RME 3102: Interfacing

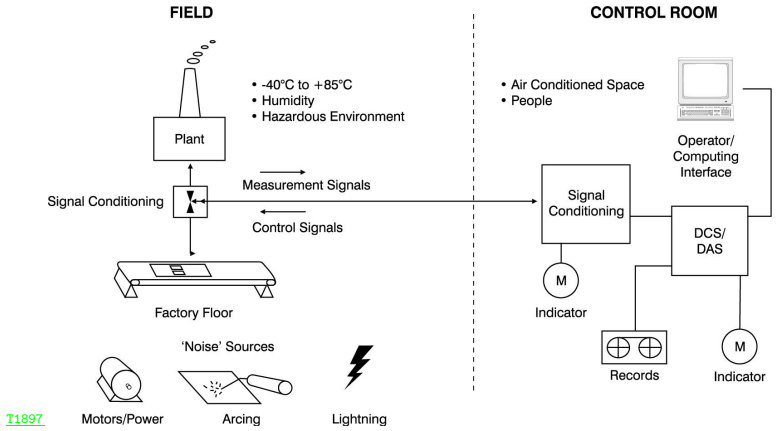
Dr. Md. Zahurul Haq, *Ph.D., CEA, FBSME, FIEB*

Professor
Department of Mechanical Engineering
Bangladesh University of Engineering & Technology (BUET)
Dhaka-1000, Bangladesh

http://zahurul.buet.ac.bd/

RME 3102: Advanced Mechatronics Engineering
Department of Robotics and Mechatronics Engineering,
University of Dhaka

`http://zahurul.buet.ac.bd/RME3102/`

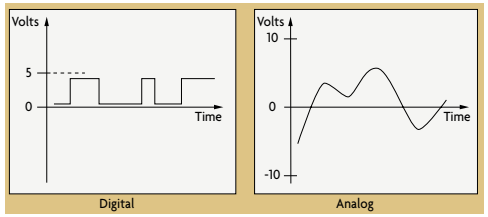


Control and Field Conditions — Industrial Measurement Environment

Signals

- Signals are often described as being either analog, digital, or pulse. They are defined by how they convey useful information (data). Attributes such as amplitude, state, frequency, pulse width, and phase can represent data.
- In instrumentation and control applications most analog signals are in the range of -10 to +10 volts or 4 to 20 mA.
- Digital and pulse signals have binary amplitude values, they are represented by only two possible states–low and high.
- Electrical equivalents produced by input transducers are commonly in the form of voltage, current, charge, resistance, or capacitance.

Analog & Digital Signals



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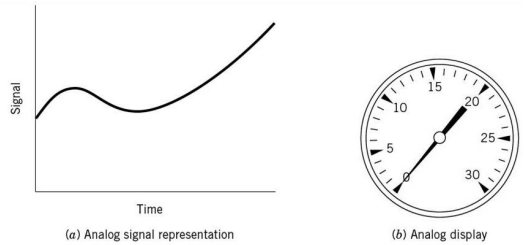
- Natural processes tend to vary smoothly over time (*analog*).
- Computers manipulate data in *digital* form of 0 & 1's.
- Digital form of data transmission involves noise immunity.
- Pulses are easier to detect than to read analog values.

Analog & Digital Signal Concepts



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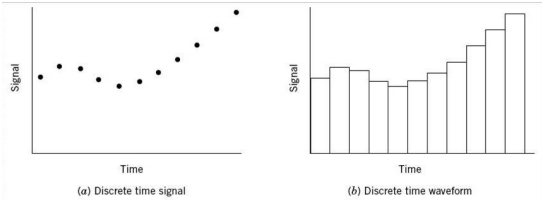

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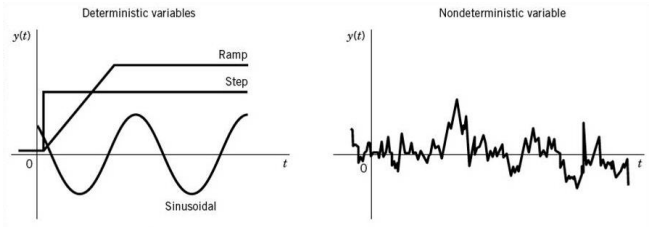
Dynamic Signal Representation



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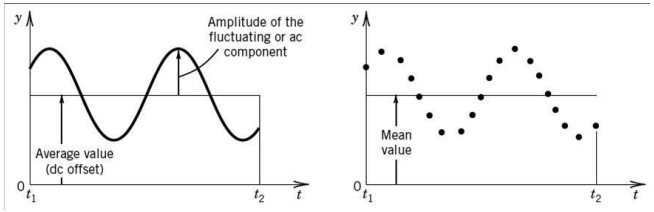

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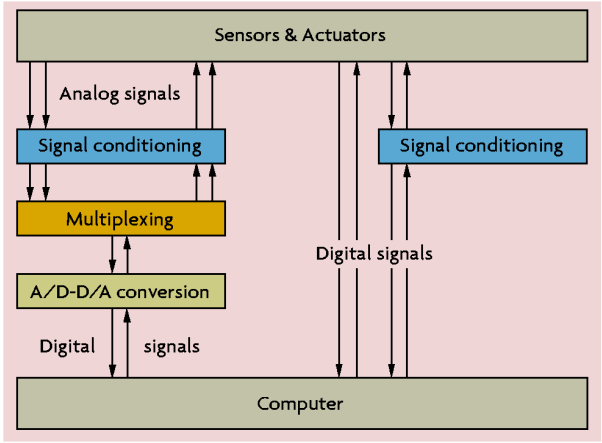
Basic Signal Conditioning Requirements for Interfacing



