Industrial Data Communications - Fundamentals

Tutorial 1

This tutorial on the fundamentals of communications is broken down into the following sections:

- Communication Modes
- Synchronous versus Asynchronous
- Data Coding
- Open Systems Model

Communication Modes

In any communications link connecting two devices, data can either be sent in one of three communications modes:

- Simplex
- Half Duplex
- Duplex

These are indicated below.

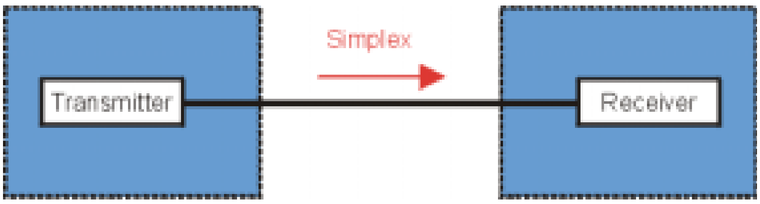

Figure 1 - Simplex Communications

A simplex system is one that is designed for sending messages in one direction only. This is illustrated in figure 1. This is of limited interest in an industrial communications system as feedback from the instrument is essential to confirm the action requested has indeed occurred.

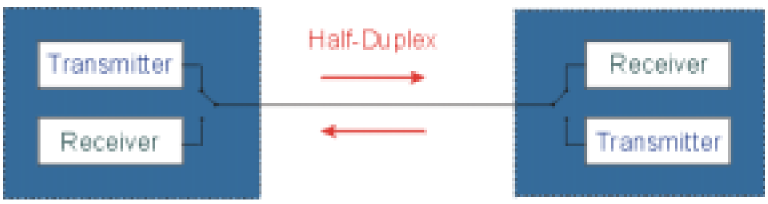

Figure 2 - Half Duplex Communications

Half duplex communications occurs when data flows in both directions; although in only one direction at a time. Half duplex communications (as discussed later) is provided by the RS-485 physical standard (to be discussed later) where only one station can transmit at a time. A protocol (which can be thought of as the pattern of bits and bytes) can be half duplex as well – an example here is Modbus

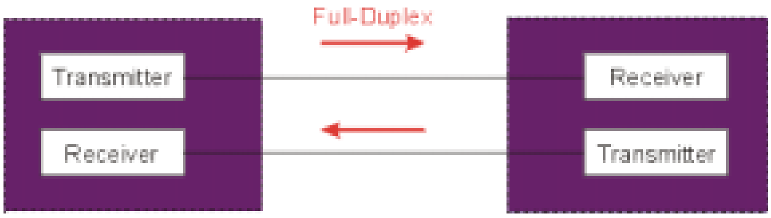

Figure 3 - Full Duplex Communications

In a full duplex system, the data can flow in both directions simultaneously. Examples of hardware standards supporting full duplex are the physical standard EIA-232E (sometimes referred to as RS-232C).

Synchronous versus Asynchronous

There are two approaches possible in transmitting data over a communications link. The asynchronous approach is the more basic one used by EIA-232E which operates at a lower speed. The higher speed Local Area Networks running at 10 Mbit/s operate using the more efficient synchronous communications.
An asychronous system is one in which each character or byte is sent within a frame. The receiver does not start detection until it receives the first bit, known as the start bit. The start bit is in the opposite voltage state to the idle voltage and allows the receiver to synchronise to the bits following.
An asychronous frame may have the following format:

- Start Bit Signals the start of the frame
- Data Usually 7 or 8 bits of data, but can be 5 or 6
- Parity Bit Optional Error detection bit
- Stop bits Usually 1, 1.5 or 2 bits.

Figure 5 - Asynchronous Frame Format

A synchronous system uses a string of bits to synchronise the receiver before the data is detected. Synchronous systems detect bits by a change in voltage rather than by reading an absolute value as with asynchronous systems. A typical synchronous system frame format is shown below in figure 6.

Preamble	SFD	Destination	Source	Length	Data	FCS

- Preamble This comprises one or more bytes that allow the receiving unit to synchronise with the frame
- SFD The start of frame delimiter signals the beginning of the frame
- Destination The address to which the frame is sent
- Source The address from which the frame is sent
- Length Indicates the number of bytes in the data field
- Data The actual message
- FCS The Frame Check Sequence is for error detection

Figure 6 - Typical Synchronous System Frame format.

Data Coding

An agreed standard code allows the receiver to understand the messages sent by a transmitter. The number of bits in the code determines the maximum number of unique characters or symbols that can be represented. The most common character set in the Western World is the American Standard Code for Information Interchange (or ASCII).

