Analog & Digital Signals

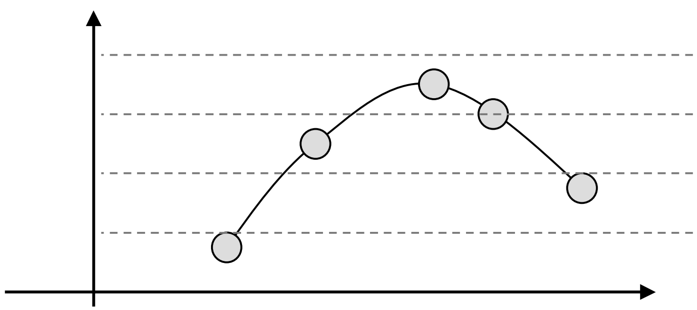
Introduction - Discrete vs Continuous

Continuous: In the real world, signals may take any value, and they rarely take 'nice' round numbers:

Temperature: 18.3267823 degrees of Celsius

Electrical current: 29.2323 mA

<u>Definition</u>: A **continuous-valued signal** can take any value, and smoothly change from one value to another.



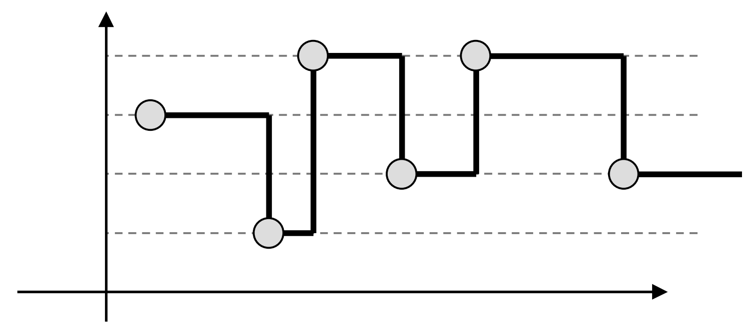
Introduction - Discrete vs Continuous

However, it is difficult to deal with infinite resolution, and we normally restrict a number's resolution to some value (rounding). This means that when they change value, they "jump" from one value to another.

For example:

