ANALOG AND DIGITAL SIGNALS

Classification of Signals

In the real world, physical phenomena, such as temperature and pressure, vary according to the laws of nature and exhibit properties which vary continuously in time, that is they are all analog time-varying signals.

Transducers convert physical phenomena into electrical signals such as voltage and current for signal conditioning and measurement within DAQ systems. While the voltage or current output signal from transducers has some direct relationship with the physical phenomena they are designed to measure, it is not always clear how that information is contained within the output signal. In the case of a flow meter, for example, the output is a digital pulse train whose frequency is directly proportional to the rate of flow. While the change in the flow rate of a fluid may be varying slowly with time, the output signal is a digital pulse train that may vary quickly in time, dependent on the flow rate, not on the speed of change in the flow rate. This is shown in Figure 2.1.

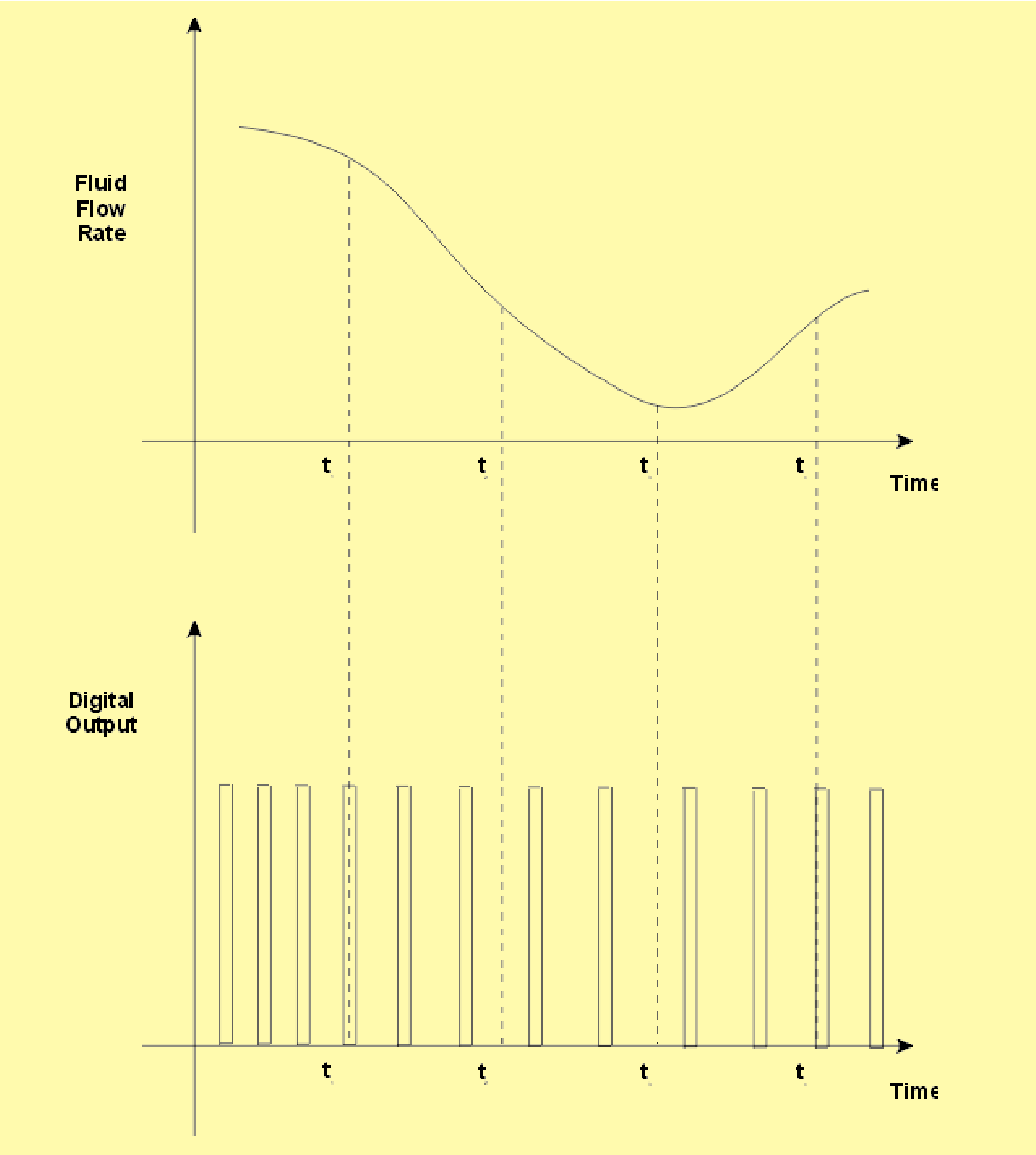

Figure 2.1
Rate of Fluid Flow and Sign at Output from a Flow Meter Transducer

This leads us to the need for the classification of signals in DAQ systems, since it is the information contained within a signal which determines its classification, and therefore the method of signal measurement or the type of hardware required to produce that signal. The classification of signals that may be encountered in data acquisition and control systems are defined in the sections below.