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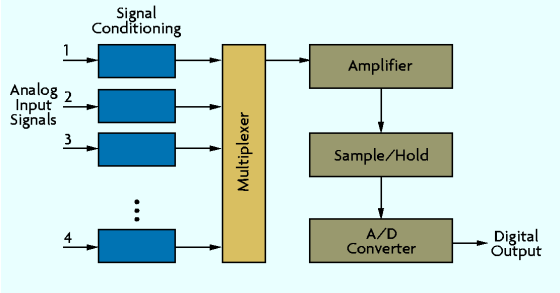
Analog Input Flow Diagram



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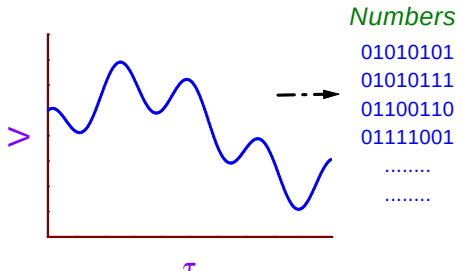
- Multiplexer (MUX) - A switching device that sequentially connects multiple inputs or outputs in order to process several signal channels with a single A/D or D/A converter.
- Sample-and-Hold (S/H) Circuit - to acquire and store an analog voltage on a capacitor for subsequent processing.

Analog to Digital Conversion

- In A/D conversion process continuous electrical signals are converted to the digital language of computers.
- If a 8-bit ADC has a 0-to-2.56 V input signal range, then a 0 V input could produce an output word of 00000000_2, while the +2.56 V level seen at the input would produce an output word of 11111111_2.



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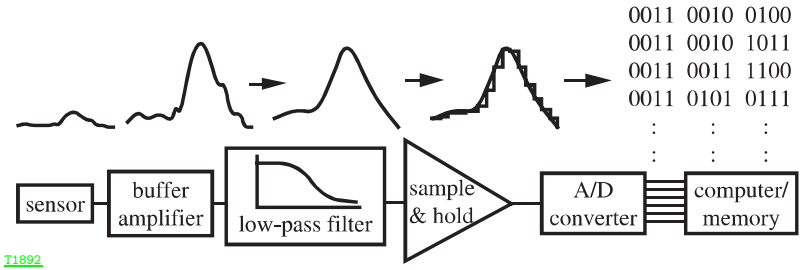
Analog to Digital Signal Conversion Steps



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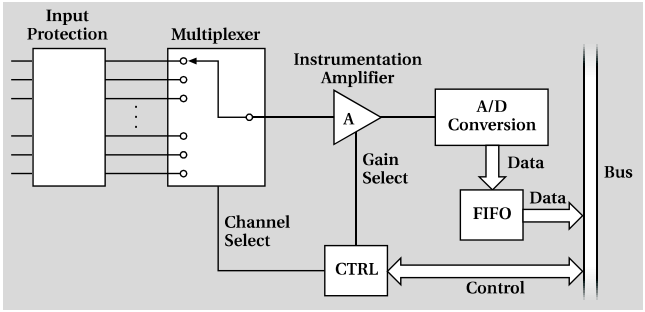
A/D converter types popular for data acquisition

Converter Type	Maximum Speed	Typical Resolution	Noise Immunity	Relative Cost
Successive Approximation	Medium (10kHz to 1MHz)	6–16 bits	Little	Low
Integrating	Slow (10Hz to 30Hz)	12–24 bits	Very Good	Low
Flash	Very Fast (1MHz to 500MHz)	4–8 bits	None	High
Sigma-Delta	Slow to Medium (Up to 1MHz or higher)	16 bits or more	High	Low

T1896

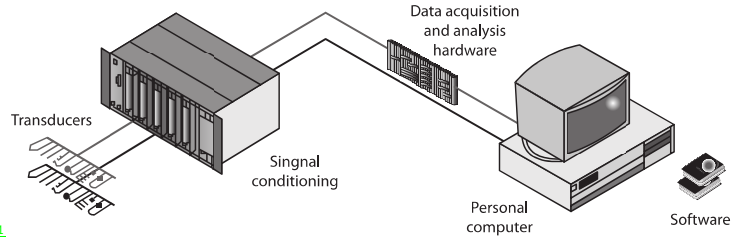


T1893

- Signal conditioning (optional)
- Multiplexer (selects a channel on multi-input A/D boards)
- Programmable instrumentation amplifier (applies gain)
- A/D converter (digitizes the signal)
- FIFO buffer (temporarily stores measurement data)
- Control circuitry (retrieves data from FIFO buffer)

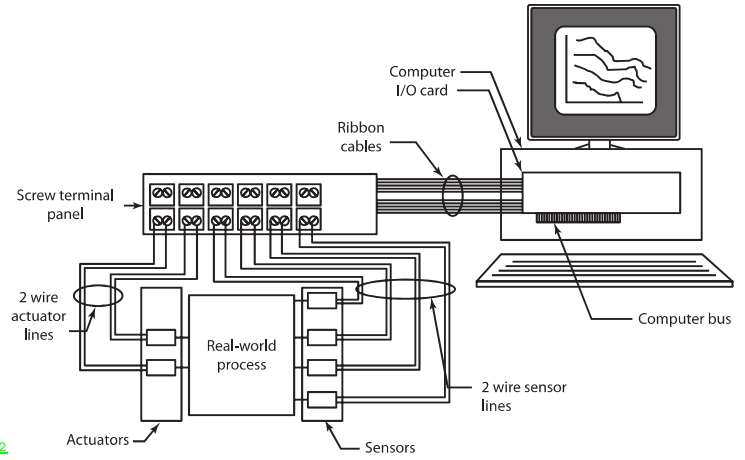
Features of Data Acquisition (DAQ) boards

