DigiPoints Volume 1

Leader Guide

Module 1 – Digital Data

Summary

This is the first module of *DigiPoints.* It answers the basic questions about what digital data is, and how it relates to analog information.

Outcomes

At the end of this block of instruction the student will have reviewed why knowing about digital data is important to them and their companies. The student will be able to state the difference between a digital and analog signal. The student will be able to convert Base 10 numbers to Base 2 and vice versa. The student will also be able to describe the difference between bits, bytes, octets, and bauds. Finally, the student will be able to describe a digital pulse (bit) and what happens to a digital signal as it is transmitted over a line.

Module Objectives

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

- Name main areas in the cable distribution system that are being impact by digital technology, and be able to describe why digital technology is important to the cable industry.
- Explain the difference between an analog and digital signal.
- Convert a binary number to a base 10 number and vice versa.
- Define and be able to describe what bits, bytes, octets and bauds are.
- Describe how a digital pulse varies depending on the span of time in which it is viewed.
- Describe the effect of attenuation on a digital signal.
- Briefly describe how a digital signal is carried on an RF system.

Prerequisites

Students should be instructed to read Chapter 1 of *DigiPoints, Volume 1*.

Length

2 – 2 ½ hours

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Materials/Preparation for Instructor

- One workbook per student
- Visual Aids
- Instructor should read Chapter 1 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.

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Module Outline

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

Objectives 1
Introduction 2
What is Digital Data? 3
What Does Data Look Like? 17
Summary 20

Objectives

EXPLAIN

REFER TO WB 1.1

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

- Name main areas in the cable distribution system that are being impact by digital technology, and be able to describe why digital technology is important to the cable industry.
- Explain the difference between an analog and digital signal.
- Convert a binary number to a base 10 number and vice versa.
- Define and be able to describe what bits, bytes, octets and bauds are.
- Describe how a digital pulse varies depending on the span of time in which it is viewed.
- Describe the effect of attenuation on a digital signal.
- Briefly describe how a digital signal is carried on an RF system.

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Introduction

BEGINNING THE CLASS

After going through the basic administrative details, and perhaps introductions, you can begin this first module in the *DigiPoints* training with a "Why Digital" opening discussion.

Write the words: "Why Digital" on the easel

DISPLAY VA 1.1

REFER TO WB 1.2

Becoming knowledgeable about digital signals is key to the individual success of every cable technician…and the companies for whom they work.

Why is digital important to know about today?

Possible answers you will get:

- Capacity…more channels because of compression
- Quality …digital gives a better picture and sound
- Security …can scramble analog signals; encrypt digital ones
- Editing and Ad Insertion
- Other services
- Add/Drop capabilities

Niche markets

"Quieter"

Harder to steal service

Digital manipulation of information

Telephony and Data

Interconnect to other networks

The networks being deployed today utilize digital technology.

This is being done for both the ongoing revenue potential that is expected to be realized with more channels and niche markets, as well as the cost reductions possible when deploying easier to manage and maintain systems.

The telephony industry is handling more traffic today with fewer people then it did a decade ago.

One reason is the introduction of digital technology.

What is Digital Data?

DISPLAY VA 1.2
REFER TO WB 1.3

Digital consists of 1s and 0s.

Or, another way of looking at it is as an "ON" or "OFF" condition. Or, "OPEN" or "CLOSE" such as on a switch.

So what?

Simplest signal for a computer engineer to work with.

There are only two states to consider:
on or off,
yes or no.

DISPLAY VA 1.3
REFER TO WB 1.4

EXPLAIN AN ANALOG SIGNAL.

Analog vs. Digital

The analog signal is a continuously varying signal. This is like voice, or music, or any other sound we hear with our ears.

Characteristics of analog include:

- It has an INFINITE number of points during its cycle.
- It has a positive and negative component called the amplitude.
- It also has a frequency, given in Hertz.

The cycle is defined as the number of times the wave repeats itself in a set time period, e.g., a second.

The term HERTZ is how this is measured. It is based on **C**ycles **P**er **S**econd (cps).

