ELECTRICAL CONNECTIONS TO ELECTRONIC APPARATUS

PREFACE

This monograph provides an insight into making successful electrical connections to and between electronic apparatus. It indicates how to avoid known problems and provides a background to connecting standards. Workers in research and development laboratories, test rooms and students engaged with experiments will find it of help.

Correct connections between electronic apparatus is an essential part of obtaining reliable measurement and control results and this publication demonstrates how to achieve this when dealing with the different types of signal in common use, these include: low level, low frequency, radio frequency, analogue and digital. There are also sections on handling extra high voltages and power connections. The final section provides pin-out designations for the most commonly used interfacing cables. Any one needing to make electrical connections will find this information useful; in particular it will b e of help to technicians, students and postgraduates working in laboratory conditions.

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CONTENTS

Cables

Avoid thinking of a cable as a wire used to conduct electricity. Wire is extruded metal whereas a cable used for transmitting electrical energy may include several metal conductors insulated from each other and arranged in a particular form with overall mechanical protection. In the case of a fibre optic cable the mechanism for transmitting information does not require a metal conductor. A particular cable will have been designed for a specific purpose, the dimensions of the conductors and insulation and the type of materials used having been chosen to meet a required specification.

Cables and their associated connectors are used to transport energy and information from one point to another. Information can be conveyed in the guise of changing voltages, currents or light and must be carried out without corrupting the information involved. A simple example would be a change in voltage or current level, called a waveform, which is used to turn something either on or off or to indicate that something has or has not occurred. As such it is a control waveform, it carries no further information and the excursion of its amplitude change may not be very critical. A signal waveform on the other hand is more a complex affair and care is needed to ensure that a true replica of what starts off at the sending end of a cable still exists at the receiving end. This poses the question "what can possibly go wrong with a signal transmitted via, what could be, a short length of insulated copper wire?" The possibilities will be explored.

First a few reminders: An electric current is always accompanied by a magnetic field and an electric field. The latter also exists between two or more points between which voltages exist. Energy can be transmitted from one circuit to another via these fields. The resistance, inductance and capacitance that are inherent in any electrical circuit impede an electric current and their combined effect on current flow is called ***impedance***.

A cable carrying current can be depicted as physically consisting of resistance (R), inductance (L), (which produces a magnetic field), and capacitance(C), (which produces an electric field), distributed along its length, see Fig 1. The magnetic and electric fields generated can couple with other cables as shown in Fig. 2. Components of current from each cable will then be introduced into each other.

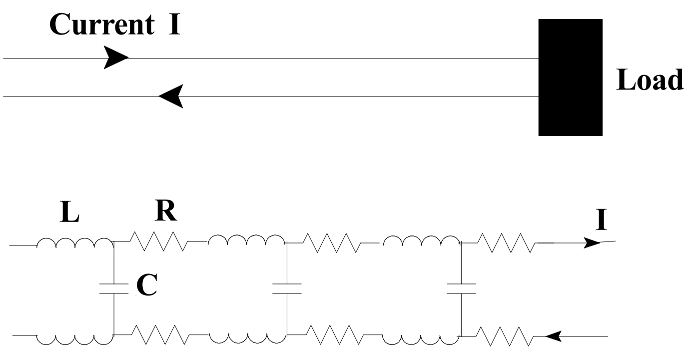

Fig. 1. *Each minute section of a current carrying cable (top), can be depicted as being made up of combinations of series connected inductance (L) and resistance (R) and shunt capacitance (C), bottom.*

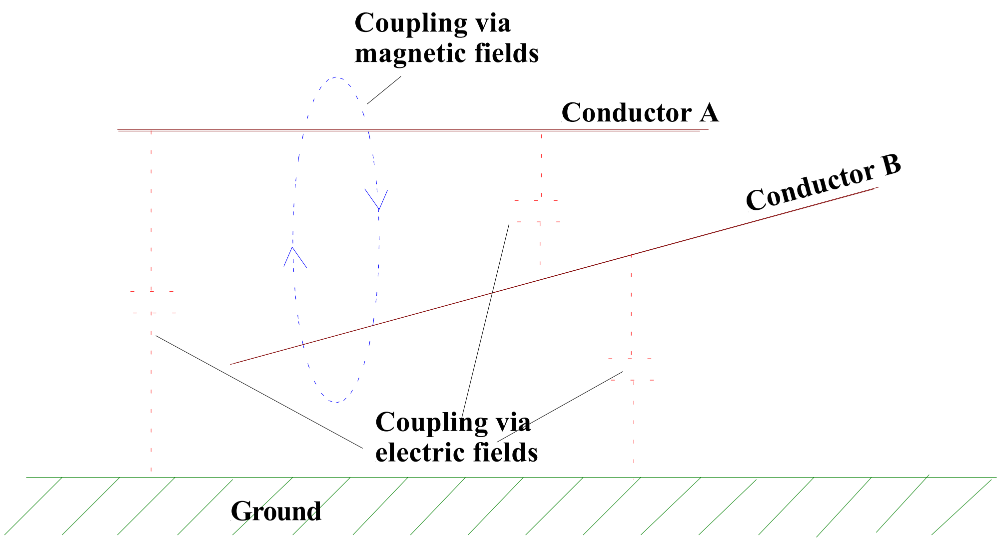

Fig. 2. Examples of capacitive and magnetic coupling between adjacent conductors and ground due to magnetic and electric fields generated by electric currents in A and B.

Such coupling, also referred to as "pick-up", will also take place between each conductor and ground. These mechanisms cannot be prevented but their effects can be reduced to insignificant amounts or avoided altogether by transmitting information in the form of modulated IR light via fibre optic cables.

When connecting two or more pieces of electronic apparatus the corresponding specifications will mention: ***source impedance*** and ***load impedance***. Source refers to where the signal originates and load refers to where it is sent, see Fig. 3, where the output voltage of the signal source (**Vo**) is the generated signal **(Vs)** minus the voltage drop across an impedance **Zs**. Assuming no voltage drop in the cable connecting the signal source and the load then the voltage developed across **Zr** is also **Vo.** For low frequency signals it is usually necessary that the load impedance be much greater than the source impedance. The importance of source and load impedances for high frequency signals is explained later.

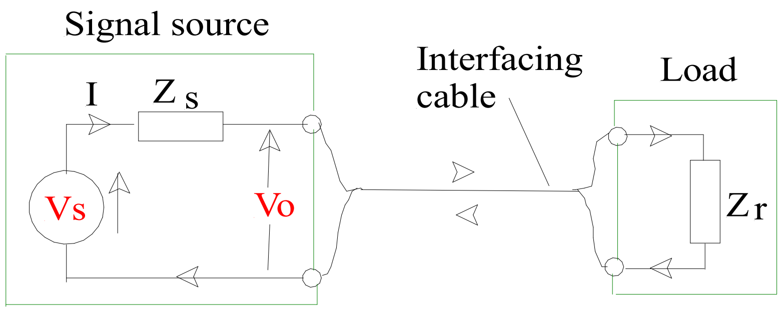

Fig. 3. The source signal current, ***I****, goes via its own impedance* ***Zs*** *to the receiving unit where it develops a voltage across the load impedance* ***Zr****.*

The signal source and the load are interfaced with connectors and cable relevant to the type of signal being transmitted between them. It is now necessary to examine the types of signal current that may flow between a signal source and a load. Three types of electrical signal will be considered:

1. Slowly changing and small, i.e. low frequency low level.
2. Quickly changing, i.e. containing radio (i.e. above audio) frequencies.
3. Digital / binary, as generated by logic circuits.

Each signal type is required to be handled in a particular way.

Low frequency low level considerations

Possible problems here are:

1. "Pickup" from adjacent cables carrying the mains supply.
2. Flexing or vibration of the screened signal lead.
3. Noise generated as a result poor connections.
4. "Loading" of a signal source.

(1). Electromagnetic pickup, called "hum", from cables carrying the mains supply can be a major problem which is aggravated if the signal source has high impedance. Physiological probes, for example, can have a medium to high source impedance, ranging from a few thousand ohms up to several million ohms, therefore the associated connecting leads are more likely to be susceptible to pickup from a nearby mains cable than leads connected to, say, thermocouples which will have a source impedance of only a few ohms. An obvious precaution is to ensure that the apparatus in use and all its associated signal cables are well clear of mains cables, including those distributing the mains supply to the outlet sockets along the working surface. Mains transformers and motors give out strong magnetic fields the effects of which can sometimes be reduced by reorienting the offending object with respect to the work piece. Screened signal cables should be used with each screen connected directly to a single common earth point. The grounded leads of each power supply, the screen for the apparatus and the mains earth (ground) should also be directly connected to the same place, see Fig. 4.

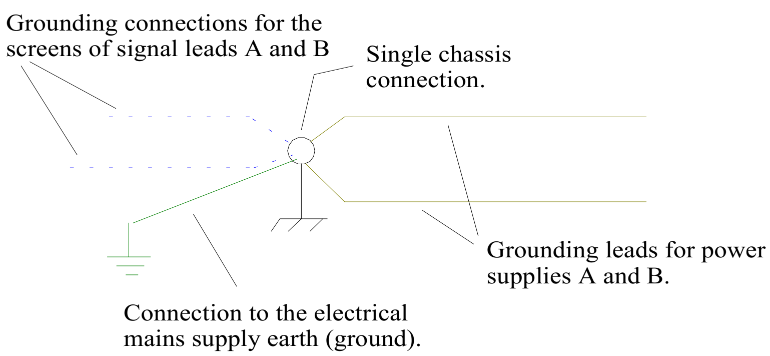

Fig. 4. A common grounding connection reduces mains supply "pickup" that can other wise be induced via ground loops, i.e. currents circulating in the ground plane.

(2). Flexing a screened cable causes movement of the screen with respect to the signal conductor, which in turn causes changes of capacitance between it and the conductor. This results in small changes of charge across the capacitance formed by the screen and conductor that appears as noise on the signal line. Vibration can inadvertently cause continuous flexing of a cable, for example, when a motor is running on the same bench thus creating charges that are superimposed onto the signal. The use of cables with a conducting layer between the screen and conductor insulation usually overcomes this problem. Note that this conducting layer must not come into contact with the body of a connector fitted to the cable.