- Least expensive method of computerized measurement and control.
- High speed available (100kHz to 1GHz and higher).
- Available in multi-function versions that combine A/D, D/A, digital I/O, counting, timing, and specialized functions.
- Good for tasks involving low-to-moderate channel counts.
- Performance adequate to excellent for most tasks, but electrical noise inside the PC can limit ability to perform sensitive measurements.
- Input voltage range is limited to approximately ± 10V.
- Use of PC expansion slots and internal resources can limit expansion potential and consume PC resources.



T1901

The DAQ hardware which act as an interface between the computer and the outside world could be in the form of modules that can be connected to the computer's ports (parallel, serial, USB, etc.) or cards connected to slots (PCI, ISA, PCI-Express, etc.) in the mother board. The newest DAQ devices offer connectivity over wireless and cabled ethernet for remote or distributed DAQ applications.



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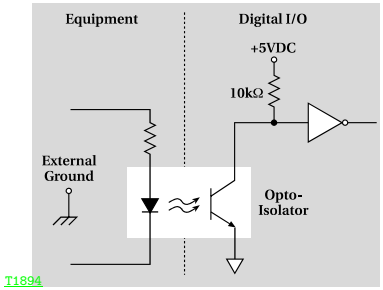
Components of a dac system and interconnections for a system with four sensors and two actuators.

Digital Isolation



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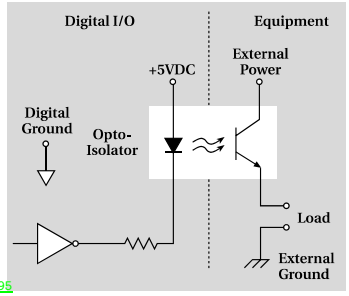
Isolated digital input



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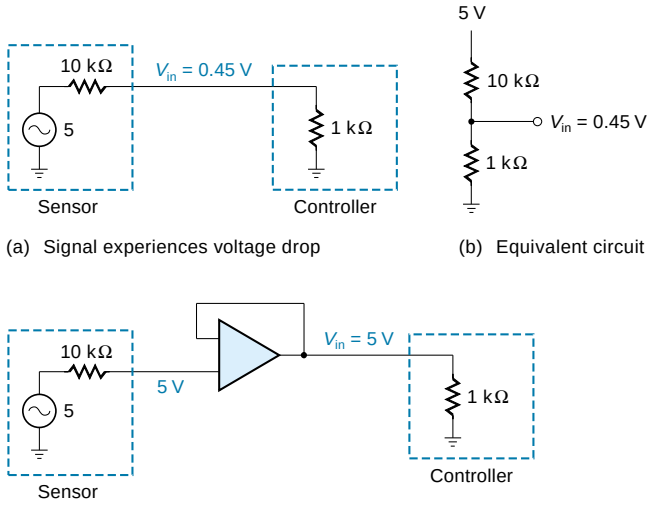
Isolated digital output

Both use an opto-isolator that provides an electrical barrier between the digital input or output and the external equipment.



(a) Signal experiences voltage drop

(b) Equivalent circuit

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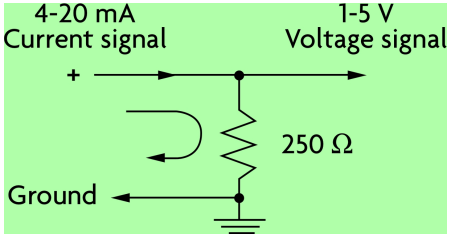
(c) No signal voltage drop

General Signal Conditioning Functions

- Scaling - Low level signals should be amplified to increase the resolution and to reduce noise. Conversely, high voltage signals may need to be attenuated.
- Filtering - A variety of physical devices and circuits are available to keep separate desired signals from specific frequencies of undesirable electrical noise such as ac line pick-up or other EMI/RFI.
- Isolation - Used to protect personal and equipment from high voltages and spikes. Isolators block circuit overloads while simultaneously passing signal of interest.
- Excitation - Signal conditioning also generates excitation for some transducers. Strain gauges, thermistors, and RTDs, for example require external voltage or current excitation.

- Linearization - Many transducers, such as thermo-couples, have a nonlinear response to changes in the phenomenon being measured. Signal conditioning is applied to have linear output for a given nonlinear input signal.
- Current-to-voltage conversion - Many transducers generate a current signal, usually 4 to 20 mA or 0 to 20 mA. Current signals are less sensitive to noise and voltage drop due to lead resistance & these can be readily converted to a voltage signal using a simple resistor.