Examples:

- A typical 120 Volt AC device in the US operates at 60 Hertz or 60 cycles per second.
- Our video signal operates at 6,000,000 Hertz or 6 Mega-Hertz (MHz). Mega represents 1,000,000 or 10^6.

Point out the sine wave on left of slide…this is the analog signal.

The figure shows one cycle of the wave.

HERTZ is the term, like joules, coulombs, watts, volts, amps, etc. Hertz is abbreviated:
Hz
MegaHertz is MHz

Note the convention on the white board or easel

Amplitude is another key characteristic of this analog signal.

This amplitude varies smoothly over time.

Watching the ripples formed from a rock being thrown into a pool of water demonstrates this characteristic.

These ripples start off at some amplitude as given to them by the impact of the rock, and as they proceed across the water, they become smaller. They lose their height…amplitude. The ripples are attenuated.

This happens to voices in the air or electronic signals on a cable or light in a fiber-optic cable.

If the observer counted how many ripples passed a fixed point in the pond during one second, the observer could tell the frequency, in Hertz or cps.

CONTINUE TO DISPLAY VA 1.3

USE THIS VISUAL AID TO EXPLAIN THE DIFFERENCE BETWEEN THESE SIGNALS.

ASK

Digital Signal

The digital signal is different. How is the digital signal different from the analog signal?

Answer:

- ◊ *It is not continuous*
- ◊ *It is discrete---The "amplitude" is either +1, -1, or 0 - discrete states*
- ◊ *No cycles indicated on the slide*
- ◊ *It does have + and - states.*

If the signal is not described in terms of Hertz, frequency, or amplitude, how can it be described?

Answer:

- ◊ *Bit Rate - How many bits per unit of time, or **b**its **p**er **s**econd, bps*
- ◊ *Polarity - That is, what are the Ones, all + or all – or what is called **UNIpolar**. If they alternate+ and -, then it is **Bipolar.***
- ◊ *Duty Cycle - This is the period of time that a + or - 1 has voltage applied.*

Analog signal: Frequency (Hertz) and Amplitude

Digital Signal: Bit rate, Polarity, and Duty Cycle

Point out the right hand side of VA 1.3 labeled "digital".

Write the answers to the question on the white board. Write them even if students do not get them.

NOTE: The fact that the signal has both + and - components indicates it is bi-polar

Back to the white board: Bit Rate, Polarity, Duty Cycle

0s have no polarity, they are naught.

This is tricky. But when you look at the digital signal you will see that the voltage for a "1" is applied for ½ the time that pulse could be applied.

ASK What types of systems are based on analog signals?

Answer:

◊ *Voice, TV, radio, & Plain Old Telephone Service - POTS*

ASK What types of systems are based on digital signals?

Answer:

◊ *Computers & their peripherals*

Binary System

Computers - Main Frames to PCs to PDAs - use digital signals consisting of 1s and 0s to communicate internally AND to other devices such as keyboards, mouse, fax/modems, floppy drives, tape drives, etc.

PDA = Personal Digital Assistant

REFER TO VA 1.2

The digital signal, 1 or 0 – On or Off – Open or Close, is the simplest signal for the computer engineer to work.

This dual state numbering system is known as the binary system.

It consists of two numbers and is called a Base 2 system.

ASK

What are those numbers?

Answer:

◊ *0 & 1*

Our common Base 10 system, which we use every day, consists of 10 numbers….0, 1, 2, 3, 4, 5, 6, 7, 8, 9.

DISPLAY VA 1.4
REFER TO WB 1.5

Binary vs. Base 10

This slide shows us how the numbers compare in Base 2, binary, versus the Base 10 system we use every day.

Because we have 10 numbers (and 10 fingers), we do not have to use "multiple symbols" such as 1 & 0 until we have ten objects…10.

In Base 2, once we go beyond one object, to TWO objects, we need to use multiple symbols, such as 10 to indicate two in Base 2.

The number **one** is represented by the symbol "1" in both Base 2 and Base 10 systems.