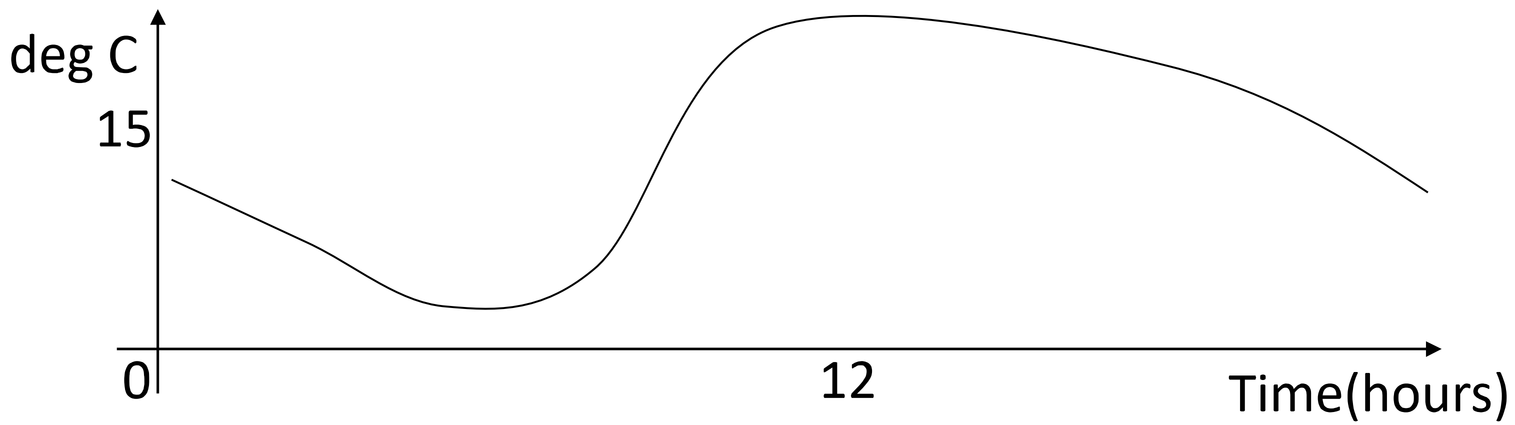
Exam Results: 73%

Definition: A ***discrete-valued signal*** can take only a limited set of values, and step-changes from one value to another.



Analog Signals

For example, if the following diagram was the outside temperature over the past 24 hours:



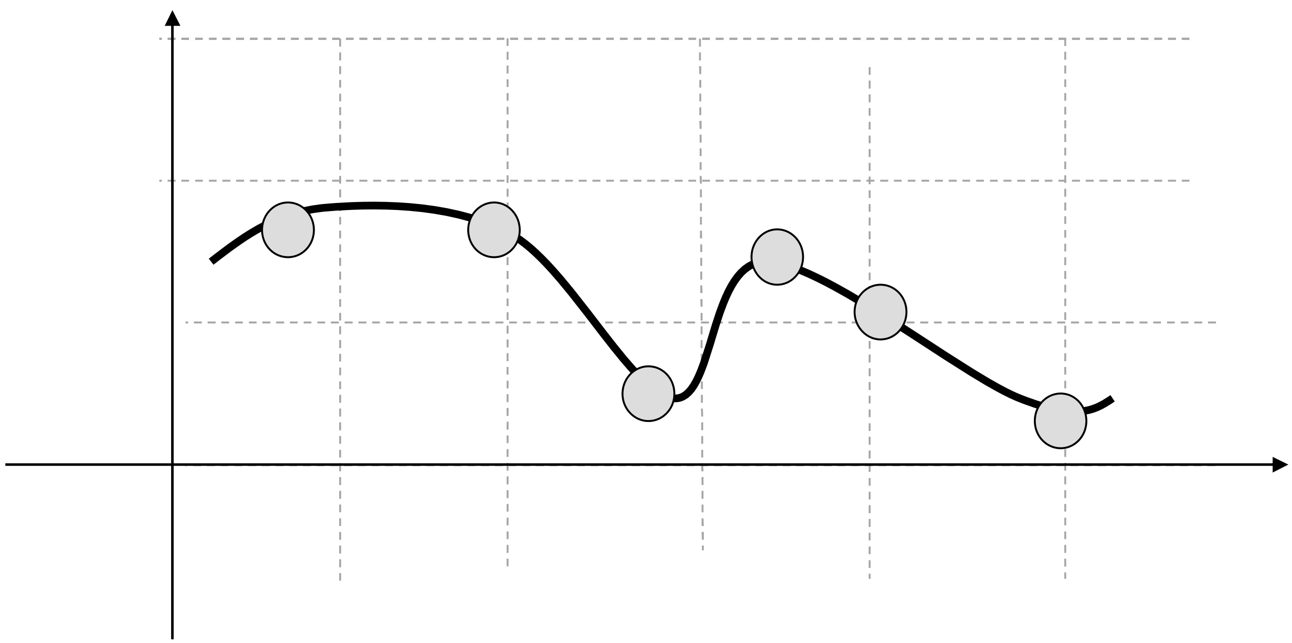
What information is the graph presenting?