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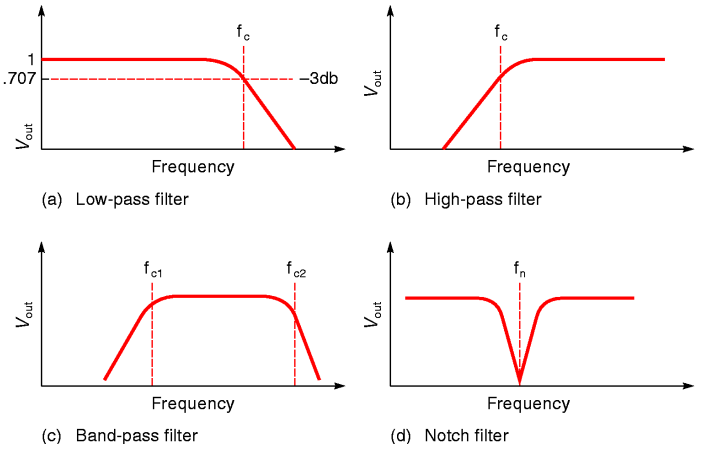
Signal Filter Classifications

- Low Pass Filter - Lower frequencies are passed to the output with little attenuation, and the higher frequencies are significantly attenuated (i.e., not passed).
- High Pass Filter - Lower frequencies are attenuated.
- Band Pass - Only a narrow band of frequencies are passed and all others are significantly attenuated.
- Band Reject/Notch Filter - A narrow band of frequencies are highly attenuated. A common use of this filter is to eliminate 50 Hz interference found on signal lines.

Characteristics of Real Filters



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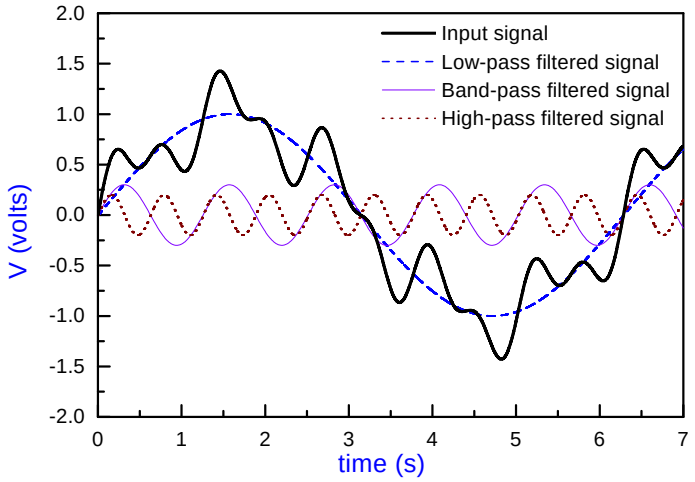
Example of Filtering



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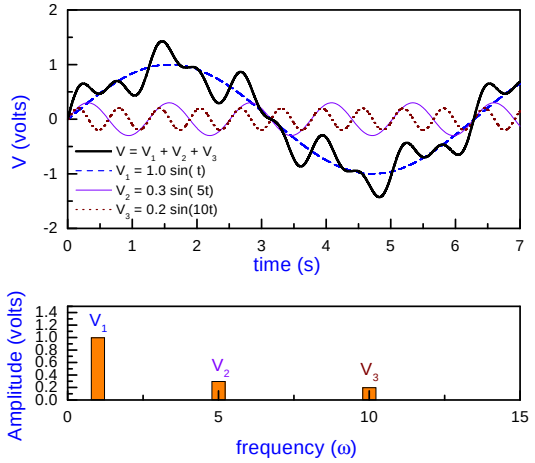
Frequency Spectrum Diagram



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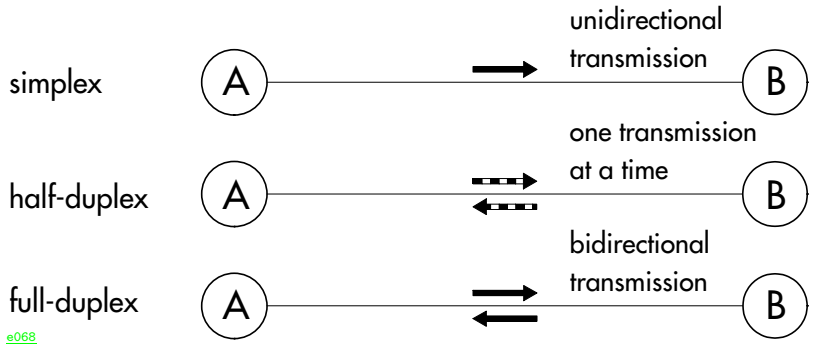
Data Transmission Modes



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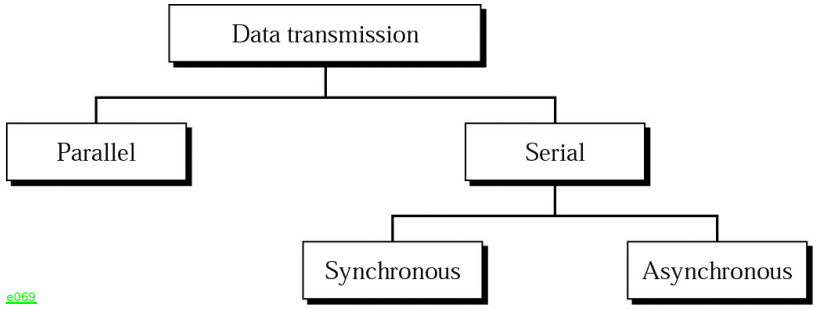
Data Transmission Types



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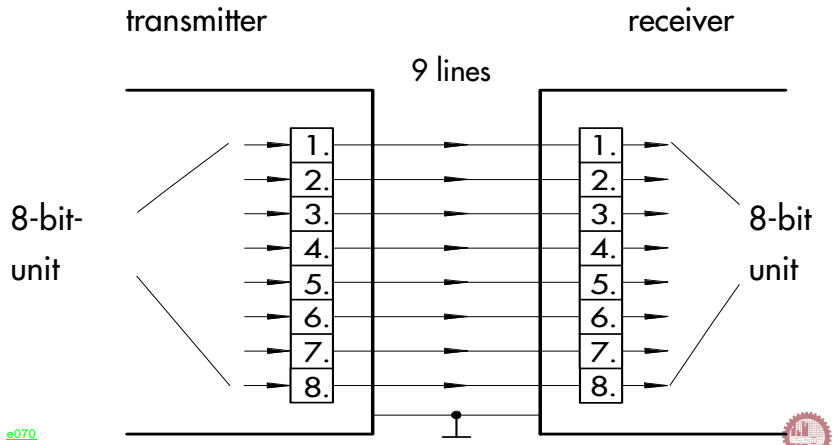
1. Parallel - n wires are used to send n bits at one time.
2. Serial - one bit follows another, so only one channel is required.