(3). All resistors generate random thermal noise, the larger the resistance the greater the noise, therefore a contributor of noise will be the resistance of the signal source. Resistance caused by poor connections joining a signal to an amplifier will be seen by that amplifier as being part of the signal source resistance. Some other possible sources of noise are:

(i) *Incorrect crimping of cable conductors to connector pins.*
(ii) Dry solder joints between cable conductors and connector pins.
(iii) Damaged surfaces of connector pins and sockets.
(iv) Loose connections between connector pins and mating sockets.
(v) The use of different materials for the mating parts.

Expanding on these points: (i) & (ii). Knowing how to use the correct tools for the job will avoid such problems.
(iii). A corrosive environment, i.e. chemical agents in the atmosphere, can destroy connecting surfaces. Many connectors have gold flashed connecting parts to reduce the possibility of this problem occurring and a good mated connector will have airtight joints between connecting parts.
(iv). Misuse may damage the mating parts of a connector causing intermittent disconnection, as will wear and tear, although the latter is unlikely to occur with normal use and good connectors.
(v). The Seebeck effect that produces small changes of voltage with temperature between conductors made from different materials may cause problems where the signals are very small. Thermocouples work on this principle therefore it is very important that the connectors and cables used with a thermocouple are designed for use with that type of thermocouple. Note that leads used with thermocouples are polarity sensitive. There are national colour codes in existence for the insulation of the alloy combinations for conductors and for overall sheathing. The American ANSI colour code is widely used and there is an international standard:
EC 584-3. Further information on the colour codes used can be obtained from: *www.omega.co.uk/uk/techref/thcprefl.htm*

(5). When monitoring a signal it is important that the instrument used does not affect that signal. This can occur if the input impedance of the measuring device is comparable to or smaller than the output impedance of the signal source whence both the amplitude and shape of the monitored signal will be affected. An example would be an oscilloscope that has an input resistance of 1 meg-ohm, monitoring a device with an internal resistance of the same order. In this example the monitored signal would appear to be half its actual value. For such circumstances there are extension probes available that increase the input impedance of the monitoring instrument. Two types of such probes are made, passive and active. The former is essentially a resistor capacitor combination that increases the input impedance by 10 or 100 times but also reduces the apparent amplitude of the signal by the same amount. An integral trimmer ensures that signal degradation can be minimised. The latter is an amplifier with very high input impedance that also preserves the signal amplitude. This type requires a source of power. Both types may reduce the range of frequencies that can be measured.

Dealing with radio frequency signals

This section deals with voltages and currents that change quickly. Such waveforms contain frequencies above the audio range and are handled using radio frequency (r.f.) techniques. Note that a single pulse or a waveform with a low repetition rate but with rapidly changing dimensions, see Fig. 5., will contain radio frequencies. Radiation from such sources is difficult to control therefore suitable cables should be used eg single or double-screened types. Twisting “live” and ground conductors also helps to reduce radiation.

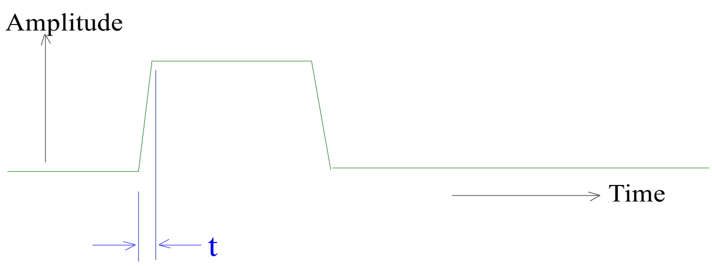

Fig. 5. The fast rise or fall time (t) of a waveform contains radio frequencies.

A previous section pointed out that a cable can be represented as a series of resistors, capacitors and inductors (Fig.1) therefore it is to be expected that a suitable measuring device would give an indication of the values of these components. Since inductive and capacitive reactance varies with frequency such a measurement would give different results at different frequencies. To be of any practical value a cable must measure the same at all frequencies. It can be shown that a uniform cable, that is one that is identical through out its length i.e. has no discontinuities, will, if it is infinitely long, have a particular ***characteristic impedance*** which is purely resistive. The value of this resistance will depend upon the dimensions and material make up of a cable and will be stated in the manufacture's specification for that cable. It follows that if a short length of uniform cable is ***terminated*** with its characteristic impedance then a measuring device will assume that the cable is infinitely long and give a value of resistance as the measurement, see Fig. 6. For this to happen it is necessary to ensure that the terminating resistance used is a pure resistance at all frequencies and does not represent a discontinuity in the cable. It must look, as far as the measuring apparatus is concerned, as an extension of the cable. This is not easy to achieve, especially at very high radio frequencies. Just connecting any resistor of appropriate value across the receiving end of a cable will not meet the requirements. Terminating loads of appropriate characteristic impedance for specific cables are available commercially. Note that such a unit must be of appropriate power rating. Typical values of characteristic impedance, symbol Z_o, for commonly used cables are 50Ω, 75Ω and 100Ω. Because characteristic impedance is resistive it is also referred to as ***characteristic resistance***, symbol R_o.

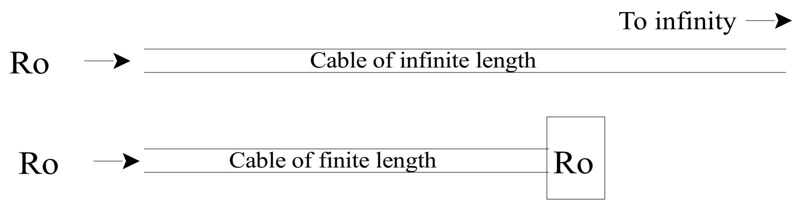

Fig. 6. If a cable of infinite length has a characteristic resistance of Ro then that same cable when of finite length and terminated with a pure resistance of value Ro will have the same characteristic resistance.

When a cable used to carry high frequencies is not properly terminated the energy propagated along that cable will not be fully absorbed at the receiving end resulting in part of that energy being re-transmitted (reflected) back to its source. For this reason it is often necessary for the output resistance of a device to be the same value as the characteristic resistance of the cable used so that if any echoes do occur they will be absorbed when received back at the sending end.

The reader may think of the transmission and reception of an electrical signal as being more or less instantaneous because it travels at the “speed of light”. In reality its rate of progress is substantially reduced within mediums other than a vacuum. Consider a pulse of electrical energy, of peak voltage amplitude V, in the shape of a rectangle, being sent along a cable, (usually called a ***transmission line***), having a characteristic impedance of R_o. The pulse takes a finite time to reach the end of the cable and during its journey it is moving through a virtual resistance of R_o so that during this time its peak current is $V/R_{o.}$ If, when it reaches the end of the cable, there is no terminating resistor, i.e. there is an open-circuit, the current that has been travelling along the cable must disappear because there is nowhere for it to go! This can only be achieved if it is cancelled by an equal and opposite pulse being generated at that point. This pulse will then be propagated back along the cable. Alternatively, suppose that the end of the cable is short-circuited. In this case it is the voltage that becomes zero and an equal and opposite voltage pulse must be generated to meet the circuit conditions at that point. This inverted voltage pulse will is then sent back along the cable. If the sending end of the cable is also not terminated with R_o these reflections will be sent back and forth along the cable until the energy in the pulses is dissipated in the cable impedance. Note that this is not the same as the cable’s characteristic resistance. The amount of reflected energy will vary between the extreme conditions of open and short-circuit becoming a minimum at R_o. Consider a train of pulses being transmitted along an un-terminated line: there will be points along it where a transmitted pulse and a reflected pulse coincide. Depending on the relative polarities of these pulses the resultant pulses at those points will be either enlarged or reduced in size. In such conditions it is possible for a pulse just leaving a transmitter to be enlarged by this means and as a result cause damage to that transmitter. Clearly, such effects are undesirable.

In the preceding paragraph the transmission of a pulse along a line was used as an example. The same arguments apply to a waveform of any shape and to other transmission mediums, e.g. wave-guides. When considering the transmission of sinusoidal waveforms the result of interaction between transmitted and reflected energy is referred to as a ***standing wave***.

Termination of a cable is not necessary if the wavelengths of the frequencies concerned are longer than the lengths of the cables being used. But when radio frequencies, whether sinusoidal or contained within a pulse, are to be sent via a cable between two pieces of equipment the characteristic resistance of the connecting cable and connectors, the source impedance at the sending end of the cable and the terminating resistance at the receiving end of the cable must all be specified to have the same characteristic resistance. Note that connectors having different characteristic resistances may appear the same but closer examination will show that they do have different dimensions. A preferred method of using an oscilloscope to measuring signals at the end of a terminated line is given in Fig. 7.

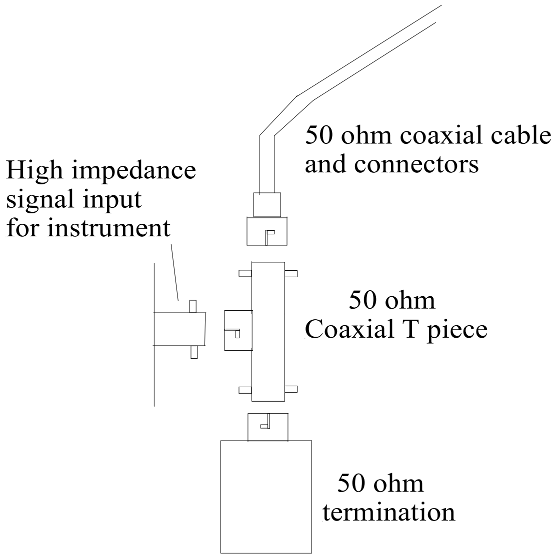

Fig. 7. Measuring high frequency signals via a high input impedance instrument.