Analog Signals

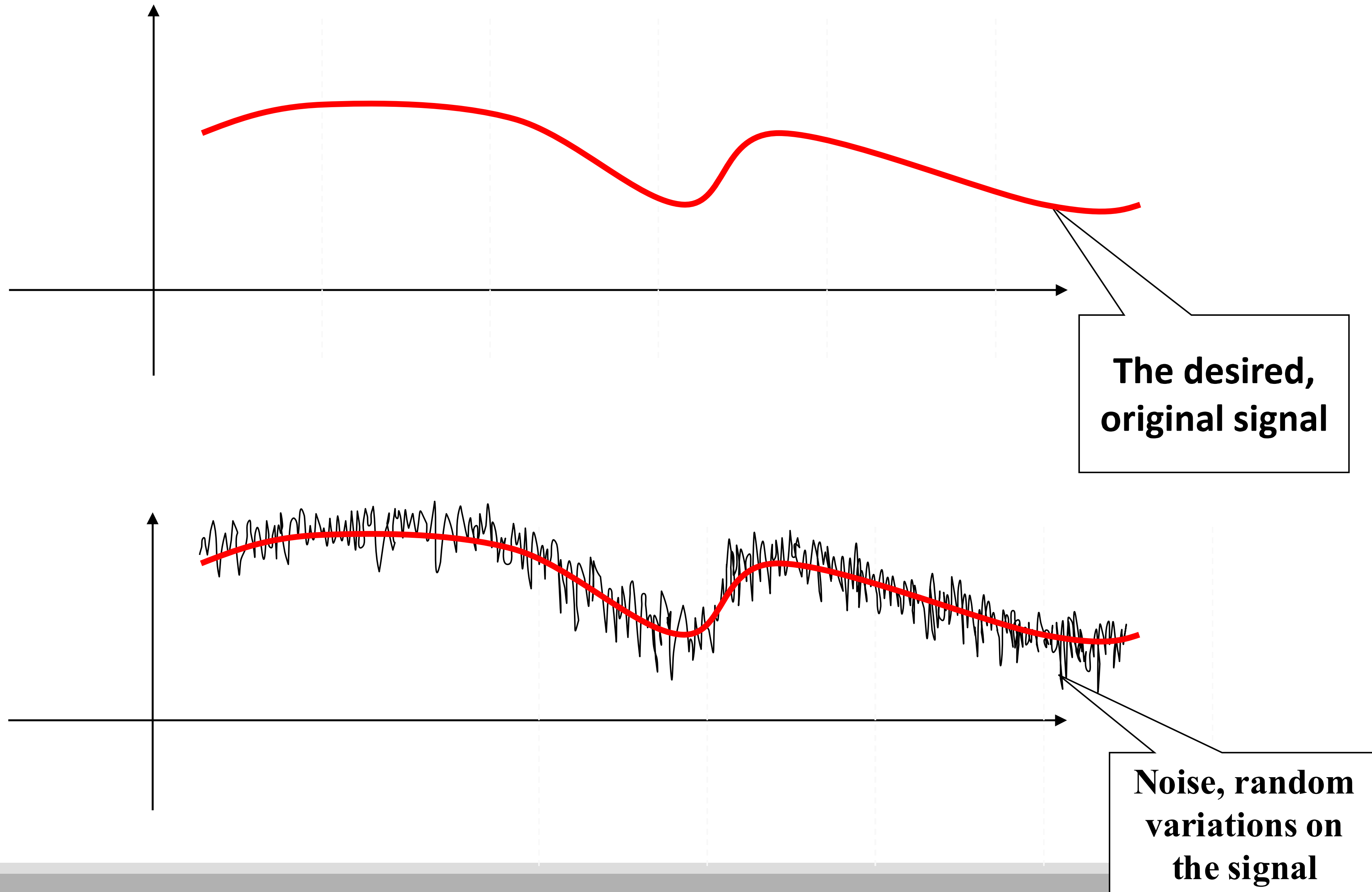
Working Definition

Analog signals: <u>Continuous</u> signals in time and in value.

Analog (sometimes spelled analogue) signals reflect the real world – for example voltage/current.