Parallel Communication



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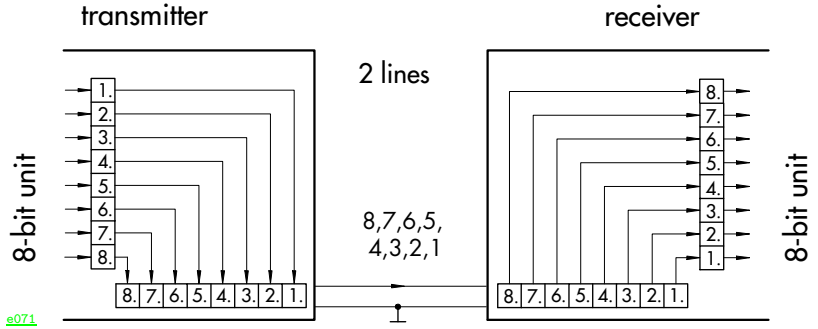
Serial Communication



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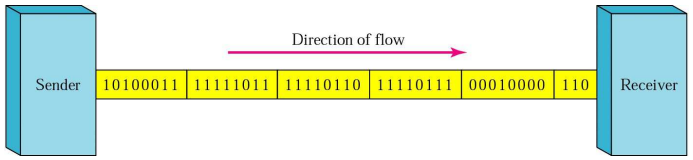
Synchronous Serial Communication

- Data are transmitted as an unbroken string of 1s and 0s, and the receiver separates that string into the bytes, or characters, it needs to reconstruct the information.
- Timing is very important, the accuracy of the received information is completely dependent on the ability of the receiving device to keep an accurate count of the bits as they come in.
- Synchronous transmissions are faster than asynchronous transmission.



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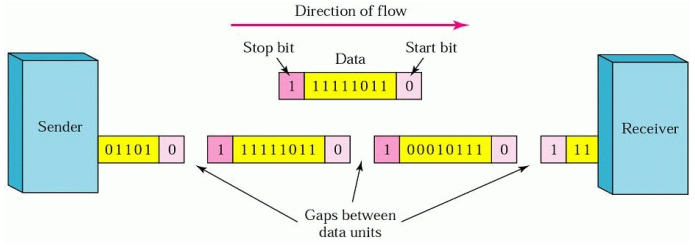
Asynchronous Serial Communication

- Timing of a signal is unimportant, rather information is received and translated by agree-upon patterns.
- To alert the receiver to the arrival of a new group, start bit, usually a O, is added to the beginning of each byte.
- To inform the end of byte stop bits, usually 1s, are appended to the end of each byte.



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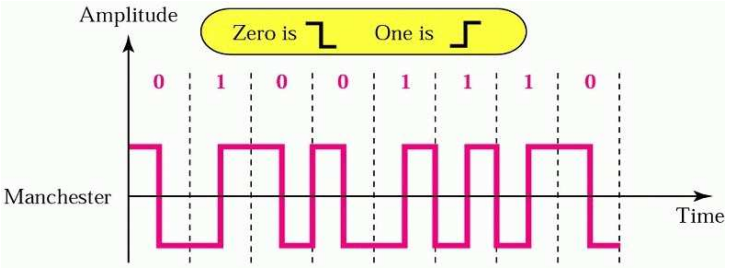
Data Conversion Methods

Transform data into signal to send from one place to another. Data conversion methods:

1. Digital-to-digital: e.g. Manchester encoding.
2. Analog-to-digital: e.g. Pulse-amplitude modulation (PAM)
3. Digital-to-analog: e.g. ASK, FSK, PSK
4. Analog-to-analog: e.g. AM, FM, PM

Digital-to-digital Encoding

In Manchester encoding, the bit information is included in the phase angle of the signal: a rising edge occurring in the middle of the bit time indicates 'high' state, while a trailing edge stands for 'low' state.



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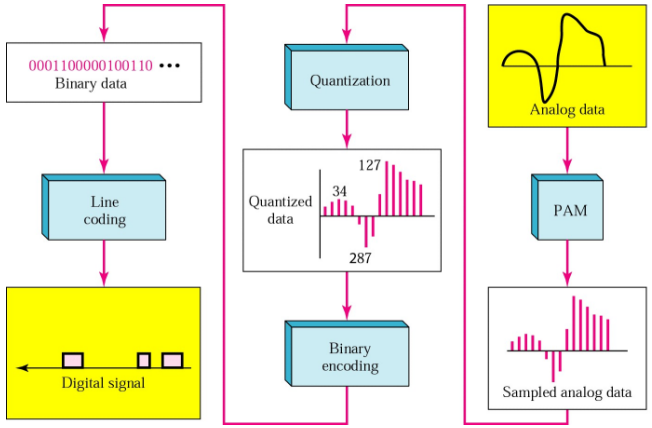
Analog-to-digital Encoding



