Information Processing
and
Digital Systems

Objectives

In this lesson, some basic concepts regarding information processing and representation are clarified. These include:

1. "*Analog*" versus "*Digital*" parameters and systems.
2. Digitization of "*Analog*" signals.
3. Digital representation of information.
4. Effect of noise on the reliability and choice of digital system representation.

Digital versus Analog

- We live in an "*Analog*" world.
- "*Analog*" means Continuous
- We use the word "*Analog*" to express phenomena or parameters that have smooth gradual change or movement.
- For example, earth's movement around the sun is continuous or "*Analog*".
- Temperature is an "*Analog*" parameter. In making a cup of tea, the temperature of the tea kettle increases gradually or smoothly.
- In an "*Analog*" system, parameters have a continuous range of values → just like a mathematical function which is "*Continuous*" ; in other words, the function has no discontinuity points
- The word "*Digital*", *however*, means just the opposite.
- In *Digital* Systems, parameters have a limited set of "*Discrete*" Values that they can assume.

- In Other words, digital parameters don't have a "*Continuous*" range.
- This means that, digital parameters change their values by "*Jumping*" from one allowed value to another.
- As an example, the day of the month is a parameter that may only assume one value out of a set of limited discrete values {1, 2, 3, …., 31}.
- Thus, the day of the month is a parameter may not assume a value of 2.5 for example, but it rather jumps from a value of 2 to a value of 3 then to 4 and so on with no intermediate values!!!

To Summarize:

- *Analog* Systems deal with *Continuous* Range of values.
- *Digital* Systems deal with a *Discrete* set of values.
- **Q**. Which is *easier* to design *digital* systems or *analog* ones?

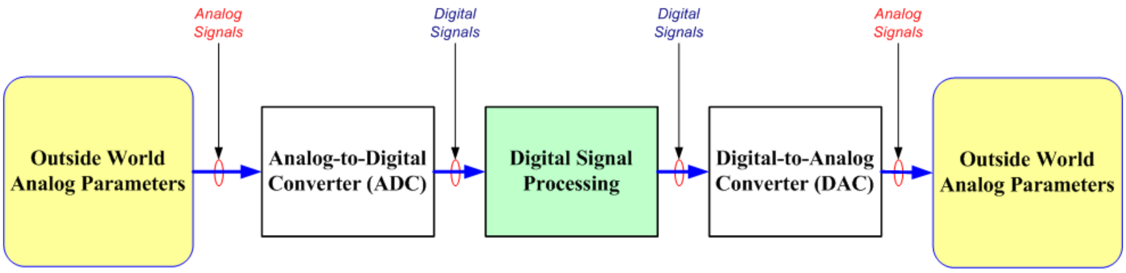
- **A**. Digital systems are *easier* to design since dealing with a limited set of values rather than an *infinite* (*or indefinitely large*) continuous range of values is significantly simpler.

Digitization/Quantization of Analog Signals

- Since the world around us is analog, and processing of digital parameters is much easier, is it is fairly common to convert analog parameters (or signals) into a digital form in order to allow for efficient transmission and processing of these parameters (or signals)
- To convert an Analog signal into a digital one, some loss of accuracy is inevitable since digital systems can only represent a finite discrete set of values.
- The process of conversion is known as *Digitization* or *Quantization*.
- Analog-to-digital-converters (ADC) are used to produce a digitized

version of analog signals.

- Digital-to-analog-converters (DAC) are used to regenerate analog signals from their digitized form.
- A typical system consists of an ADC to convert analog signals into digital ones to be processed by a digital system which produces results in digital form which is then transformed back to analog form through a DAC.