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Digital Signals Binary Signals

A digital, or binary, signal can have only two possible specified levels or states; an 'on' state, in which the signal is at its highest level, and an 'off' state, in which the signal is at its lowest level. This is shown in Figure 2.2.

For example, the output voltage signal of a transistor-to-transistor logic (TTL) switch can only have two states - the value in the 'on' state is 5 V, while the value in the 'off' state is 0 V. Control devices, such as relays, and indicators such as LEDs require digital output signals such as those provided on digital I/O boards.

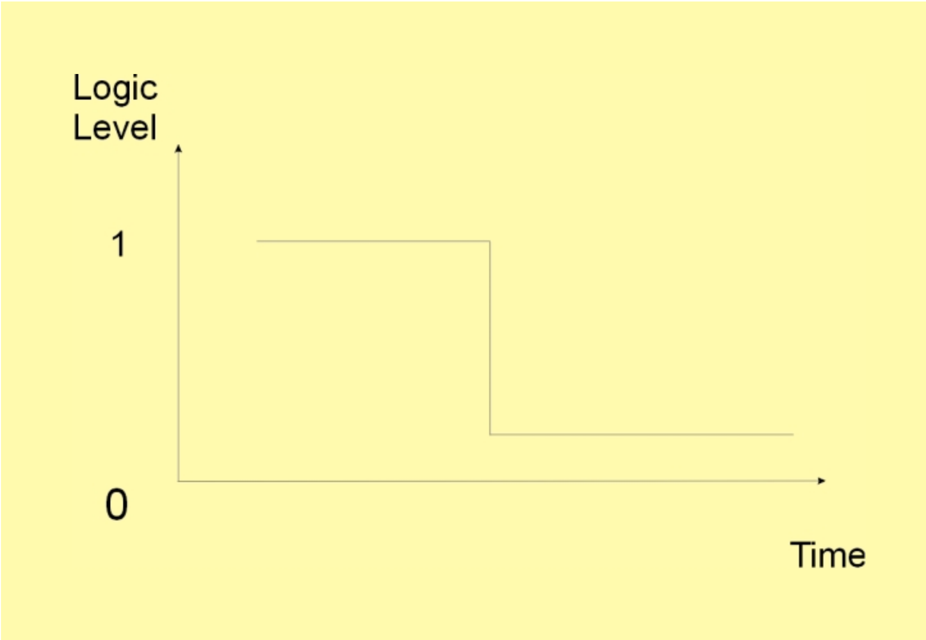

Figure 2.2 A Binary Digital Signal

Digital Pulse Trains

A digital pulse train is a special type of digital signal, comprising a sequence of digital pulses as shown in Figure 2.3. Like all digital signals, a digital pulse can have only two defined levels or states. It is defined as a pulse because it remains in a non-quiescent state for a short period of time. A positive going pulse is one which makes a transition from its lowest logic state to its highest logic state, remains at the high logic state for a short duration, then returns to the low logic state. A negative going pulse makes a transition from its highest logic state to the low logic state, remains there for a short duration, then returns to the high logic state. The information conveyed in a digital pulse train is conveyed in the number of pulses that occur, the rate at which pulses occur or the time between pulses.

The output signals from a flow meter or from an optical encoder mounted on a rotating shaft are examples of a digital pulse train. It is also possible for a DAQ system to be required to output a digital pulse train as part of the control process. A stepper motor, for example, requires a series of digital pulses to control its speed and position. While input and output digital pulse trains can be practically measured or produced using digital I/O boards, counter/timer I/O boards are more effective in performing these functions.