The number **two** is represented by "2" in Base 10, and, in Base 2, two digits are needed to represent the number **two**: "10".

Note that there are two digit positions in used in Base 2.

Continuing to the number **eight,** the Base 10 system uses the symbol "8".

In the Base 2 system a total of 4 digit positions must be used to represent the number **eight** with the two symbols 1 & 0. **Eight** in Base 2 is represented by: "1000".

The next visual aid discusses how this works.

Ask the class if anyone is familiar with ROMAN numerals. Write out some numbers on the board:

1 = i, 2 = ii, 5 = V

10 = X, 100 = C

115 = CXV

What base system is this? Answer: None, used letters for numbers. No mathematical concept for ZERO.

Point: Let students know there have always been different ways of counting.

DISPLAY VA 1.5
REFER TO WB 1.6

Powers of 2

We are looking here at 8 digit positions.

Each digit position is an exponent or power of "2"; thus, position 1 is 2^0, and position 2 is 2^1, and position 3 is 2^2 and so on to position 8 which is 2^7.

If this is not enough, there is a value to be represented in each of these digit positions. Thus, $2^0 = 1$, and $2^1 = 2$, and $2^2 = 4$, and so on until $2^7 = 128$.

If you keep this chart in your mind, or better yet in front of you, the conversion of Base 10 and Base 2 numbers should be relatively straight forward. So, lets try it.

It may help the students to see it if you do

2x2 = 4

2x2x2 = 8

2x2x2x2 = 16

2x2x2x2x2= 32,

etc. to

2x2x2x2x2x2x2 =128

DISPLAY VA 1.6
REFER TO WB 1.7

EXAMPLES									Base 10 Value
Binary A	1	0	0	1	0	0	1	1	XXX
Value	+128	+0	+0	+16	+0	+0	+2	+1	147
Binary B	0	0	0	1	1	0	1	0	26
Binary C	1	1	1	1	1	1	1	1	255
Binary D	0	1	0	1	0	1	0	1	85
Binary E	0	1	1	0	0	0	0	1	97

You need to get the students to fill in the grid. You have the answers to your left.

You need to review, carefully,* DigiPoints, Volume 1, *Chapter 1, page 6.

Consider Binary A: 10010011

The digit in position 1 (where is that?) is:

Answer:

◊ *Far Right*

What is its Value?

Answer:

◊ *1*

The digit in position 2 is what? What is its Value?

Answer:

◊ *1, 2, so the value is 2+1 = 3*

The digit in position 3 is what? What is its Value?

Answer:

◊ *0, 0, so the value is 0+2+1=3*

The digit in position 4 is what? What is its Value?

◊ *0, 0, so the value is 0+0+2+1=3*

The digit in position 5 is what? What is its Value?

Answer:

◊ *1, 16, so the value is 16+0+0+2+1=19*

The digit in position 6 is what? What is its Value?

Answer:

◊ *0, 0, so the value is 0+16+0+0+2+1=19*

The digit in position 7 is what? What is its Value?

Answer:

◊ *0, 0, so the value is 0+0+16+0+0+2+1=19*

The digit in position 8 is what? What is its Value?

Answer:

- ◊ *1, 128, so the value is*
  128+0+0+16+0+0+2+1=147

Now, who wants to try the next one?

This is Binary A… now, walk them through Binary B to Binary E.

DISPLAY VA 1.7
REFER TO WB 1.8

CONVERT A BINARY NUMBER TO A BASE 10 NUMBER AND VICE VERSA.

Powers of 2	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	Base 10 Value
A	1	0	0	0	1	1	0	0	**140**
B	0	0	0	1	1	1	0	1	**29**
C	0	1	1	0	1	0	0	0	**104**
D	**0**	**0**	**0**	**1**	**1**	**0**	**0**	**1**	25
E	**1**	**0**	**1**	**1**	**1**	**0**	**1**	**0**	186
F	**0**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	127

Let the class work in groups of 2 or 3 to solve these problems.

Do one problem at a time.

Let a student come to board to explain solution.