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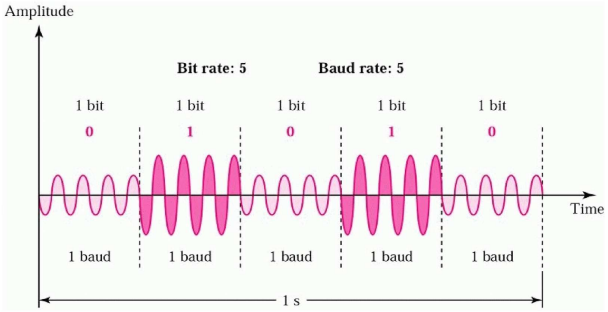
D/A Conversion: Amplitude Shift Keying (ASK)



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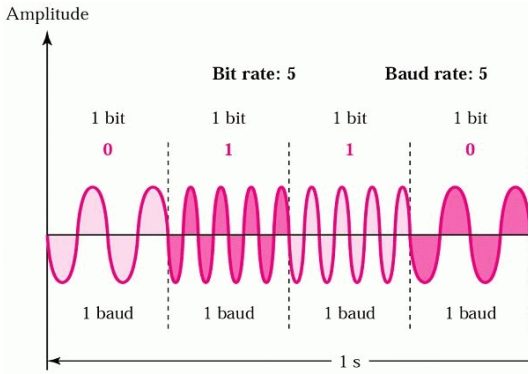
Strength of the signal is varied to represent binary 1 or 0; both frequency and phase remain constant while the amplitude changes.

D/A Conversion: Frequency Shift Keying (FSK)



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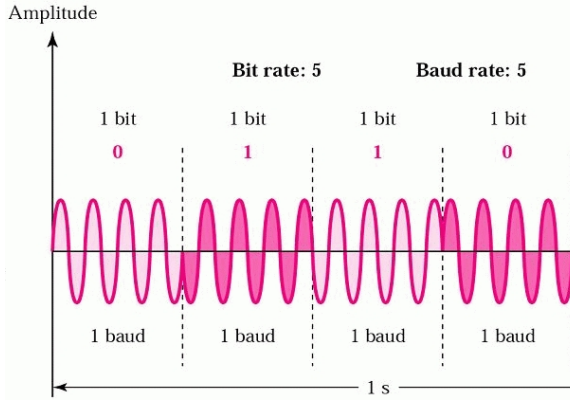
Frequency of the signal is varied to represent binary 1 or 0; both peak amplitude and phase remain constant.

D/A Conversion: Phase Shift Keying (PSK)



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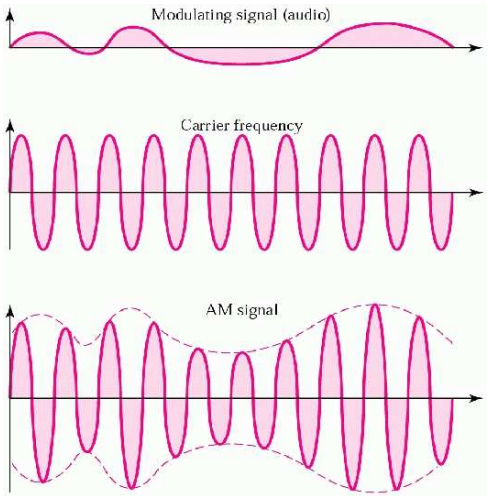
Phase of the signal is varied to represent binary 1 or 0; both frequency and peak amplitude remain constant.

A/A Conversion: Amplitude Modulation (AM)



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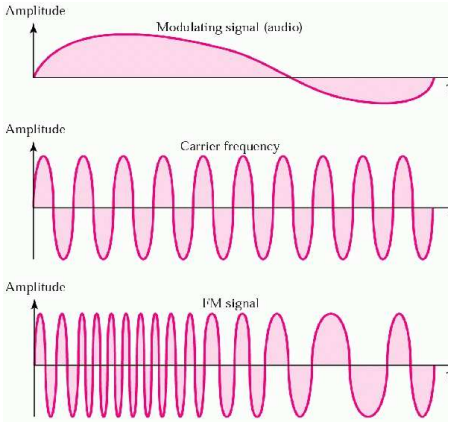
A/A Conversion: Frequency Modulation (FM)



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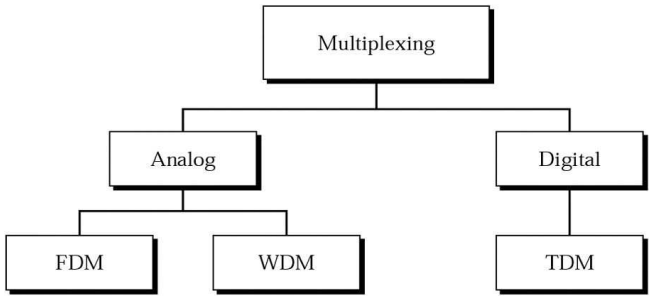
A/A Conversion: Phase Modulation (PM)

In PM transmission, the phase of the carrier signal is modulated to follow the changing voltage level (amplitude) of the modulating signal. The peak amplitude and the frequency of the carrier signal remain constant, but as the amplitude of the information signal changes, the phase of the carrier changes correspondingly. The analysis and the final result (modulated signal) are similar to those frequency modulation.