Ensure that interfacing printed circuit boards made in house do not have their input/output impedances jeopardised with sloppy layout or long leads and note that conductors on a printed circuit board have a characteristic resistance, usually around 100 ohms. At radio frequencies every millimetre affects circuit performance and is a source of radiation distributing that energy throughout adjacent circuits and, if screening has not been properly carried out, over a substantial distance.

Digital signals

Integrated circuits (ICs) for digital signals are designed to work with rectangular pulses having specified dimensions with minimum and maximum voltage levels that define two logic levels referred to as 0 and 1. Digital circuits will not work reliably or may be damaged if the signal voltages applied to them are outside of the specified limits or become distorted. The faster such pulses change state, (i.e. from a 0 to a 1 or vice versa), the higher the radio frequencies that are contained within it. Thus the methods, outlined in the previous section, for working with such frequencies should also be observed when working with digital signals.

Connecting to computer ports

The processor in a computer communicates with devices connected to it via its "ports". These may be used for internal functions, such as disk drives, or provide a means of sending and receiving data external to the computer such as via its serial or parallel connector points that are provided as with a PC. Additional means for the PC to communicate with external equipment can be satisfied with the use of extra cards, (printed circuits board with components), that plug into slots provided within the computer. The number and type of such slots available varies with PC manufacturer. Operation of commercially bought "plug-ins" is facilitated via software provided with them. It is also possible to write software that will provide or accept a sequence of digital signal from a PCs standard ports.

Interconnecting cables that transmit digital signals to and from computers and standard peripheral equipment are well specified. In some circumstances satisfactory results may be obtained using unspecified cables but this may lead to performance problems that may not be immediately evident. The specifications will limit the length of cable that should be used in given circumstances, exceed this limit and the signals will deteriorate beyond the ability of the associated digital circuits to properly respond to them. Two methods are used to send signals between equipment: serial and parallel transmission. A portion of digital information comprised of, say, 8 units could be sent as a succession of pulses along a single conductor, in which case it is serial transmission, alternatively all 8 units could be sent simultaneously using 8 conductors in which case it is parallel transmission. Conductors carrying such signals are called a **bus**. The choice of transmission method used tends to be a matter of horses for courses at a particular time of technical development. Currently the common interfaces for interconnecting equipment and computers are:

1). RS232 and derivatives.
2). USB (Universal Serial Bus).
3). RS1394 (Fire Wire).
4). Parallel (printer).
5). SCSI.
6). GBIB / IEEE488.
7). LAN's (Ethernet, Token Ring).

There follows some general information about each of the interfaces just listed. Connector pin-out details are given in the Pin-Out section.

The RS232 family

The first personal computers incorporated facilities for connecting the computer to peripheral equipment using specifications that already existed for other uses. The serial port (RS232 or EIA232) was one of these. It was originally designed for the transmission of digital information over voice-frequency telephone lines so that business machines such as main frame computers could communicate with each other over substantial distances and down load information to remote terminals and printers. When digital signals generated within a computer need to be transmitted along voice frequency lines they are transformed into an audio signal which is ***modulated*** to simulate the 0s and 1s of the digital signal. At the receiving end these audio signals are reconstituted into digital form, using a process called ***demodulation***. The apparatus that performs the **mod**ulating and **dem**odulating processes is called a **modem**. For such transmissions to be successful it is necessary to ensure that the modems at the sending and receiving ends of the telephone line are switched on and available to receive information and that the sending and receiving machines are both ready to communicate with each other. In other words it involves both ends of a link to agree to do something before doing it. Where computers are multi-tasking this interrogation can be a continuous affair. Such procedures involve signals going between several sources within the computers and the local modems, thus the reason for using multi-way cable between the two. The fully specified serial port uses a 25 way “D” connector but the advent of the personal computer, where its peripherals, such as modems, printers, etc, are adjacent, enabled the connecting system to be simplified by creating a pseudo RS232 interface via a 9 way “D” connector. This reduced pin-out only allows non-synchronous operation. Modern personal computers usually have an internal modem thus permitting a single ‘phone lead to be used between the computer and a ‘phone socket. PC’s usually have two serial ports, one using a 25 way “D” connector, the other a 9 way. They are referred to as COM1 or serial 1 and COM2 or serial 2, reflecting their original use in **com**munications, but only one device per port can be used at any one time. Electrical and connector pin-outs are specified in RS232; also referred to as EIA232. For more information try: *www.arselect.com/rs232.htm.*

A development of RS232 using differential signals has been introduced as RS449. This uses a 37 way D connector. A reduced facility version of this standard known as RS530 uses a 25 way D connector. RS232 & RS449 communicate between just 2 devices. RS422, RS423 and RS485 were introduced as serial transmission standards that could communicate between several pieces of equipment. RS422 and RS485 provide balanced, i.e. differential, interfaces. In addition, RS485 accommodates multiple ***transceivers***; RS423 is unbalanced. Fig.7 shows the transmission configurations for RS422 and RS485. RS422 provides the electrical specification for RS449. RS422/423/485 do not provide pin-out specifications.

Some Macintosh computers are supplied with a RS422 port but a plug-in card is required to provide this standard with an IBM PC. At component level RS485 parts are interchangeable with RS422 counterparts but RS422 drivers should not be used in a RS485 system because they cannot relinquish control of the bus. RS422, RS423 and RS485 provide only electrical specifications, connector pin-outs designations being referred to RS449 / 530 but some manufacturers use other connector styles.

Some terminologies to be aware of with the serial transmission of data are:
Simplex: Transmission one way only.
Duplex: Simultaneous 2-way transmission on a single line.
Half duplex: 2-way transmission, one-way at a time, on a single line.
Full duplex: 2 separate simplex lines used, one for each direction.
DTE: (Data Terminal Equipment) - Machines that communicate with each other via a telecommunications line, e.g. computers.
DCE: (Data Circuit-terminating Equipment) - The device that sends and receives modulated signals, e.g. a modem.

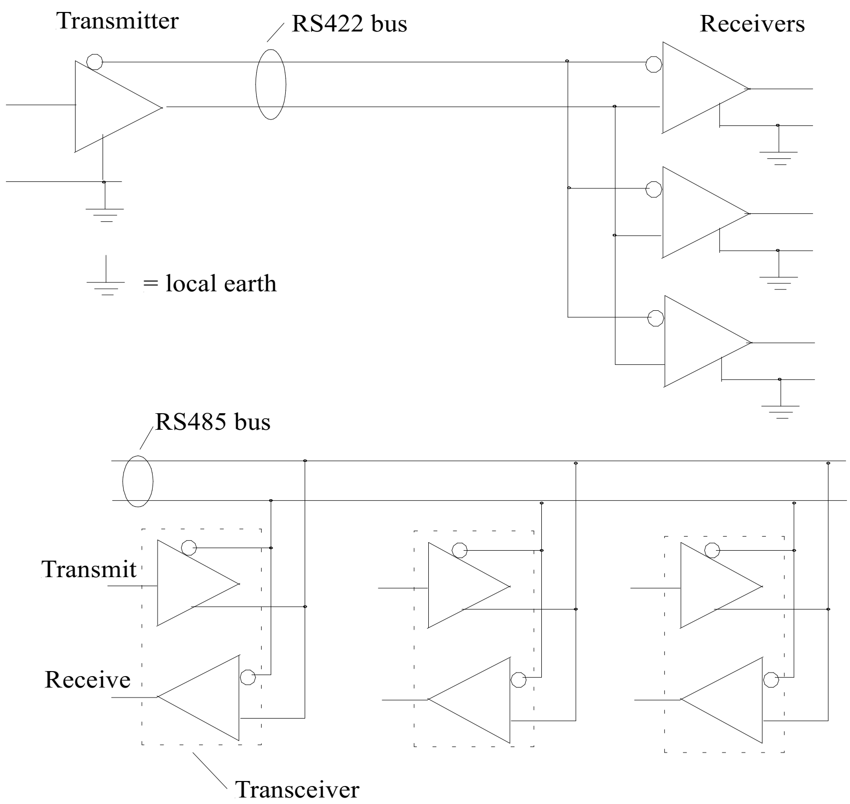

Fig. 8. Top: Circuit configurations for RS422, which provides differential transmission to several receivers. Bottom: RS485 accommodates multiple transmitters and receivers operating in differential mode. Each triangle represents a logic circuit and the apex of the triangle points to the direction of signal flow. The receivers and transceivers are connected to the devices being communicated with.

The Universal Serial Bus (USB)

This is a serial port specifically designed for use with personal computers and their peripherals. USB 1.1 requires Windows 98 or later or an Apple iMac. There is a patch (OSR 2.1) for Windows 95 but it is not operationally reliable. There is no USB support for NT. USB 2.0 can be used with later versions of Windows, e.g. XP and 2000 and is backward compatible with USB 1.1 The bus facilitates the connection of many compatible devices to a single computer by using USB hubs one of which may be built into a PC. The maximum length of cable that can be used between devices is limited (3 or 5m depending on the speed of the device) but this is not a problem where a PC's peripherals are adjacent. A four-core cable is used; two data lines and 2 power supply lines. There are two types of connector, one has 4 in-line pins, (Type A), and plugs into a PC or a hub, the other, (Type B), is square with 2 pairs of pins and plugs into the device being controlled.

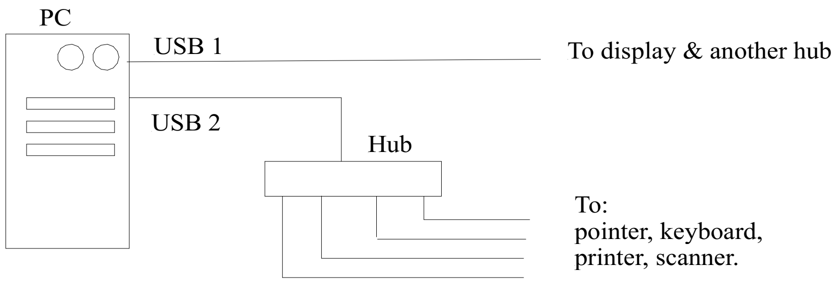

Fig. 9. A PC has at least 2 USB ports that can support many devices via external hubs. Some PC's have a built in hub to provide more than two ports.