This is going to take the rest of the period for this module.

VA 1.8

These are the answers

Review with class.

ASSIGN PRACTICE
VA 1.9

Practice Assignment

If the students have not yet read Chapter 1 of *DigiPoints*, they should read it now. Also, students need to review what they have done in class with respect to converting numbers between the two systems.

REVIEW ANSWERS
VA 1.10
WB 1.9

To reinforce today's learning, assign the students the work shown on VA 1.9. Review using VA 1.10.

DISPLAY VA 1.11

REFER TO WB 1.10

Hexadecimal System

Another number system that is used and referred to is the HEXADECIMAL System - Base 16. These are used in computer systems also. There are 16 symbols used:

0-9 plus A - F.

So, Base 10 1 = 1 Base 16

15 = F

16 = 10

32 = 20

38 = 26

160 = A0

179 = B3

We are not testing anyone on this. This is FYI.

This is Jedi Knight material

Use board on easel or white board.

Base 16, the Hexadecimal system, deals with powers of 16, that is 16^n.

Thus, the far right column is 16^0 or 1 - 15 base 10. Column 2 is 16^1, or 16 to 240.

Do not get bogged down in this material. If you have a JEDI Knight who wants to learn it, they can do so outside of class.

This may be a good time to take a break.

DISPLAY VA 1.12
REFER TO WB 1.11

Bits

The point to make here is that we have another name for the ones and zeros….**MARK** and **SPACE**. This is used versus ON & OFF or OPEN & CLOSED.

However, MARK & SPACE have a last name!

MARK & SPACE form the BIT family unit. Thus, both a one and a zero are known as a bit. Bit is the contraction of the ***BI****NARY DIGI****T*****.** A bit is the smallest unit of information.

Apparently, this 'immigrant' had its name shortened when it joined society.

You used this VA earlier in this module …but it has *MARK* ***&*** *SPACE* ***added now along with*** *± 3* ***and*** *0.*

Write BIT on board or easel.

Write *B****I****nary* ***digi****T*

Obscure joke referring to name changes that happened to people entering this country.

DISPLAY VA 1.13
REFER TO WB 1.12

Bytes

8 BITs, and the bits can consist of ones or zeros, is known as a BYTE.

This byte is sometimes referred to as an OCTET or, in other places as a WORD.

We shall refer to the Binary Digits at BITS and 8 bits as a BYTE.

Bits and Bytes are the terms to be used.

Point out and count on the slide the 8 *bits* ***for 1*** *byte****.***

DISPLAY VA 1.14
REFER TO WB 1.13

So, how many **b**its **p**er **s**econd, **bps**, are being transmitted?

When a speaker is referring to the speed of a modem, for example, as being 56 K, or 28.8, or 9.6, what is being referred to in "shorthand" is the speed of the device in bits per second…56K = 56,000 bits per second or 56 kilobits.

28.8 is 28,800 bits per second. 9.6 is 9,600 bps. This is the number of bits being carried by a channel each second.

The answer to the question on the slide is 10 bps…. this is really SLOW.

Baud

So, what is a baud? By definition a baud is the number of signal changes that are possible on a circuit per unit of time.

Write BAUD on the board.

The only allowed line conditions on a line are Mark and Space, that is 1 or 0, then the baud rate is equal to the bit rate…1200 bps = 1200 baud.

Mark (1) & Space (0) are the only conditions, then

BAUD rate = bps

This used to be the case in the 60s and even into the 70s. In fact, people got used to using the terms bps and baud interchangeably, though that was wrong.

Consider: a signal has four (4) distinct states it can be in on the line. In this case, there are 4 distinct states.

On easel write:

00 01 10 11

This is twice as many states as the 1,0 condition in the same time frame. Thus our 1200 baud system can transmit 2,400 bps.

On easel write:

Consider a signal has eight (8) distinct states it can be in on the line. In this case, there are 8 distinct states.

000 001 010 011

100 101 110 111

This is 4 times as many states as the 1,0 condition in the same time frame. Thus our 1200 baud system can transmit 4,800 bps.