The ASCII Table

0	1	2	3	4	5	6	7
000	**001**	**010**	**011**	**100**	**101**	**110**	**111**
(NUL)	(DLE)	Space	0	@	P	`	p
(SOH)	(DC1)	!	1	A	Q	a	q
(STX)	(DC2)		2	B	R	b	r
(ETX)	(DC3)	#	3	C	S	c	s
(EOT)	(DC4)	$	4	D	T	d	t
(ENQ)	(NAK)	%	5	E	U	e	u
(ACK)	(SYN)	&	6	F	V	f	v
(BEL)	(ETB)		7	G	Q	g	w
(BS)	(CAN)	(	8	H	X	h	x
(HT)	(EM)	)	9	I	Y	i	y
(LF)	(SUB)	*	:	J	Z	j	z
(VT)	(ESC)	+	;	K	[	k	{
(FF)	(FS)	,	<	L	\	l	|
(CR)	(GS)	-	=	M	]	m	}
(SO)	(RS)	.	>	N	^	n	~
(SI)	(US)	/	?	O	_	o	DEL

Table 1 -ASCII Code Table

For example in the table, ‘D’ = ASCII code in binary 1000100

Open Systems Model

In digital data communications, wiring together of two or more devices is one of the first steps in establishing a network. As well as this hardware requirement, software must also be addressed. The OSI reference Model consists of the following seven layers:

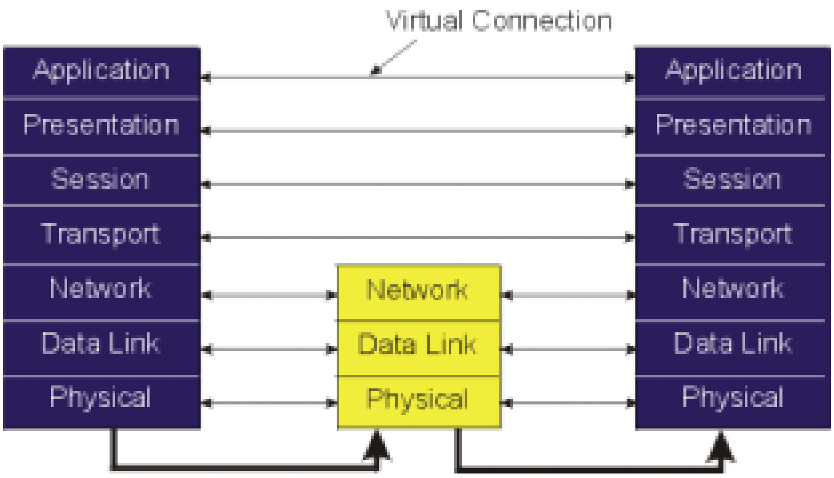

Figure 7 - The Layers of the OSI Model

- Layer 1 Physical Layer Electrical and mechanical definition of the system
- Layer 2 Data Link Layer Framing and Error correction format of the data
- Layer 3 Network Layer Optimum routing of messages from one network to another
- Layer 4 Transport Layer Channel for transfer of messages of one application process to another
- Layer 5 Session Layer Organisation and synchronisation of the data exchange
- Layer 6 Presentation Layer Data format or representation
- Layer 7 Application Layer File Transfer, message exchange

The OSI Model can be visualised as a collection of entities, such as software programs situated at each of the seven layers. It provides an overall framework for the vendor in which to package their communications solutions comprising the hardware communications links and the protocols.
In the world of instrumentation, this OSI model is often simplified to use only three layers:

- Layer 1 Physical Layer
- Layer 2 Data Link Layer
- Layer 3 Application Layer

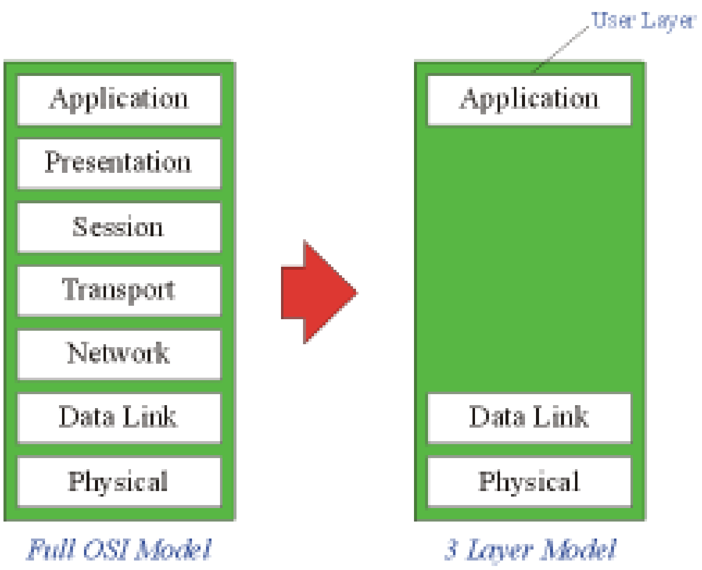

Figure 8 - OSI and Simplified OSI Models

This simplifies the operation of the overall system significantly. You will notice that there is another layer mentioned in the three layer model above entitled User layer. This is not part of the OSI model but is a critical part of the overall system and will be discussed later under Fieldbus systems.

Examples of how these layers are applied:

- RS-232 and RS-485 are examples of the Physical Layer
- The Modbus Protocol is an example of the Data Link Layer
- Ethernet comprises the Physical and Data Link Layers
- The HART smart instrumentation protocol comprises the Physical, Data Link and Application Layers
- Profibus and Foundation Fieldbus comprise the Physical, Data Link and Application Layers.

Now click here to go to the short quiz based on this tutorial.