A personal computer may have 2 USB plus the traditional serial and parallel ports or if it is "legacy free" there will be only a group of USB and Fire Wire connectors for use with compatible peripherals. If separate hubs (bus-stations) are required it may be advisable to ensure that they are the "active" type, i.e. they have their own power supply to support 500mA per port down stream. Passive types rely on taking power from the USB bus. Also consider the use of hubs with pre-port switching to prevent a failed device crashing an entire chain. The USB system is consistent with PC ***plug & play*** architecture and compatible peripherals should install themselves on boot-up. Further information is at: http://www.usb.org. Additional developments include: USB On The Go, (OTG), designed for portable devices which require smaller connectors, see: www.usb.org/developers/onthego and USB 2.0 incorporated into a LAN (see a later section) via an adaptor.

IEEE-1394 (Fire Wire or i.LINK)

Apple Computers originated this serial bus. It is a high speed, wide bandwidth interface for use between a personal computer and (principally) consumer electronics such as digital cameras, VCR's, camcorders, audio visual peripherals, etc. Unlike USB, Fire Wire was designed specifically for the applications just listed and provides peer to peer interfacing so that, for example, the bus can be used for dubbing from one camcorder to another without the use of a personal computer. The specification allows daisy chaining of up to 16 peripherals without the use of a "hub" and these can be connected to a live bus. It also specifies asynchronous and isochronous data transmission. The latter is important for video use and guarantees data transfer at a predetermined rate. The cable used provides:

power, ground and two twisted pairs for data and control signals. The power lines can supply up to 1.5A at voltages between 8V and 40V. Further information at: *www.1394.org/*

The PC Parallel Port

Also known as the printer port and sometimes labelled LPT, (Line Printer Terminal). It is based on a specification originated by Centronics and was already in existence before the advent of the PC. Originally it was a one-way port but since 1994 it has been re-defined as IEEE1284. This is backward compatible with the Centronics specification but provides a bi-directional standard signalling method for peripherals interfacing with personal computers via a parallel interface. IEEE1284 also provides a choice of operating modes for which the connector pin assignments vary, see the Pin-Out section. It also recommends the use of a MDR-36 pin connector for new equipment. Although performing what may be considered a mundane task this port requires the use of a good quality cable. Twisted pairs with separate grounds are used plus overall shielding with foil wrapping. The specification also calls for a maximum cable length of 3m. On personal computers the printer port uses a 25 way D connector, the printer has a 36-way Delta (Centronics) connector. An additional printer can be supported via a parallel port card that plugs into a spare slot within the PC. ISA and PCI versions are available. Current PCs and printers are usually provided with parallel and USB connections and if it is required to use 2 printers with a PC that has a Parallel port and USB ports it may be found less troublesome to use one printer connected to the parallel port and the other to a USB port.

SCSI, (Small Computer Systems Interface)

Developed to overcome the limitations of the ISA bus used in early PC's it provides a standard means for computers to exchange data at high speed over a parallel bus between daisy-chained devices such as disk drives, disk arrays, printers, scanners, etc. Daisy chaining is facilitated by each SCSI device having input and output bus connectors. The bus is widely used for network servers and Unix workstations but its application is limited for use with a single personal computer. A standard IBM compatible PC will require a SCSI host adapter card to make use of SCSI compatible devices. A very large hard disc and / or multiple peripherals may justify its use with a PC. Apple McIntosh computers provide a SCSI port but the standard 25 way D connector used means making a compromise on grounding arrangements and therefore is not recommended for high speed data transfer. Several versions of the SCSI bus with improving performance have been developed; see Table 1.

Table 1

Type/Name	Bit width bits	Transfer rate Mb/s
SCSI-1 or Standard SCSI	8	5
SCSI-2 or Fast SCSI	8	10
Fast Wide SCSI-2	16	20
SCSI-3 or Ultra SCSI	8	20
SCSI-3 Fast 20 or Wide Ultra SCSI	16	40
Ultra 2 SCSI	8	40
Wide Ultra 2 or U2W	16	80
Serial SCSI (being developed – 2001).		

With plug and play arrangements, (SCSI-3 and later), a SCSI sub-system should install itself at boot-up. Older systems require an ID, i.e. a distinct address, to be manually assigned to the host adapter and to each peripheral via selector switches that are a part of those devices. An 8-bit version of SCSI supports up to 8 devices with addresses identified with Ids between 0 and 7. The host adapter requires one of those Ids. Similarly a 16-bit SCSI bus supports 16 addresses. In a SCSI system, devices that request I/O processes are called initiators and those that perform operations requested by the initiators are called targets. In a simple arrangement the host adapter card controls itself and up to 7 or 15 other targets but only requires a single IRQ line. Each target has its own controller and is capable of addressing additional SCSI devices. Because the SCSI bus is designed to exchange information between SCSI devices without using up computer cycles it is capable of working faster than the computer bus. The integrity of the high frequency signals is maintained by properly terminating the bus lines. Plug-in terminators are available for this purpose. SCSI devices for use inside a computer may have a bank of terminating resistors that can be left or removed depending on the position of the device on the SCSI bus. See Fig. 10 for possible arrangements. The type of connector used depends upon the version of SCSI being supported; see the Connector Pin-Out section. Further information from: www.scsita.org/ .

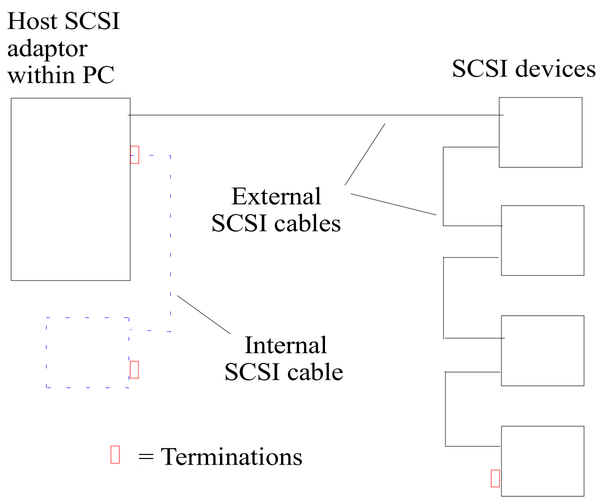

Fig. 10. Each end of a chain of SCSI devices must be terminated. When there are also SCSI devices within the PC (shown dotted) an internal termination is also applied to the last of them. If there are no internal devices the termination is applied to the host adapter. Note: It is not recommended to mix 8 and 16 bit devices in a chain.

Measurement and Control via a PC

With some programming and electronic circuit knowledge plus an understanding of the operating system of a personal computer, digital inputs and outputs can be provided via the standard ports previously described. A basic example would be an output from the serial or parallel port that would switch an integrated logic device that controlled an indicator or relay. Alternatively, commercially available plug-in extension boards to which external operations can be connected may be used. Appropriate software is provided with these boards which range in complexity from basic digital input/output (I/O) services to multi function devices with analogue to digital (ADC) and/or digital to analogue (DAC) facilities. These boards have multi-way connectors that are available at the back of a PC. The advice already given for handling different types of signal applies to the cables and connections made to such boards. Ensure that a chosen board is compatible with the computer bus and that the power supply of the computer can supply the current the board requires.

The control of instrumentation by a computer can be done with the ***General Purpose Interface Bus*** (GPIB, IEEE-488 or IEC-625). This was originated by

Hewlett Packard and provides a means of automating measurement and control processes using standard instrumentation furnished with a GPIB interface. Software supplied with the PC controller card manages the functions of each instrument. The latter are daisy chained and given unique addresses; these may have to be chosen manually. The connectors used can be stacked; the interconnection arrangements making use of this design are shown in Fig 11.
Also see: http://standards.ieee.org/ . Go to IEEE Standards Online then to Search.

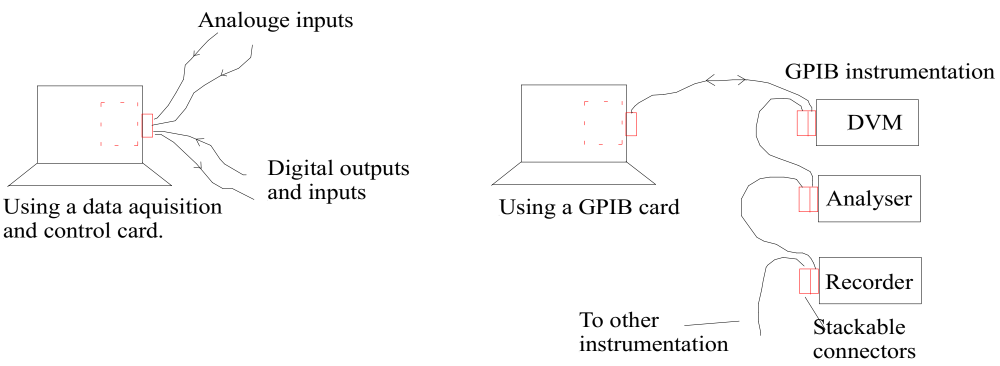

Fig. 11. Two ways of making measurements and controlling apparatus via a PC.

Local Area Networks - (LAN's)

Resource and information handling between file servers, PC's and peripherals necessitates high speed direct connections between them throughout a building or campus. This is done using local and wide area networks – LAN's and WAN's which are usually implemented using either Ethernet or Token Ring systems. There are different flavours for each of these systems and software implementation for them is different. In essence, a PC with an appropriate interface card can be connected to a LAN or WAN whence it can then pick-up data that is flowing along that network and send data to specific targets via it. The two most popular LANs, Ethernet and Token Ring, are now considered.

Notes on Ethernet: Acquaintance with the following terms will be useful when doing further reading on the subject.

AUI: Attachment Unit Interface. This consists of a multi-way cable and connectors for signals and power to an MAU.
DTE: Data Terminal Equipment. This organises signalling arrangements. Also see section on RS232.
FO: Fibre optic.
MAC: Medium Access Control; a 48 bit hardware address.
MAU: Medium Attachment Unit. This is essentially a transceiver, ie it transmits and receives signals
MDI: Medium Dependent Interface.
OUI: Organizationally Unique Identifiers.