Consider:

0000 0001 0010

0011 0100 0101

0110 0111 1000

1001 1010 1011

1100 1101 1110

1111

And, if a signal had sixteen (16) distinct states, how fast would the 1200 baud line be?

Answer:

- ◊ *1200 x 8 = 9600 bps.*

What if it was a 2400 baud line?

Answer:

- ◊ *19,200 bps*

TAPE this easel paper up to wall….you will use it with VA 1.18.

DISPLAY VA 1.15

REFER TO WB 1.14

Electrical Bits

Originally, the EIA and CCITT - standards setting bodies-recommend that +3 Volts be used to represent a Space and -3 volts be used to represent a Mark.

Read this VA from left to right. There are three separate, but related figures.

The de facto standard that came into being in the computer industry is 0 voltage for a Space and -3 volts for a Mark.

This is the middle picture.

Why is it important to have standards?

Answer:

- ◊ *So that information can be sent between machines of different manufacture.*

3rd figure.

The telephone industry came up with a different scheme.

0 is used for space. ± 3 volts represent 1.

This form of transmission is also called AMI, or Alternate Mark Inversion.

Why do the Marks alternate between +3 and -3 volts?

Answer:

- ◊ *By alternating between +3 and -3, the average voltage on a line approaches ZERO. This allows better overall performance on twisted pair cables.*

DISPLAY VA 1.16

REFER TO WB 1.15

Regeneration

Read from left to right. The signal that starts on the left degrades over time.

This slide shows what happens to a digital signal as it travels down a twisted copper pair of wires.

The output from the first regenerator is a 1 -1 1 as shown at Time 1.

By the time the signal gets to a point called Time 2, the nice square waves are degenerating, i.e., attenuating; however, at this point, the signal is still higher than the "threshold levels" indicated on the figure.

So, at Time 2, we could expect to read the signal as 1 -1 1.

At Time 3 the signal is not in good shape. In fact, the 2nd Mark has been attenuated to less than the threshold level.

ASK

What would you expect the regenerator on the far right to "read" and output?

Answer:

◊ *Input expected is 1-11. OUTPUT would be 1 0 -1 (or, do not argue over this, -1 0 1). NOTE: Depending on the intelligence of the equipment, it may or may not detect the obvious error.*

Trivia Question:

How does this regenerator differ from an RF amplifier with respect to what it does with the signal?

Answer:

◊ *The amplifier boosts the entire signal, including noise. The regenerator "reads" the incoming signal, and then creates, regenerates, the signal for output. Thus, a 1 -1 1 coming into the regen would be recreated as 1 -1 1. Noise would stop at the regen.*

What Does Data Look Like?

DISPLAY VA 1.17
REFER TO WB 1.16

The real world is a little different from the world of theory.

We talk about a "square wave" and suggest that the pulse has nice 90° corners, and we can even set a scope to show that nice square wave.

What we are starting with is a 250 nanosecond pulse of +3V…this is our "bit".

However, if we change the view on the scope from 500 nsec/div to 100 nsec/div, we see that there is a rise and fall of the voltage.

Why? Because we cannot instantaneously go from 0 to 3 volts or from 3 volts to 0.

On figure B we see this rise and fall. Our square wave looks like a trapezoid.

As our electrical pulse travels through the circuit…which contains electrical components that can store energy, such as capacitance and inductance…it starts to attenuate…degrade.

In addition to losing its voltage level, that is declining from +3 V to something lower, the wave itself loses its shape.

See "A" on VA 1.17 -

Note that 250 nano second pulse looks square on a 500 nsec/division.

NANO = 10^{-9}

1 billionth of a second

See "B" on VA 1.17 -

Note that a 100 nsec/div shows a slightly different pulse with rise and fall times.

See "C" on VA 1.17 -

Here we have the pulse downstream from the input.

The farther we go, the more degradation of the signal occurs.

See "D" on VA 1.17 - Here we have the pulse even further downstream from the input

It can get to the point that our original +3V square wave is no longer recognized as such by a receiver.