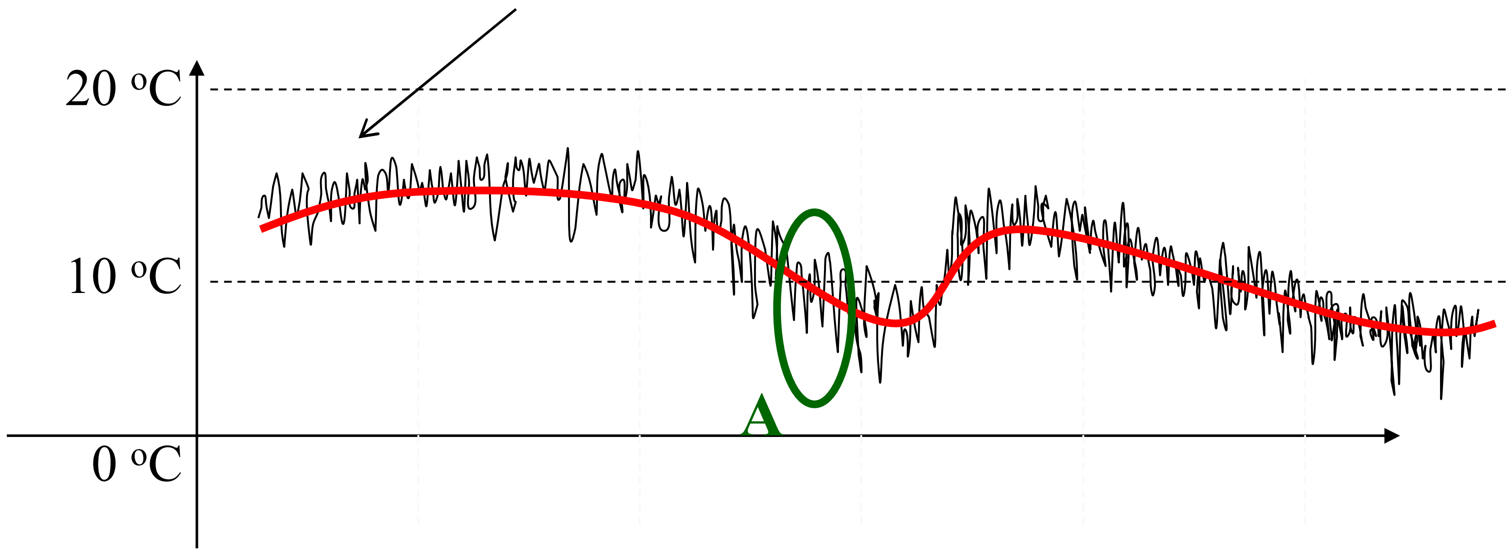


Noise and Analog Signals



Noise and Analog Signals

Actual Value is the continuous line.



What's the temperature at point A as you read it?

What was the temperature meant to be?