See Fig.12 for further explanation.

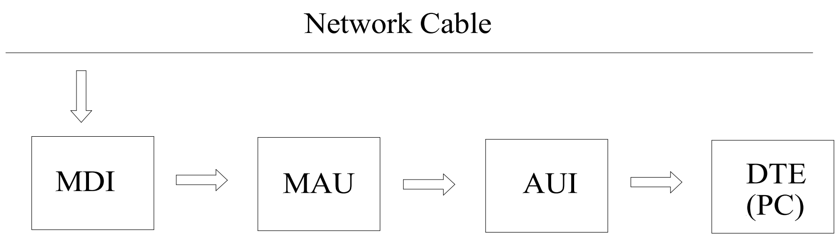

Fig. 12. Relationship of components mentioned in the text. If the MAU is integrated within the PC the AUI is not visible as a separate item.

Ethernet is available in several styles that can be mixed:

Thick Coax or 10 base 5 (“Base” indicates base-band).
Thin Coax or 10 base 2
Twisted Pair or 10 base–T (T indicates twisted pair)
Fibre Optic or 10 base–F. (F indicates fibre optic)

Thick Ethernet uses a transceiver that taps the coaxial cable by piercing it. This operation is carried out without disturbing the operation of the LAN. A multi-way cable and connectors, called an AUI, is used to connect the transceiver and PC. Thin Coax Ethernet uses a smaller cable connecting directly to each PC via a “T” piece. With this configuration a LAN section may be interrupted when an additional PC is inserted into that section. Repeaters (Hubs) can be inserted in this chain to provide branch lines. Fig.13 shows basic connecting arrangements for Ethernet Thick and Thin Coax configurations.

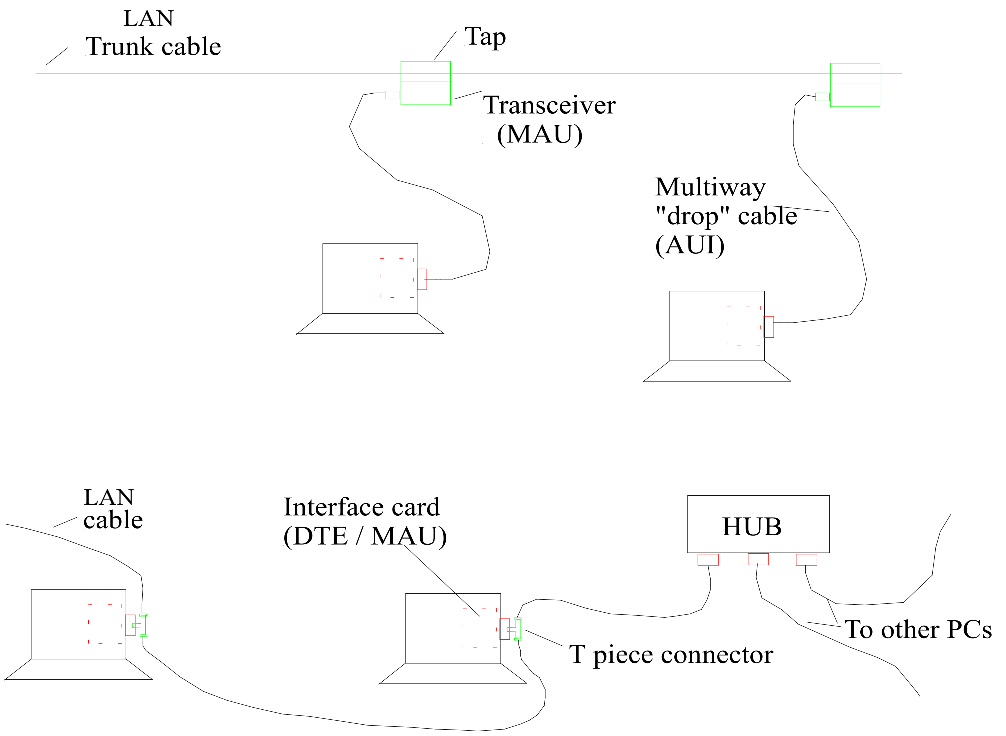

Fig. 13. Making connection to Thick Coax Ethernet, (top), and Thin Coax Ethernet, (bottom).

Twisted pair and fibre optic systems also use hubs (multi-port repeaters), which are connected to the main trunk cable to enlarge a LAN. The fibre optic implementation requires an extra component to convert between optic and electrical signals. Generalised configurations are shown in Fig. 14. A “Telco” 50-way connector used in the telephone industry sometimes replaces the RJ 45 style connector. Note that the standard telephone jack cable must not be used in place of the specified twisted pairs cable.
Also see: www.ots.utexas.edu/ethernet.
news:comp.dcom.lans.ethernet .

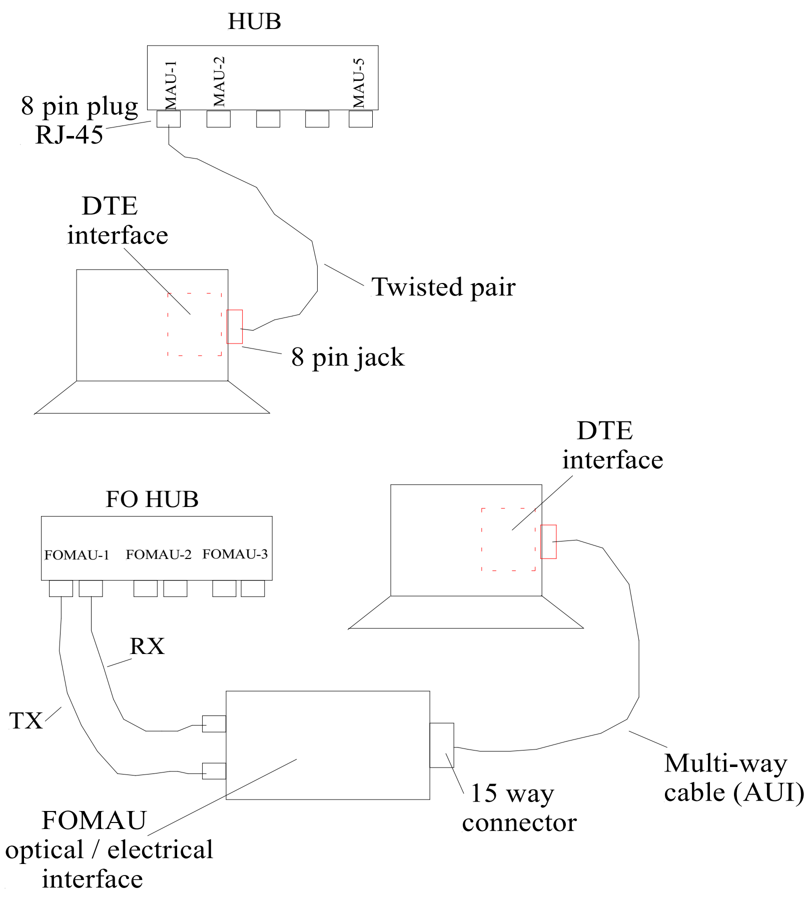

Fig. 14. Top: This HUB provides connections to a LAN for 5 PCs via twisted pair cables. Bottom: The fibre optic implementation requires transmit (TX) and receive (RX) cables; the HUB shown provides connection to a LAN for 3 PCs.

Notes on Token Ring

Physical implementation of the LAN is likely to be in the form of a star-wired ring using screened twisted-pair cable to connect to individual computers known as *stations* which include the necessary hardware and software to carry out the function of a DTE. Groups of stations are connected to the LAN via a Multi-station Access Unit, (MAU or MSAU) sometimes known as a *concentrator*. 4-way *Lobe Cables* connect stations to MAU's and *Ring In/Ring Out, (Patch), cables* connect individual MAU's so that the combination form a ring. These arrangements are depicted in Fig. 15. Interfaces with the LAN cable arrange for a station to be by-passed should it not be switched on. Self-shorting connectors are used so that manually disconnecting a lead automatically shorts the terminals to which the station was connected thus maintaining continuity around the ring. Local expansion of the ring can be made with a *Controlled Access Unit,* (CAU). This is an intelligent MAU, and supports 4 *Lobe Attachment Units,* (LAU's), each of which can in turn support up to 20 stations.

It is usual to use *Shielded Twisted Pair* (STP), *Unshielded Twisted Pair* (UTP) or optic fibre cabling. IBM may use their *Universal Data Connectors,* (UDC's), which attach to each other without the necessity of male or female designations. DB-9, RJ45 and RJ-11 connectors are also used

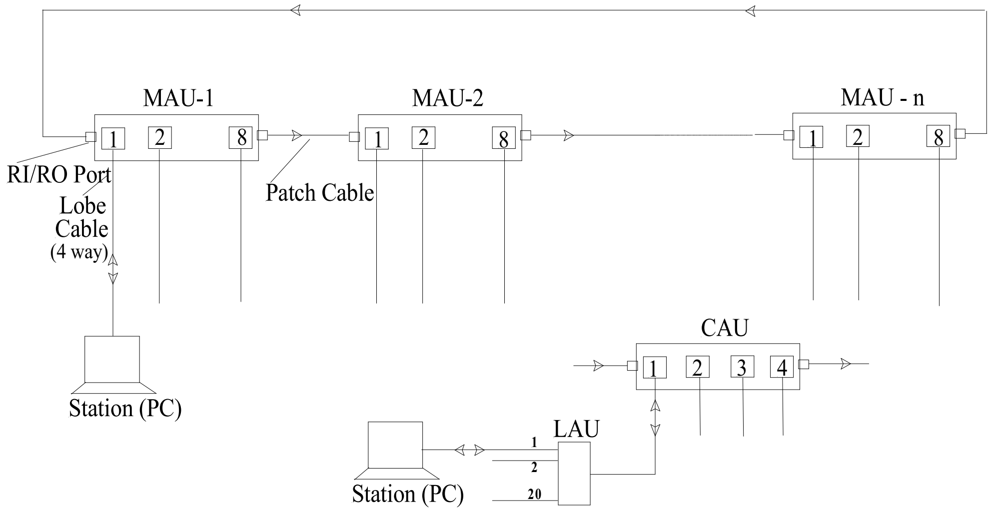

Fig. 15. Tokens of digital information circulate around the ring sequentially calling at each station. An MAU services up to 8 local stations and a CAU / LAU combination up to 4 x 20 stations.