The voltage level continues to decline AND the readable pulse duration becomes less.

In other words, our signal is falling off in signal level and the pulse itself is so degraded that the duration of the voltage (pulse) itself is significantly less.

At this point our original "bit" of +3V and 250 nsec duration is unreadable

How do you prevent this? You do not. How do you overcome it…by having the distance between regenerators such that the received signal can be read and a new pulse generated.

Who determines that distance? The engineers.

If asked to go out on the line and measure the signal, what would you be looking at (we are talking about a digital signal on coaxial plant)? What would you expect?

Ask this question and give the students some time to discuss and think about this.

Answer:

- ◊ *Digital pulses, in the form of +/- voltages are not transmitted on coax…(these digital signals, which computers use…and the telephone industry with specific equipment) do not transmit on a coaxial cable. What is used is an RF signal.*

DISPLAY VA 1.18
REFER TO WB 1.17

The 16VSB signal shown is **A** modulation technique.

It is used as an example to show how complex reading the digital signal on a RF system is…in fact, the digital signal cannot be read directly.

To look at the digital signal, the RF signal would have to be demodulated to detect it.

Also, if noise is picked up by this RF signal, the impact can be on multiple bits of information.

So, although we cannot directly observe the digital signal in the RF signal, the RF signal is IMPORTANT and useful in measuring digital signal power.

Also, the system can experience transmission/reception difficulties if the RF signal is degraded because of noise and/or interference.

So, the plant must be “tight”.

To determine bit error rates (BER) requires that the digital signal be looked at AFTER it is demodulated.

This will be discussed in additional detail in a later class.

Multiple bits of information can be impacted by noise since, depending on the modulation technique, multiple bits may be carried. Look at the easel paper you put on the wall just before you went to VA 1.15… discussing bits & baud rates.

Summary

DISPLAY VA 1.3
REFER TO WB 1.18

What are the characteristics of an analog signal?

A digital signal?

Analog:	Digital:
Continuous	Discrete 1s & 0s
Frequency	Duty Cycle (duration)
Amplitude	Bit rate
	Polarity

Go to easel/white board to summarize.

Write: ANALOG vs DIGITAL - get characteristics of these signals.

Record information from students

Where do we find analog signals being used?

Answer:

◊ *Examples - TV, voice, radio*

Digital?

Answer:

◊ *Computers, DTV, telephony*

What is the binary system?

Answer:

◊ *Binary is a Base 2 numbering system…only two numbers available…0 and 1. This is in contrast to the Base 10 system we use every day which has 10 numbers, 0,1,2,…,8,9.*

What is the following number:

Base 2 Base 10

1010 = 10

and

Base 10 Base 2

…12 = 1100

Have students figure it out.

Mention hexadecimal system again…16 numbers.

What is the difference/relationship between bits, bytes, octets, and bauds? And Marks and Spaces?

Answer:

- ◊ *BIT = smallest piece of binary information*
- ◊ *8 BITS = 1 BYTE = 1 OCTET*

Mark 1, Space 0.

Baud: The number of signal changes per unit of time on the line.

What is the difference between bit rate and baud rate?

Answer:

- ◊ *Bit rate is the rate at which data moves. Baud rate is the rate at which that data is signaled.*

Okay, we have electrical bits traveling on a circuit. What does a bit look like?

Answer:

- ◊ *Voltage pulse*

What happens to the bit as it travels down the circuit?

Answer:

- ◊ *It degrades…loses voltage and shape.*

Why?

Answer:

- ◊ *Because the circuit itself contains inductance and capacitance and this degrades the digital signal.*

BAUD is the tricky one here for students.

Make sure they understand the difference between baud rate and bit rate.

Right now, limit this to +/- voltages. The bit will start as a square wave. (See VA 1.13 for this.)

VA 1.18

Are digital bits sent over coax? How?

Answer:

- ◊ *Actual digital pulses are not sent over coax. Digital information is; it is modulated onto an RF signal. Thus, you can have digital TV, but you cannot see the "bits" until it is demodulated.*