency within English language words. More frequently used letters are assigned to the shorter pulse strings. The purpose of this order of assignment is to minimize the time it takes to transmit any given message.

5. What makes Baudot code a sequential code?

   The Baudot code is sequential because it uses control characters that define the meaning of characters that follow.

6. What mechanism for error correction is contained in the BCDIC code, and how does it work?

   BCDIC code uses a parity bit to detect errors. The parity bit is part of each binary word, and is set to 1 or 0 such that all bits associated with the word are either odd or even.

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7. What are the two most widely used code sets today?

   ASCII and EBCDIC.

8. What is the difference between serial and parallel transmission?

   Serial transmission sends all bits of a data stream over one lead, while parallel transmission provides one lead per bit within a binary word.

9. What is the difference between synchronous and asynchronous transmission?

   Asynchronous transmission uses start and stop bits to define a character, while synchronous transmission needs some type of clock to keep track of character positions.