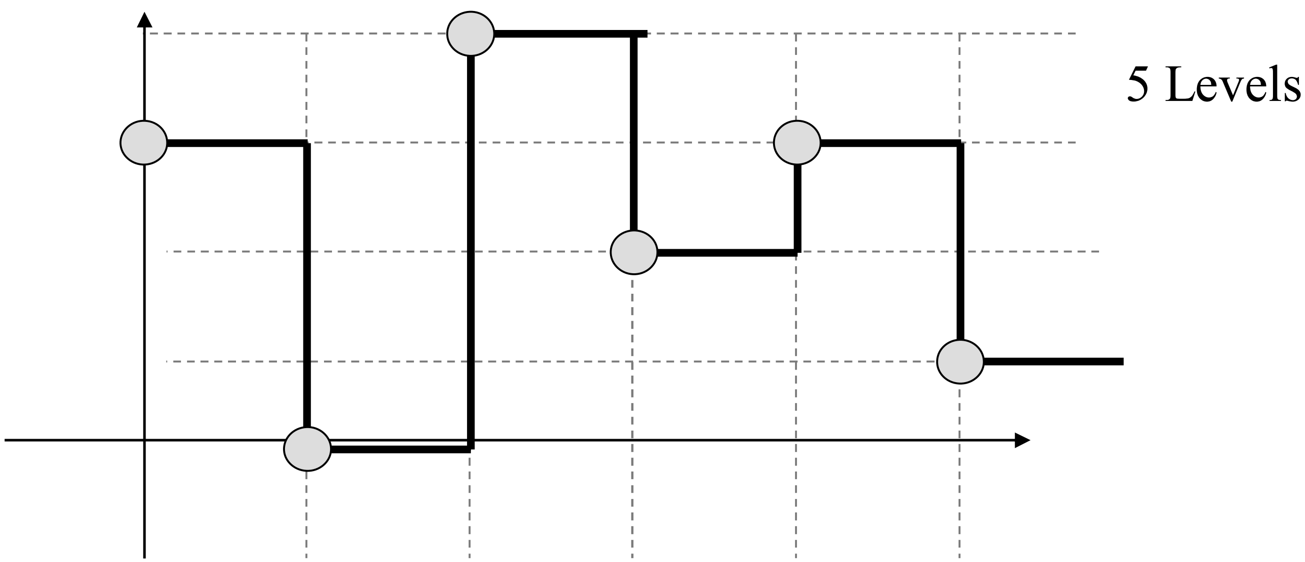
In analog systems, it is impossible to distinguish between the intended value and the noise. All possible values are acceptable.

Digital Signals

Working Definition

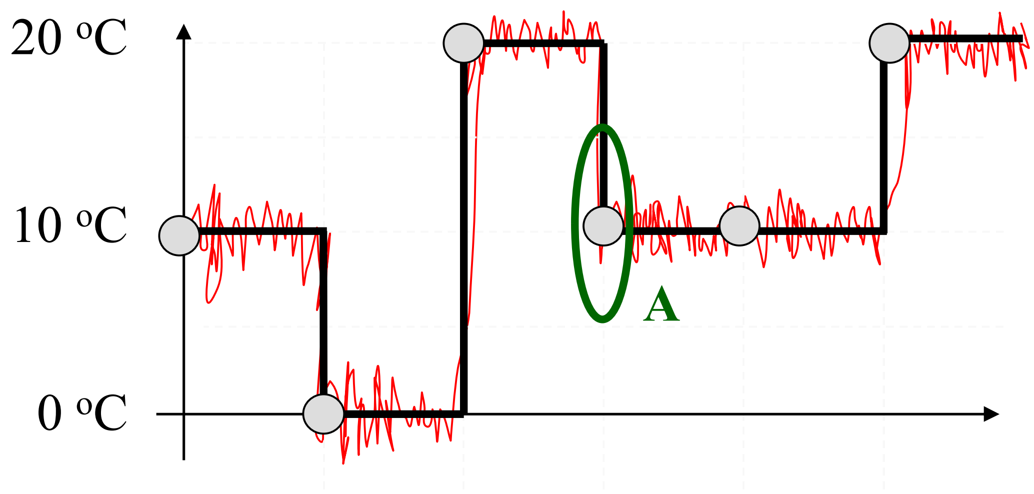
Digital: Digital Signals are discrete in time and in value.

Example is the computer world.



Noise and Digital Signals

Now consider a digital signal with noise:



3 levels

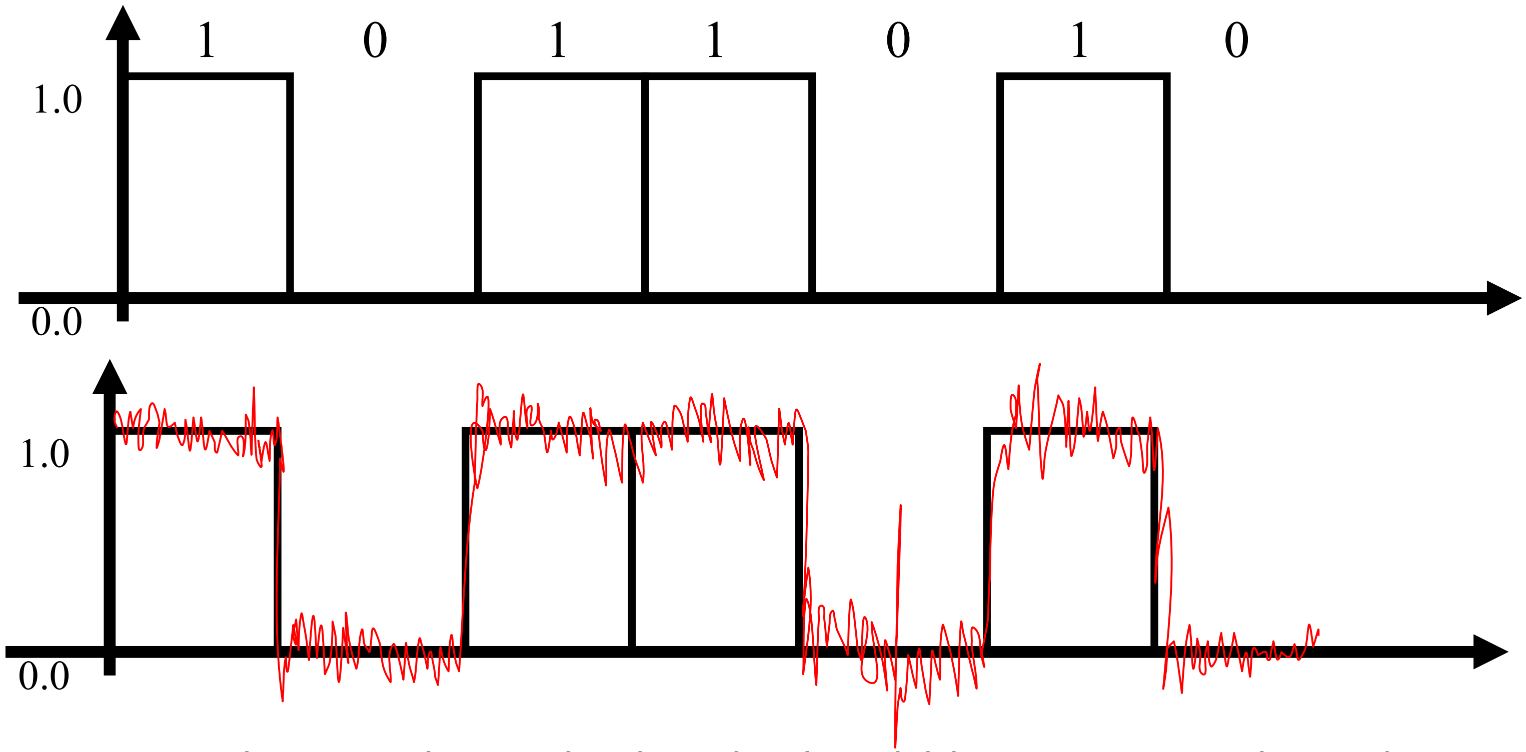
What's the temperature at point A as you read it?

What was the temperature meant to be?

Can you distinguish between the two?