Also see: http://standards.ieee.org/catalog/IEEE802.3.html
news:comp.dcom.lans.tokenring

Power connections

(i) The a.c. electrical mains supply.
(ii) d.c. power supply connections.

(i) Flexible mains cables, or cords, are used to connect electrical equipment to the electricity mains supply at a nearby socket outlet. These cords are usually taken for granted but giving them a little thought may prevent problems occurring. By international agreement the colour code used for the insulation of the conductors is: brown for live, blue for neutral and green with a yellow stripe for ground, also referred to as earth. A "live" conductor will have a high voltage existing between itself and neutral. The neutral conductor is usually (but not always) connected to ground at some remote point therefore a high voltage also exists between live and ground. Because a voltage drop will exist along the neutral conductor to the remote grounding point, a relatively small voltage will exist between it and the local ground. This may only be a few tens of volts but if the neutral conductor comes into contact with a local grounding conductor a potentially excessive current, (a proportion of that from all loads connected to that supply line which would otherwise flow along the neutral conductor), will flow through that connection to the local ground. Dangerous situations will also exist if the live and neutral conductors are interchanged; for example: If the controlling switch is single pole, i.e. only switches one conductor, the equipment may cease to work when switched off but electricity will still be present in the lead and apparatus. Worse still, if the earth and live conductors are interchanged the metal parts of the equipment case may become live.

When selecting a flexible mains cord consider its current carrying capacity, length and environmental conditions in which it is used. The first two conditions are related to the conductor's electrical resistance and therefore its cross sectional area. The latter must be large enough to prevent over heating, which could damage the insulation or be a fire hazard, and also prevent an excessive voltage drop along its length. If the cable is working in, or is connected to, equipment having a higher than normal ambient temperature, use heat resisting cable. A cable's given rating assumes free airflow around it. Also give attention to the possibility of chemical or mechanical damage occurring to a cable and the connector attached to it. A corrosive atmosphere, (e.g. fine spray from an orange), may corrode connector electrodes thus isolating an essential earth connection and /or increasing the electrical resistance of the live and neutral electrodes. The latter will lead to over heating of the plug and socket.

The fuse or over-load trip controlling the mains supply to a piece of equipment should be chosen to protect the smallest size of cable used. Protection of the equipment is a matter for the designers of that equipment. A fuse, no matter how small, cannot protect against an electric shock. A current as small as 30mA through a human body can have severe effects. The use of a ***residual current device*** (RCD) that disconnects the mains supply if there is a hazardous electrical leakage to ground provides protection for some circumstances. Note that it cannot provide protection for leakage between live and neutral. In laboratory situations ensure that a high electrical resistance exists between yourself and any high voltages.

(ii) A d.c. supply may be "raw", i.e. unregulated, therefore its output varies with the mains supply from which it draws its energy, and un-stabilised, which means that its output varies with the amount of current it supplies to a load. Regulated and stabilised d.c. power supplies may be linear or switching types. Either can be designed to provide constant voltage, constant current or constant power. The switching types are more compact but are prone to r.f. radiation. This may cause problems therefore it is wise to keep all signal leads well clear of such supplies and any cables connected to them. A constant voltage power supply only keeps the voltage constant at its output terminals, it cannot compensate for a voltage drop along external cables connected to those terminals. It can be arranged for the voltage across a load at the end of long leads to be kept constant if the stabiliser senses the voltage across the load via sensing leads, see Fig. 16.

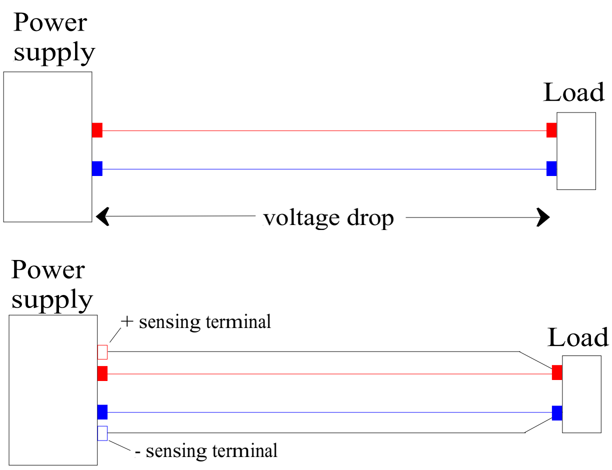

Fig. 16. Sensing leads used to maintain voltage constant at load terminals.

Not all power supplies are designed with sensing terminals available externally but where they do exist and are not in use they must be connected to the respective output terminal, e.g. + SENSE to + OUTPUT.

Constant voltage power supplies should not be connected in parallel to provide extra current unless designed to operate that way. Small differences in their output voltages combined with the low output resistance of such units can result in damaging circulating currents.

In general, power units are supplied with “floating” voltages. This means that neither terminal, positive or negative, is directly connected to ground. There will, however, be a high resistance and capacitance between each terminal and ground therefore where high voltage power supplies are concerned it is possible to receive an electric shock when simultaneously touching one of the terminals and ground. Why this should be so is demonstrated in Fig. 17.

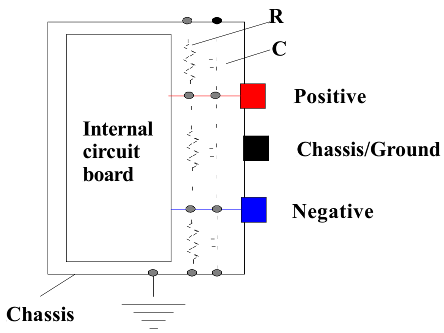

Fig. 17. Stray resistance (R) and capacitance(C) between terminals and the earthed chassis result in an indeterminate voltage existing between any terminal and ground.

It is conventional to refer the measurement of voltages with respect to ground therefore if the negative terminal of a floating power supply is connected to ground the voltage measured at the positive terminal will be positive with respect to ground. It could be said to be so many volts above ground. If, on the other hand, the positive terminal is grounded then the voltage at the negative terminal will be negative with respect to ground or so many volts below ground. Such terminology cannot be used if the terminals of the power supply remain floating because then there is no ground reference. For such cases voltages can be referred to one of the outputs which is then referred to as the ***common*** line. Floating power units can be connected in series as shown in Fig. 18. There are caveats to such arrangements, for example: maximum-working voltages with respect to chassis and comparable maximum circulating currents must be considered. Also, because individual units stabilise at different rates it is advisable to use voltage limiters such as zener diodes across their output terminals. This will protect circuits connected to them from any transient over voltage that may occur at switch on. This precaution is also shown in Fig. 18.

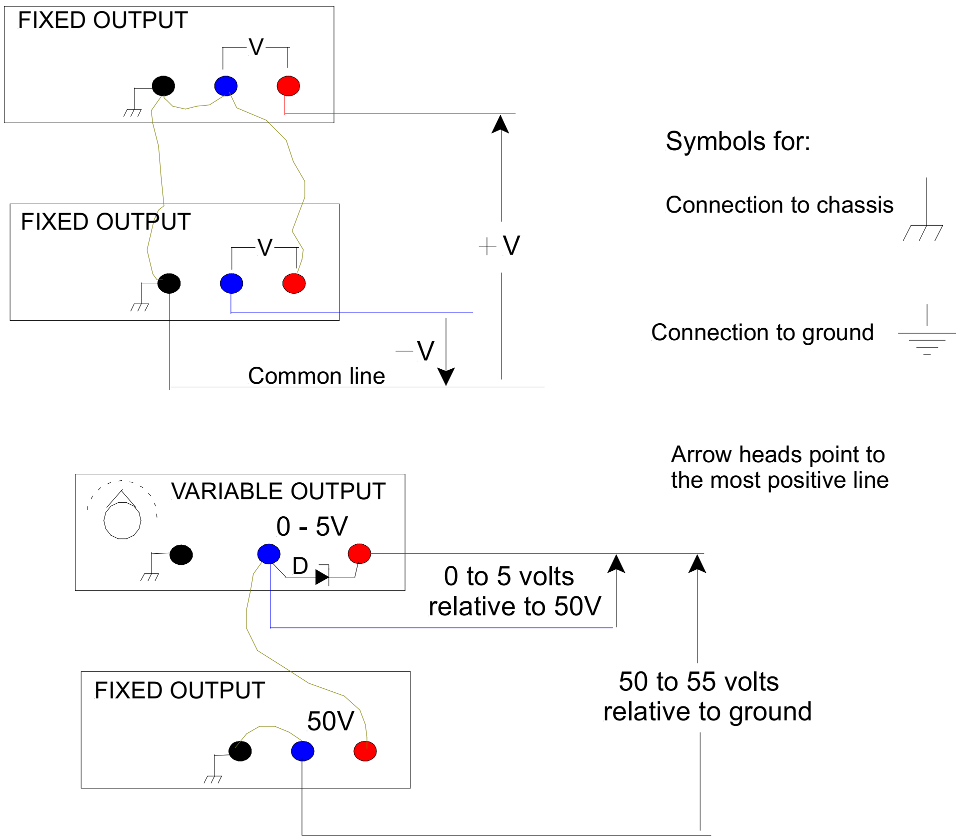

Fig. 18. There are different symbols for connection to ground/earth and to chassis but a chassis may be connected to ground via the main electricity supply. Top: Connecting arrangements for two similar supplies to produce ± V relative to the common line. Bottom: Here it is assumed that each chassis is grounded. The variable output supply "sits on top of" the 50V fixed supply. The zener diode D, rated at 5.6V, prevents surges from the 50V supply that may damage components connected between the 0 - 5V terminals.