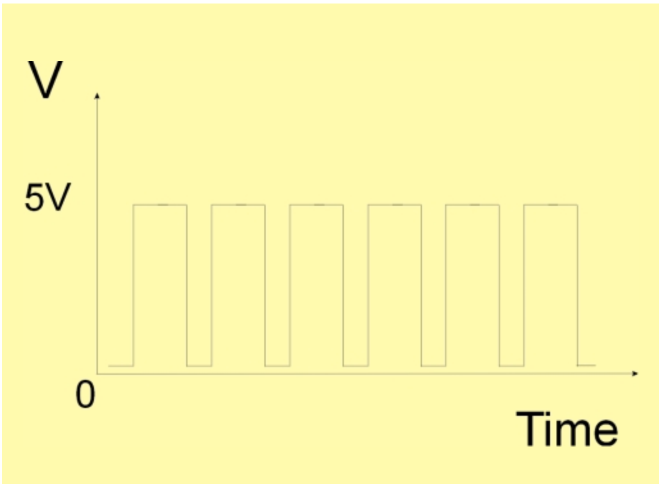

Figure 2.3 Digital Pulse Train Signal

Analog Signals

Analog signals contain information within the variation in the magnitude of the signal with respect to time. The relevant information contained in the signal is dependent on whether the magnitude of the analog signal is varying slowly or quickly with respect to time or if the signal is considered in the time or frequency domains.

Analog DC Signals

Analog DC signals are static or slowly varying DC signals. The information conveyed in this type of signal is contained in the level or amplitude of the signal at a given instant in time, not in how this level varies with respect to time. This is shown in Figure 2.4.

As the timing of the measurements made of slowly varying signals is not critical, the DAQ hardware would only be required to convert the signal level to a digital form for processing by the computer using an analog-to-digital converter (ADC). Low speed A/D boards would be capable of measuring this class of signal. Temperature and pressure monitoring are just two examples of slowly varying analog signals in which the DAQ system measures and returns a single value indicating the magnitude of the signal at a given instant in time. Such signals can be used as inputs to digital displays and gauges or processed to indicate a control action (e.g. turn on a heater or open a valve) required for a particular process.

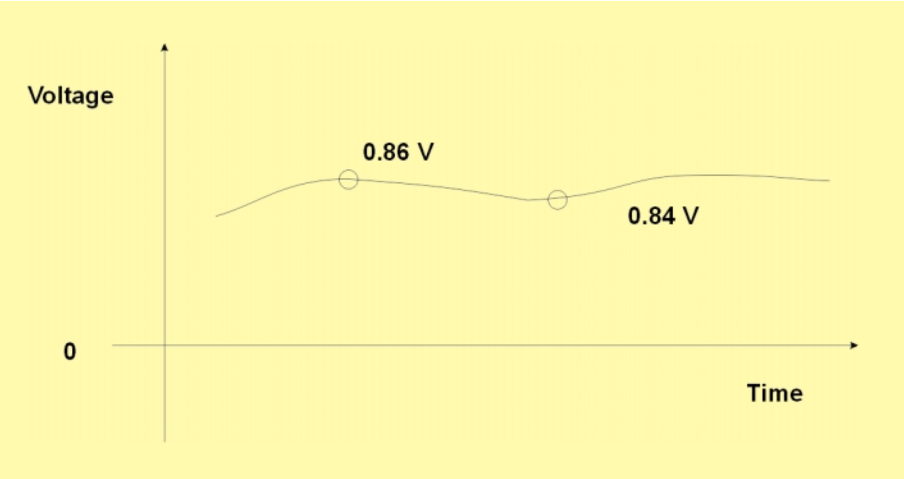

Figure 2.4 An Analog DC Signal

Control hardware, for example, a valve actuator, requires only a slowly varying analog signal, the magnitude at a given point in time determining the control setting. DAQ hardware that could perform this task would only be required to convert the digital control setting to an analog form using a digital-to-analog converter (DAC) at the required instant in time. A low speed general purpose D/A board could perform this function.

The most important parameters to consider for low speed A/D boards and D/A boards is the accuracy and resolution in which the slowly varying signal can be measured or output respectively.

Analog AC Signals

The information conveyed in analog AC signals is contained not only in the level or amplitude of the signal at a given instant in time, but also how the amplitude varies with respect to time. The shape of the signal, its slope at a given point in time, the frequency and location of signal peaks can all provide information about the signal itself. An analog AC signal is shown in Figure 2.5.