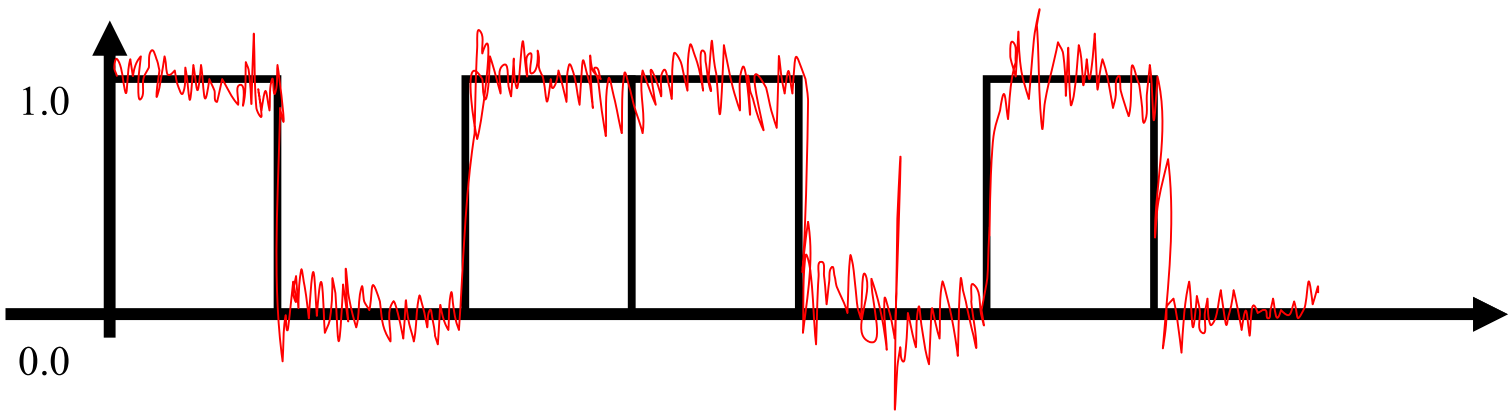
Noise and Digital Signals

In a binary digital system, the **decision threshold** is at 50%



In digital systems, we know where the levels should be, so we make a decision as to which "expected level" the received signal is closest to. If the noise added doesn't cause the signal to cross the decision thresholds, then we will always make the right decision. This means a small amount of noise can be removed. Large noise values will mean we occasionally make the wrong decision.

Noise Margin



Definition: **Noise margin** is the maximum amplitude of an extraneous signal that can be algebraically added to the noise-free input level without causing the decided output to deviate from the expected signal level.

Analog vs Digital Signals

Accuracy/ truthfulness

- An analogue signal is the only way to truly and completely capture an analogue source.
- A digital signal is, at best, an approximation of an analogue source.
- A source that is naturally digital is not easily described by an analogue signal.

Transmission Quality and Noise:

- Analogue signals will always lead to degradation in quality between the transmitter and the receiver due to the unavoidable effects of noise.
- Digital signals are the only way to transmit data error-free. Where there is excessive noise, clean but incorrect signals will result.

Converting Analog to Digital

The process of converting an analog signal (like speech) into a digital one (bits) is called **Analog to Digital conversion (ADC)**.

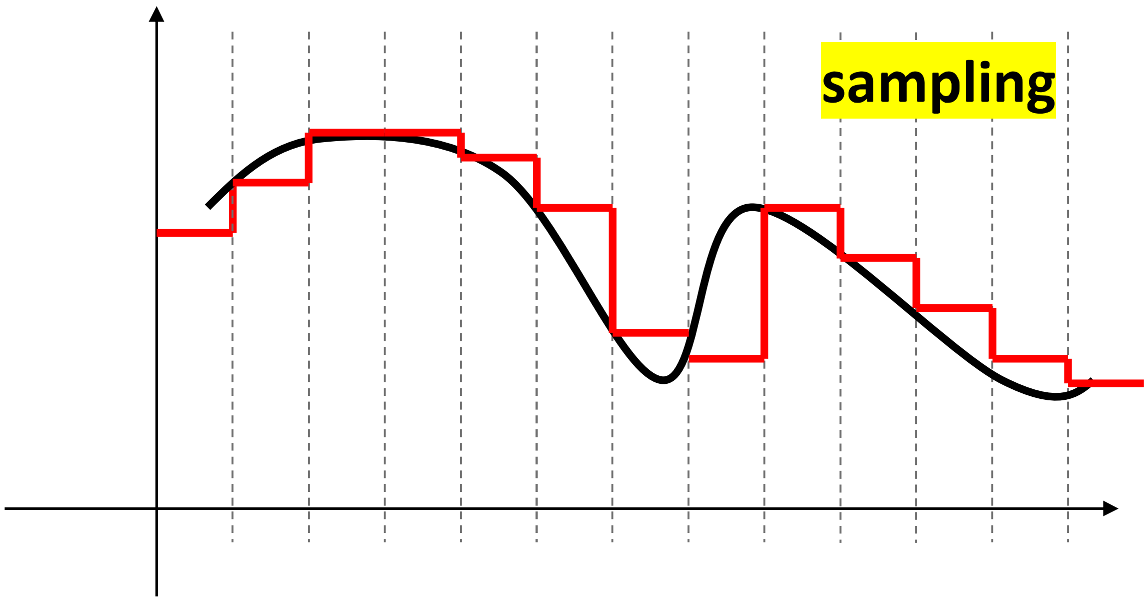
The analog to digital conversion can be modeled in a two-step process: **sampling** and ***quantization.***