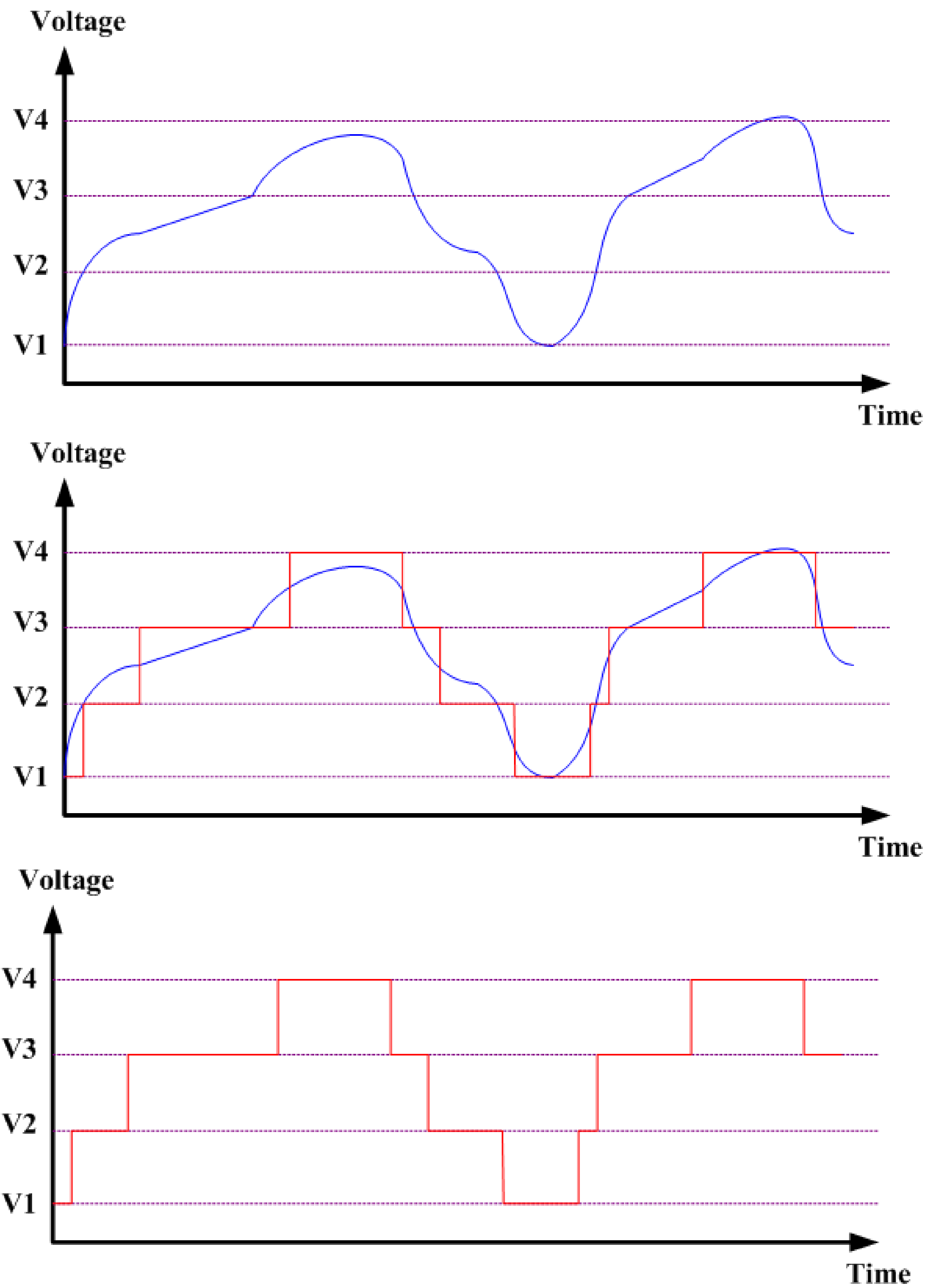


- In this course, we will only be studying digital hardware design concepts, where both the input and output signals are digital signals.

Digitization Example

- As an example, consider digitizing the shown voltage signal assuming that the digitized version allowed set of discrete voltages is {V1, V2, V3, V4}.

- Analog signal values are mapped to the closest allowed discrete voltage ∈ {V1, V2, V3, V4} as shown in Figure.