High voltage connections

An electronic component will have a maximum voltage rating that must not be exceeded even if its power rating is within specification. For example: connecting 1000 volts across a 1 watt 1 meg-ohm resistor may meet the power rating for that component but if its voltage rating is 350 volts then it will break down and a consequence may include damage to other components. Note that voltage ratings refer to peak values and the peak value of the mains voltage supply is over 1.4 times its r.m.s. value.

Electric current passing through part of the body will cause an electric shock and just 30mA, (0.03 parts of 1 amp), could be fatal. The voltage supplying the current must be high enough for that amount of current to flow. Depending on circumstances the body resistance between one hand and the other may be several hundred thousand ohms or 10 times lower than this. An electric shock can be obtained from unexpected sources such as a charged capacitor, an earthed frame as depicted in Fig. 19 or via a contaminated insulator over which a high voltage can “track”.

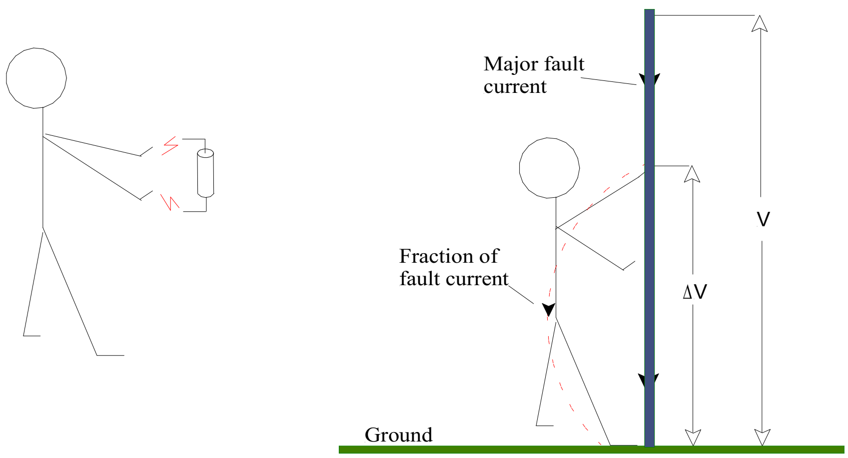

Fig. 19. Left: Beware of capacitors charged to high voltages. Right: A high current flowing along an earthed frame may have a substantial voltage drop along its length making alternative grounding routes dangerous.

Connector pin-out designations

Leads for standard specifications are available commercially but requirements to monitor specific signals, use them for other purposes or trouble shoot, necessitates knowing on which connector pin the signal is available. This section gives some standard pin-out arrangements for those purposes. Leads made in-house must use the cable specified for the application. Efforts have been made to ensure that the pin-out data given is correct but the author is not responsible if this information leads to any damage.

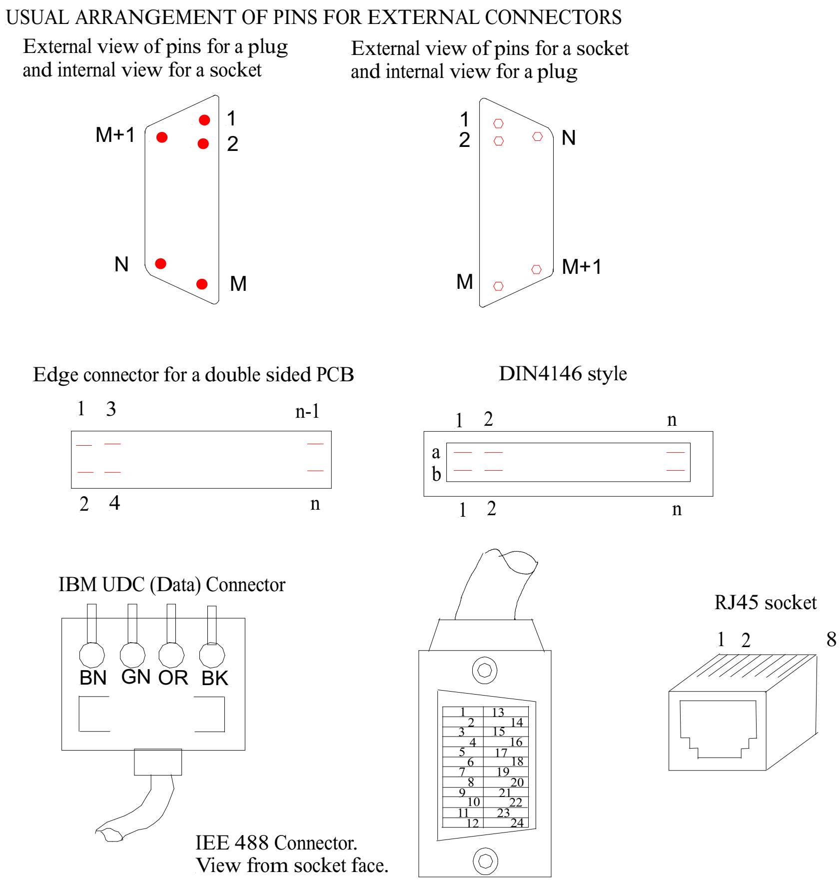

Fig 20: Some general connector arrangements showing pin positions for connectors mentioned in the text. The Centronics style connector uses plates instead of pins. The IBM data connector is hermaphroditic, i.e. neither male nor female. The "D" range of connectors may be designated as being either D or DB and the RJ45 plug is of similar form to a telephone jack.

TOKEN RING:

UDC (IBM) CONNECTOR

Red	Receive +
Green	Receive –
Orange	Transmit +
Black	Receive –

DB-9 (9 way D) CONNECTOR

Pin 1	Red	Receive +
Pin 5	Black	Transmit –
Pin 6	Green	Receive –
Pin 9	Orange	Transmit +

RJ-45 (8 wire twisted pair cable)

Pin 3	Blue/White	Transmit –
Pin 4	White/Orange	Receive +
Pin 5	Orange/White	Receive –
Pin 6	White/Blue	Transmit +

RJ-11 CONNECTOR

Pin 2	Blue/White	Transmit –
Pin 3	White/Orange	Receive +
Pin 4	Orange/White	Receive –
Pin 5	White/Blue	Transmit +

The first listed colour is the background and the second given colour the stripe.

ETHERNET:

DB-15 AUI CONNECTOR (drop cable for 10 base 5)

Pin 1	Drain Wire	Pin 9	Collision –
Pin 2	Collision +	Pin 10	Transmit –
Pin 3	Transmit +	Pin 11	Logic Ref.
Pin 4	Logic Ref.	Pin 12	Receive –
Pin 5	Receive +	Pin 13	Power +
Pin 6	Power (0V)	Pin 14	Logic Ref.
Pin 7	NC	Pin 15	NC
Pin 8	Logic Ref.		

The Drain Wire and Logic Ref conductors are connected together. The 0V Power is separate.

RJ-45 STYLE CONNECTOR FOR 10BASET

Pin 1	Transmit + (TD+)	Pin 3	Receive + (RD+)
Pin 2	Transmit – (TD-)	Pin 6	Receive – (RD–)

UNIVERSAL SERIAL BUS

TYPES A and B CONNECTOR

Pin 1	Vcc	Red
Pin 2	– data	White
Pin 3	+ data	Green
Pin 4	Ground	Black

FIRE-WIRE (IEEE1394)

Pin 1	Power	(24V off-load)
Pin 2	Ground	(Power & inner shield)
Pin 3	TPB–	
Pin 4	TPB+	
Pin 5	TPA–	
Pin 6	TPA+	

±TPA and ±TPB are twisted-pairs for the differential signals.

THE IEEE-488 CONNECTOR

Pins 1– 4	Data D1 – D2	Pin 10	Service Request
Pin 5	End or Identify	Pin 11	Attention
Pin 6	Data Valid	Pin 12	Shield Ground
Pin 5	Not Ready for Data	Pins 13 – 16	Data D5 – D8
Pin 8	No Data Accepted	Pin 17	Remote enable
Pin 9	Interface Clear	Pins 18 – 24	Grounds

Also see: www.8025.org/ www.1394ta.org/ www.usb.org/ www.ots.utexas.edu/ethernet

PARALLEL PORT

Originally called the Centronics parallel printer port later the IEEE 1284 parallel port which is backward compatible with the Centronics specification and now provides a general purpose bi-directional parallel peripheral interface capable of operating in several modes. These are: SPP - Standard Port: the original Centronics specification. Communication is essentially one way, from computer to printer. EPP - Enhanced Parallel Port: Bi-directional operation primarily used by non-printer peripherals. ECP - Extended Capability Port: Bi-directional operation used by some printers & scanners. In addition, two reverse direction only methods of communication, i.e. from peripheral to computer, are specified: Nibble Mode which uses the status lines to send 4 bits at a time and Byte Mode which uses the data lines to send 8 bits at a time. SPP, Nibble and Byte modes are implemented via software. EPP and ECP modes use hardware to assist data transfer. Use of these modes relies on both the operating system and the peripheral supporting the IEEE1284 standard.

The Standard Parallel Port (SPP). Each data & control line forms a twisted pair with its own ground line situated on opposite facing pins of the connector. The active state of a control line is shown in parentheses: (L) = Low, (H) = High. When not give n, the state either varies or is determined by the manufacturer. The printer has a Centronics connector and the PC a D connector.

36 WAY CENTRONICS CONNECTOR:

Pins 17, 18, 34 & 35 have no connections.