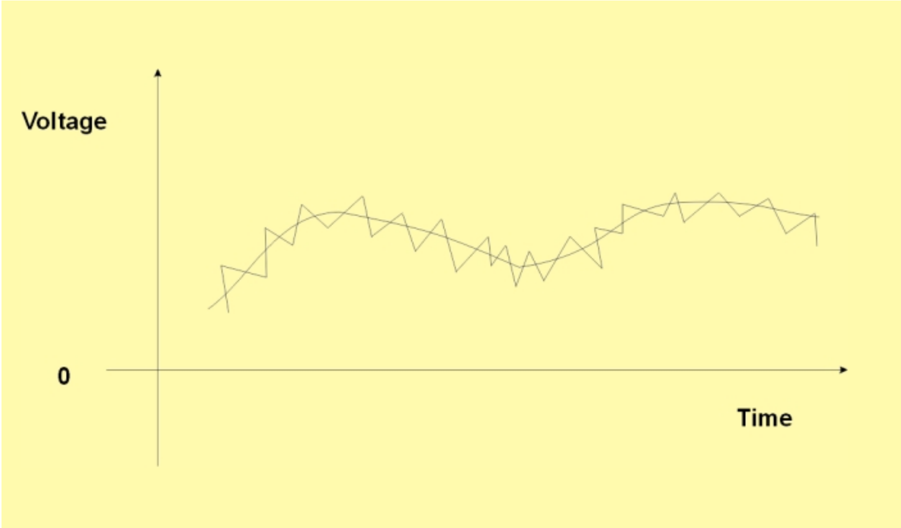

Figure 2.5 An Analog AC Signal

Since an analog AC signal may vary quite quickly with respect to time, the timing of measurements made of this type of signal may be critical. Therefore, as well as converting the signal amplitude to a useful digital form for processing by the computer using an ADC, the DAQ hardware would be required to take the measurements close enough together to reproduce accurately the shape, and therefore the information, contained in the signal. Further to this, the information extracted from the signal may vary depending on when the measurement of the signal started and ended. DAQ hardware used to measure these signals would require an ADC, a sample clock to time the occurrence of each A/D conversion, and a trigger to start and/or stop the measurements at the proper time, according to some external event or condition, so that the relevant portion of the signal could be obtained. A high-speed A/D board would be capable of performing these functions.

As all time varying signals can be represented by the summation of a series of sinusoidal waveforms of different magnitudes and frequencies another useful way of extracting information is through the frequency spectrum of a signal. This indicates the magnitudes and frequencies of each of the sinusoidal components which comprise the signal rather than the time-based characteristics of the signal (i.e. shape, slope at a given point etc). This is shown in Figure 2.6.

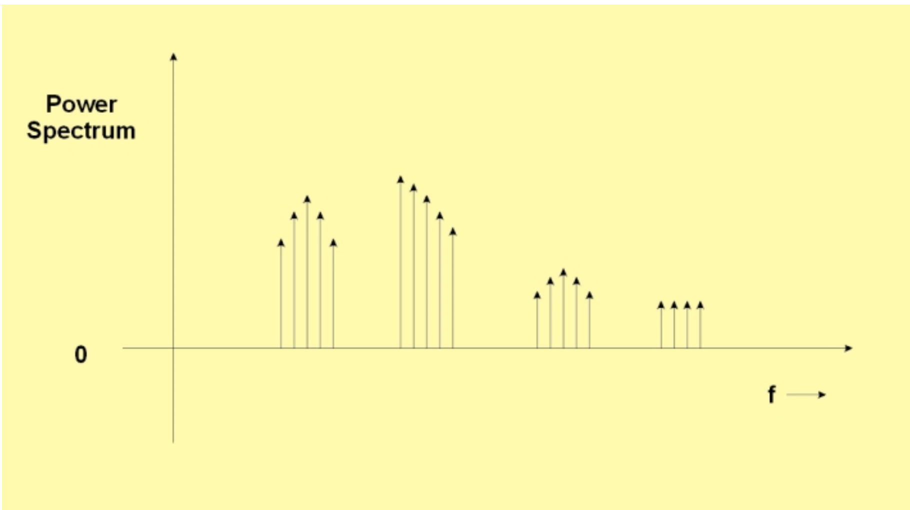

Figure 2.6 An Analog AC Signal in the Frequency Domain

Analysis in the frequency domain allows for easier detection and extraction of the wanted signal, by filtering, from unwanted noise components with frequencies much higher than the wanted signal. The digital signal processing (DSP) required to convert the time-measured signal into frequency information and possibly perform analysis on the frequency spectrum can be achieved in software or with special DSP hardware.