The Resulting Digitized Waveform

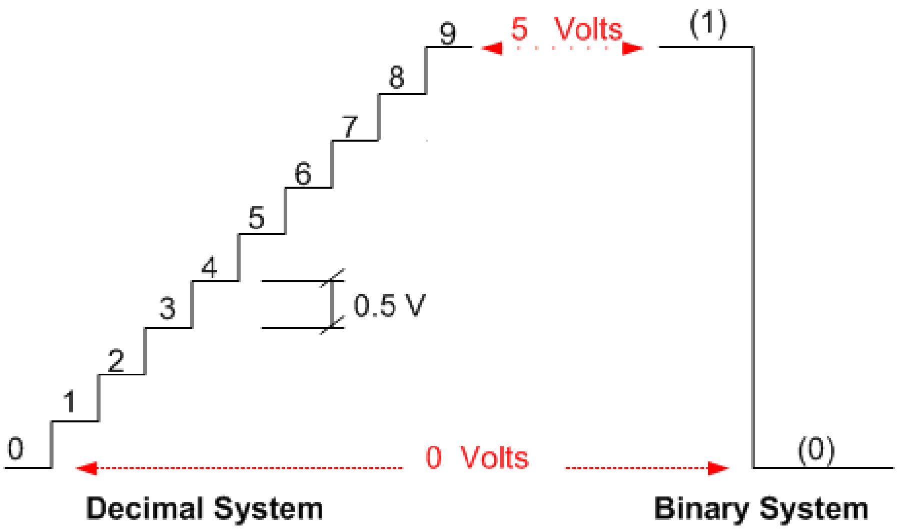
Information Representation

How Do Computers Represent Values (e.g. V1, V2, V3, V4) ?

1. Using Electrical Voltages (Semiconductor Processor, or Memory)
2. Using Magnetism (Hard Disks, Floppies, etc.)
3. Using Optical Means (Laser Disks, e.g. CD's)

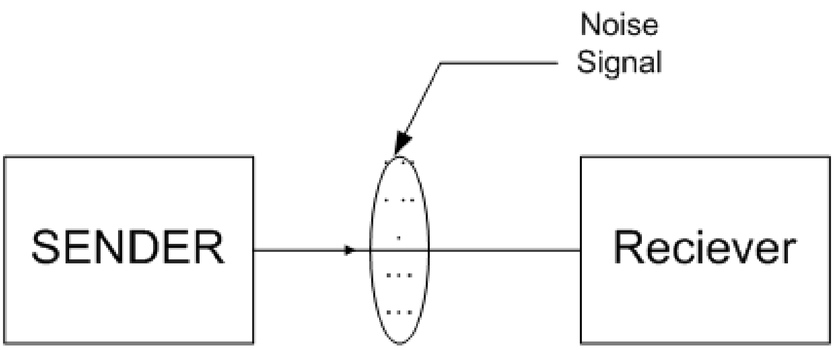
Consider the case where values are represented by voltage signals:

- Each *signal* represents a *digit* in some *Number System*
- If the *Decimal Number System* is used, each signal should be capable of representing one of *10 possible digits* (0-to-9)
- If the *Binary Number System* is used, each signal should be capable of representing only one of *2 possible digits* (0 or 1).
- Digital computers, typically use low power supply voltages to power internal signals, e.g. 5 volts, 3.3 volts, 2.5 volts, etc.
- The voltage level of a signal may be anywhere between the 0 voltage level (Ground) and the power supply voltage level (5 volts, 3.3 volts, 2.5 volts, etc.)
- Thus, for a power supply voltage of 5 volts, internal voltage signals may have any voltage value between 0 and 5 volts.
- Using a decimal number system would mean that each signal should be capable of representing 10 possible digits (0-to-9).
- With 5 volt range signals, the 10 digits of the *decimal* system are represented with each digit having a ***range*** of only 0.5 a volt
- If, however, a *binary* number system is used only 2 digits {0, 1} need to be represented by a signal, allowing much higher Voltage ***range*** of 5 volts between the 2 binary digits.



The Noise Factor

- Typically, lots of *noise signals* exist in most environments.
- Noise may cause the voltage level of a signal (which represents some digit value) to be changed (either higher or lower) which leads to misinterpretation of the value this signal represents.



- Good designs should guard against noisy environments to prevent misinterpretation of the signal information.
- **Q.** Which is more reliable for data transmission; binary signals or decimal signals ?
- **A.** Binary Signals are more reliable.

- **Q**. Why?
- **A**. The Larger the gap between voltage levels, the more reliable the system is. Thus, a signal representing a binary digit will be transmitted more reliably compared to a signal which represents a decimal digit.
- For example, with 0.25 volts *noise level* using a decimal system at 5 volts power supply is totally unreliable

Conclusions

- Information can be represented either in an analog form or in a digital form.
- Due to noise, it is more reliable to transmit information in a digital form rather than an analog one.
- Processing of digitally represented information is much more reliable, flexible and powerful.
- Today's powerful computers use digital techniques and circuitry.
- Because of its high reliability and simplicity, the binary representation of information is most commonly used.
- The coming lessons in this chapter will discuss how numbers are represented and manipulated in digital system.