- The process of converting an analogue signal to discrete signal value levels is called **quantization.**
- The process of converting an analogue signal to discrete time periods is called **sampling**.

A digital system requires both quantization and sampling to occur.

Converting Analog to Digital

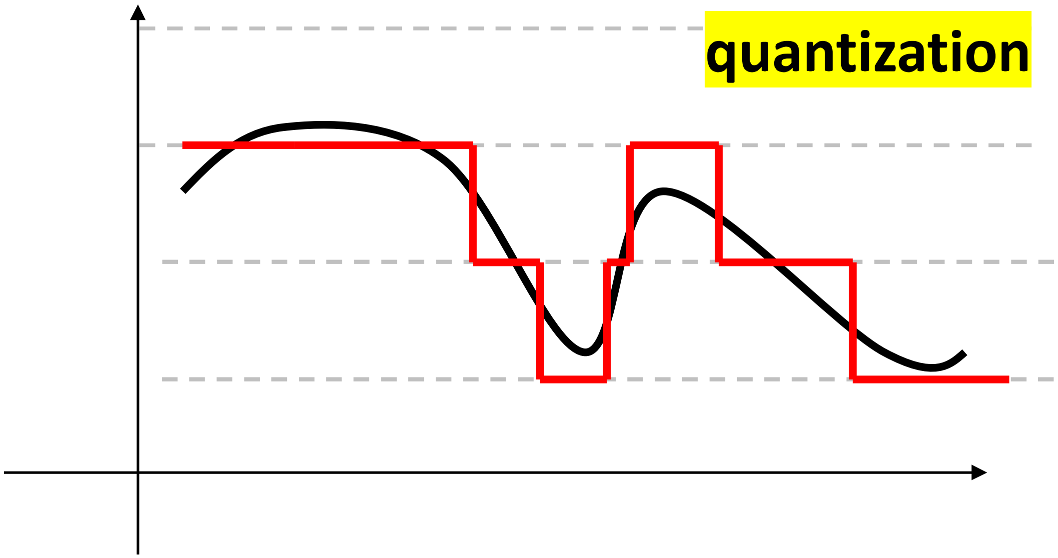
We start with a time-continuous & amplitude-continuous signal. The process of converting an analog signal to discrete time periods is called **sampling**. Sampling converts a time-varying voltage signal into a **discrete-time signal**.



*After sampling, we have a time-discrete & amplitude-continuous signal → **Discrete Signal***

Converting Analog to Digital

The process of converting an analog signal to a discrete signal value levels is called **quantization**. Quantization replaces each real number with an approximation from a finite set of discrete values.



After quantization, we have a time-discrete & amplitude-discrete signal → ***digital signal***

Both processes (sampling and quantization) introduce errors. The more levels we have, and the smaller the time period, the smaller these errors.