Categories of Multiplexing



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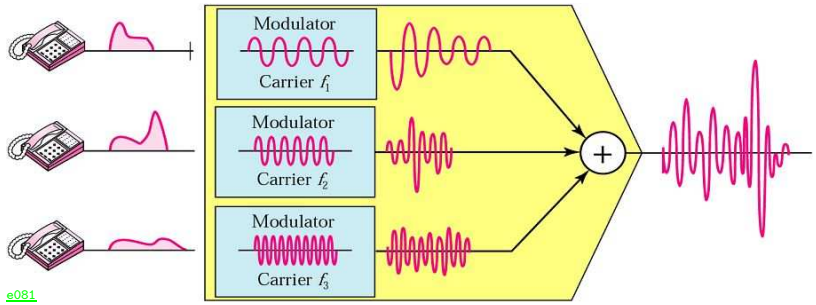
FDM - Frequency division multiplexing

TDM - Time division multiplexing

WDM - Wave division multiplexing

FDM Multiplexing, time domain



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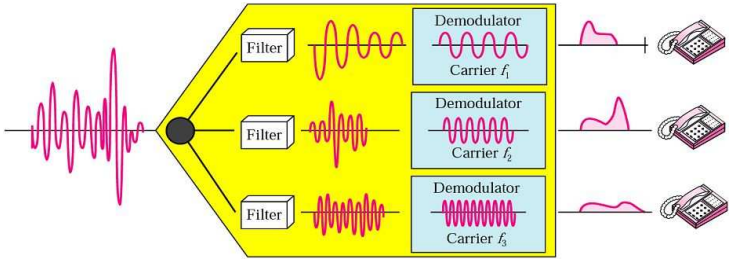
FDM de-Multiplexing, time domain



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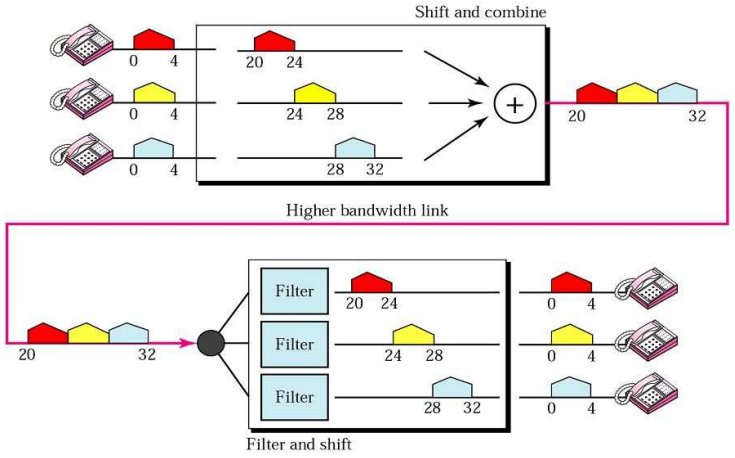
FDM, frequency domain



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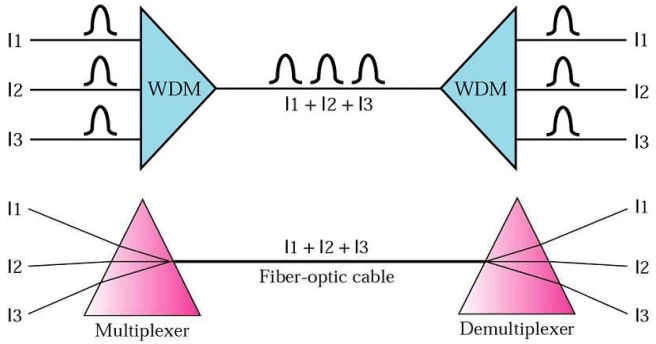
WDM Multiplexing and de-Multiplexing



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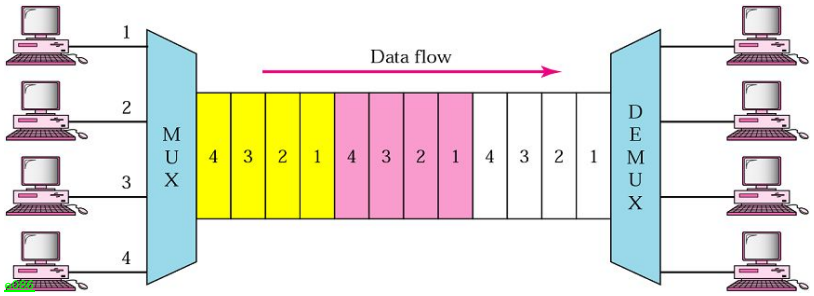
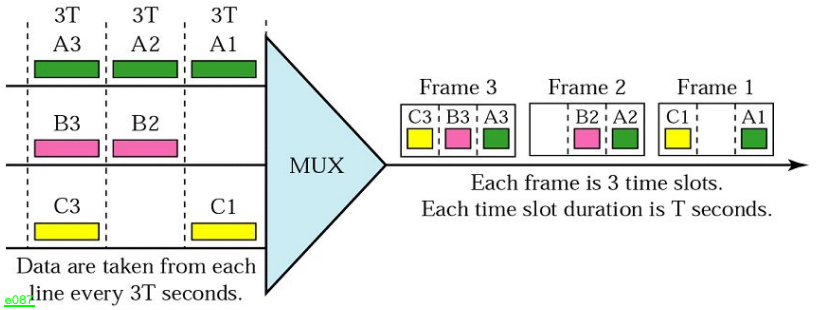
TDM Multiplexing



Synchronous TDM Multiplexing

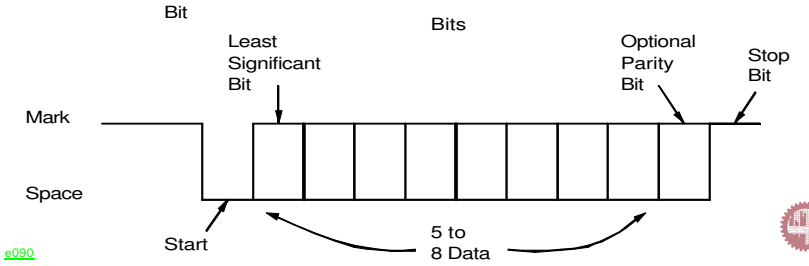


Data Coding & Transmission

- Any binary code that both ends agreed upon can be used. However, the most common is the ASCII (American Standard Code for Information Exchange) code.
- The designer of Universal Asynchronous Receiver/Transmitter (UART)s have chosen to send the least significant bit first.
- Asynchronous serial communication is used as the characters can be sent as any time and not synchronized with any other processes in either sending and receiving units. To synchronize, data bits are encapsulated between two other bits known as start bit and end bit.

...

- The rate at which bits are sent is called the baud rate. The data rate can be any value, however standard baud rates are: 110, 150, 300, 600, 900, 1200, 2400, 4800, 9600, 14400, 19200, 38400, 57800.
- The logic one and zero levels are called Mark and Space, respectively. When the transmitter is not sending anything, it holds the line at the mark level, i.e. logic one.



Standard Electrical Signal Levels

- 20-mA Current Loop: 20 mA of current signifies a mark and zero current a space.
- TTL: a system a may define mark and space with standard TTL voltages and currents.

	TTL		CMOS	
	low	high	low	high
input	0 - 0.8 V	2.0 - 5.0 V	0 - 1.5 V	3.5 - 5.0 V
output	0 - 0.5 V	2.7 - 5.0 V	0 - 0.05 V	4.95 - 5.0 V

- TTL – Transistor-transistor logic
- CMOS – Complementary Metal Oxide Semi-conductor

Standards for Serial I/O Interfaces

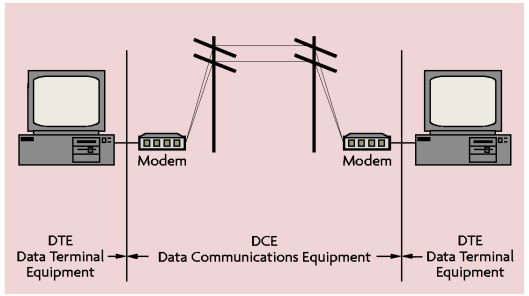
Standards are required to allow different manufacturers' equipment to be interconnected and must define the following elements:

- Handshaking signals
- Direction of signal flow
- Types of communication devices
- Connectors and interfaces
- Electrical signal levels

RS-232 is used in most serial interfaces. When the signals must transmit farther than 50 ft or greater than 20kbps, RS-422, RS-423 or RS-485 should be chosen. For each of these, handshaking, direction of signal flow and the types of communication devices are based on the RS-232C standard.

DCE-DTE Interface

- Data Circuit-Terminating Equipment (DCE) - is any device that transmits or receives data in the form of an analog or digital signal through a network.
- Data Terminal Equipment (DTE) - is any device that is a source or destination of any binary digital data.



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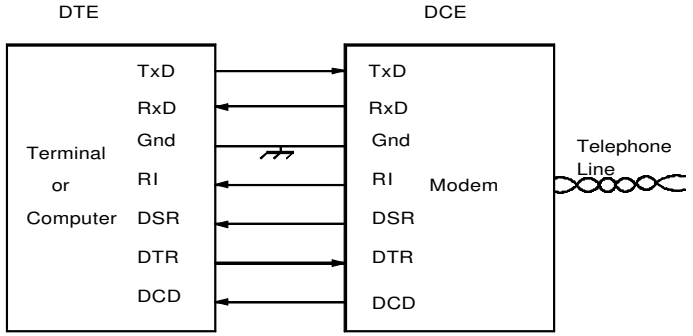
Modem Handshaking Signals



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Modem Handshaking Signals . . . contd.

- Ring Indicator (RI): a special tone that rings the phone. The terminal can use RI to start some processes such as notifying the user that the other end is calling or to answer the telephone in an answer modem.
- Data Set Ready (DSR): this signal tells the DTE that the modem has established a connection over the telephone line to the far end.
- Data Terminal Ready (DTR): this signal comes from the DTE and informs the modem that is ready to operate.
- Data Carrier Detect (DCD): sourced by DCE, received by DTE. Indicates that a DCE has detected the carrier on the telephone line.

Modem Handshaking Signals . . . contd.

- Request to Send (RTS): Sourced by DTE and received by DCE. RTS is asserted by the DTE when it wants to send data. The DCE responds by asserting CTS.
- Clear to Send (CTS): Received by DTE and sourced by DCE. CTS must be asserted before the DTE can transmit data.
- Transmitted Data (TxD): Sourced by DTE and received by DCE. DTE cannot send unless RTS, CTS, DSR and DTR are asserted.
- Received Data (RxD): Received by DTE and sourced by DCE.
- Signal Ground (SG): ground reference for the signal.

Summary of Serial Communication Standards

Specification	RS-232C	RS-422	RS-423	RS-485
Driver output (V)	±5 to ±15	±2 to ±5	± 3.6 to ±6	±1.5 to ±5
Max. Data Rate	20 kb/s	10 Mb/s	100 kb/s	10 Mb/s
Max. Length	50 ft	4000 ft	4000 ft	4000 ft
No. of driver	1	1	1	32
No. of receiver	1	10	10	32