Pin	Designation	Source
1	Data Strobe (L)	PC
2 – 9	Data D1 – D8	PC
10	Acknowledge (L)	Printer
11	Busy (H)	Printer
12	Paper Out (H)	Printer
13	Printer Selected (H)	Printer
14	Line Feed (L) [Supply Ground]*	PC
15	Error (L) [Oscillator Transmit]*	Prin ter
16	Ground	
19 - 30	Data/Control line Grounds	
31	Reset / Input Prime (L)	PC
32	Fault/Paper Out / Deselect (L)	Printer
33	Ground	
36	Select Input (L) [no connection]*	PC

25 WAY "D" CONNECTOR:

Pin	Designation	Source
1	Data Strobe (L)	PC
2 - 9	Data D1 – D8	PC
10	Acknowledge (L)	Printer
11	Busy (H)	Printer
12	Paper Out (H)	Printer
13	Printer Selected (H)	Printer
14	Line Feed (L)	PC
15	Error / Deselect (L)	Printer
16	Initialise printer (L)	PC
17	Select Input (L)	PC
18 - 25	Grounds	

Pre IBM PC/XT: Error (pin 15) and Fault (pin 32) perform the same function so either or both may be used by a printer manufacture. Busy (pin 11) may be used for non-ready conditions.

Pin-outs for the Enhanced Parallel Ports and the Extended Capability Ports:

IEEE 1284-A PIN-OUT FOR THE 25 WAY D CONNECTORS.

Pin	ECP Mode	EPP Mode	Source
1	Host Clk.	-Write (L)	Host
2 – 9	Data 1 - 8	AD 1 - 8	Either
10	Periph. Clk.	Interupt (H)	Peripheral
11	Periph. Ack.	- Wait (L)	Peripheral
12	Ack. Reverse (L)	(user defined)	Peripheral
13	Xflag	(user defined)	Peripheral
14	Host Ack.	- D Strobe (L)	Host
15	-Periph. Request (L)	(user defined)	Peripheral
16	- Initiate (L)	- Reverse Request (L)	Host
17	IEE1284 Active	- A Strobe (L)	Host
18 – 25	Grounds	Grounds	

IEEE 1284-B PIN-OUT FOR THE 36 WAY CENTRONICS CONNECTOR

Pin	ECP Mode	EPP Mode	Source
1	Host Clk.	- Write (L)	Host
2 – 9	Data 1 – 8	AD1 – AD8	Either
10	Periph. Clk	Interupt (H)	Peripheral
11	Periph. Ack.	- Wait	Peripheral
12	- Ack. Reverse (L)	(user defined)	Peripheral
13	Xflag	(user defined)	Peripheral
14	Host Ack.	-D Strobe (L)	Host
15	(not defined)	(not defined)	
16	Logic Ground	Logic Ground	
17	Chassis Ground	Chassis Ground	
18	Periph.Logic Hi.	Periph.Logic High	Peripheral
19 – 30	Grounds	Grounds	
31	- Initiate (L)	- Reverse Req. (L)	Host
32	- Periph. Req. (L)	(user defined)	Peripheral
33 – 35	(not defined)	(not defined)	
36	IEEE1284Active	- A Strobe (L)	Host

IEEE 1284-C PIN-OUT FOR MDR CONNECTORS: *

Pin	Compatible Mode **	ECP Mode	EPP Mode	Source
1	Busy (H)	Periph. Ack.	-Wait (L)	Peripheral
2	Select (H)	Xflag	(user defined)	Peripheral
3	Acknowledge (L)	Periph. Clk.	Interupt (H)	Peripheral
4	-Fault (L)	-Periph. Request (L)	(user defined)	Peripheral
5	Error (H)	-Ack. Reverse (L)	(user defined)	Peripheral
6 – 13	Data 1 – 8	Data 1 – 8	AD 1- 8	Either
14	-Initiate (L)	-Initiate (L)	-Reverse Request (L)	Host
15	-Strobe (L)	Host Clk.	-Write (L)	Host
16	-Select (L)	IEEE-1284 Active	-A Strobe (L)	Host
17	Line Feed/Parity/Control	Host Ack.	-D Strobe (L)	Host
18	Host Logic High	Host Logic high	Host Logic High	Host
19 – 35	*Grounds*	*Grounds*	*Grounds*	
36	*Periph. Logic High*	*Periph. Logic High*	*Periph. Logic Hi.*	*Peripheral*

** Recommended for new designs.* *** Operating in the same mode as a Standard Parallel Port.*

THE RS232 FAMILY

An IBM PC may have two RS232 based serial ports: a 25-way D connector labelled Serial-1 or COM-1, and a 9-way D connector labelled Serial-2 or COM-2. The 9 way pin-outs only provide non-synchronous operation.

Below: RS/EIA232signals are referred to ground. 2nd (Secondary) refers to a second channel that can be used for administrative functions. RS/EIA449 works differentially, lines “A” (+) & “B” (–) forming a twisted pair. RS/EIA532 is the intended pin-out for RS/EIA422, 423 & 425 but D9 and RJ type connectors are often used. (> means from DCE to DTE & < from DTE to DCE).

RS/EIA-232		***IBM PC serial Port***	***RS/EIA 449***	***RS/EIA-532***
25-way D# connector:		**9-way D connector**	**37 way D connector**	**25 way D conn.**
Pin	Designation	Designation	Designation	Designation
1	Shield/Screen	Data carrier detect (2)*	Shield - A	Shield - A
2	Transmit data <	Receive data (5)*	Signal rate indicator	Transmit data - A
3	Receive data >	Transmit data (6)*	NC	Receive data - A
4	Request to send <	Data terml. Ready (3)*	Transmit data - A	Request to send - A
5	Clear to send >	Ground (4)*	Transmit timing - A	Clear to send - A
6	Data set ready >	Data set ready (1)*	Receive data - A	Data set ready
7	Signal ground	Request to send (8)*	Request to send - A	Signal ground
8	Data carrier detect >	Clear to send (7)*	Receive timing - A	Receive sig. detect - A
9	(Reserved for testing)	Ring indicator	Clear to send - A	Receive timing - B
10	(Reserved for testing)		Local loop back	Receive sig. detect - B
11	Select transmit chan.		Data set ready - A	External timing - B
12	2nd carrier detect >		Data terminal ready – A	Transmit timing - B
13	2nd clear to send >		Receive signal detect – A	Clear to send - B
14	2nd transmit data <		Remote loop back	Transmit data - B
15	Transmit timing >		Incoming call	Transmit timing - A
16	2nd received dat >		Select frequency	Receive data - B
17	Received timing >		External timing – A	Receive timing - A
18	Local loop back <		Test mode indicator	Local loop back
19	2nd request to send <		Signal ground	Request to send - B
20	Data terminal ready<		Receive common	Data terml. ready - A
21	Loop back control >		NC	Remote loop back
22	Ring-indicator>		Transmit data – B	Data set ready - B
23	Data rate select <		Transmit timing – B	Data terml. Ready - B
24	Transmit signal timing<		Receive data – B	External timing - A
25	Test indicator >		Request to send – B	Test mode
26	–		Receive timing - B	
27			Clear to send – B	
28	–		Terminal in service	
29			Data set ready - B	
30	–		Data terminal ready - B	
31			Receive signal detect - B	
32	–		Select standby	
33			Signal quality	
34	–		New signal	
35			External timing - B	
36	–		Standby indicator	
37			Send common	

 # EIA-232-E allows a 26 way Alt A *connector to be used; pin 26 is not connected.*
**Pin numbering to EIA-561 for an RJ45 Block connector; see: www.jneuhaus.com/applser.html*

To connect a DTE (e.g. a PC), to a DCE (e.g. a modem), via 25-way cable connectors, pin n of connector A goes to pin n of connector B. To connect two DTE’s or DCE’s the lines are cross connected and called a Null Modem link. When the timing, secondary and test signals are not required the pin-out for asynchronous working can be reduced to:

ASYNCHRONOUS CONNECTIONS

25 way D to 25 way D connections: **9 way D to 25 way D connections:**

Null Modem.		**DTE**	**DCE**	**DCE**	**DTE**	**DTE**	**DTE**
A to	**B**	**PC to**	**Modem**	**Pin to**	**Pin**	**Pin to**	**Pin**
1	1	1	1	1	8	1 & 6	20
2	3	2	2	2	3	3	2
3	2	3	3	3	2	3	3
4	5	4	4	4	20	4	6
5	4	5	5	5	7	5	7
6 & 8	20	6	6	6	6	7	5
7	7	7	7	7	4	8	4
20	6 & 8	20	20	8	5	9	-
				9	22		

Synchronous operation requires the use of the timing signal on pin 24. A Null Modem cable that can be used for either synchronous or asynchronous operation has the following links between connectors A and B:

A pins	1	2	3	4	8	6	20	7	17	24
to										
B pins	1	3	2	8	4	20	6	7	24	17

Pseudo hardware hand shaking can be implemented by linking, within the same connector: Request to Send to Clear to Send and also connect the pins for Carrier Detect, Data Set Ready & Data Terminal Ready together, see page 34. If software hand shaking is used only 3 pin-outs: Transmit Data, Receive Data and system ground are required.

It is common to use either a 9 way D or a RJ type connector for operating RS422 asynchronously and the pin-out used varies with manufacturer. When the RS532 pin-out is used for RS423 the B (–) lines are connected to signal ground.

Further information:

www.epanorama.net/links/tele-interface.html
www.sigtech.com/keltec/instrumentation/rs485_spec.html
http://www.jneuhaus.com/applserl.html.

SCSI APPROVED CONNECTORS (2001):

System	***Connector***	***SCSI ref.***
8 bit Fast	*50 pin High Density (1)*	*Alternative 1, A*
8 bit Standard	*50 pin "Centronics" style.*	*Alternative 2, A*
16 bit Fast / Wide	*68 pin High Density (2)*	*Alternative 3, P*
SCSI-3 / Ultra (3)	*68 pin VHDCI*	*Alternative 4, P*

(1) Also known as a SCSI 2 Connector. (2) Also known as a SCSI 3 Connector. (3) Newly defined.

8 bit single ended 50 pin internal header & high density Alt 1, A cable connector:

All odd numbered pins plus 20, 22, 24, 30 & 34 are ground.(– indicates active low).

Pin	**Designation**	**Source**	**Pin**	**Designation**	**Source**
2	–D0	Initiator/Target	26	Terminal Pwr.	
4	–D1	``	32	–Attention	Initiator
6	–D2	``	36	–Busy	Initiator/Target
8	–D3	``	38	–Acknowledge	Initiator
10	–D4	``	40	–Reset	``
12	–D5	``	42	–Message	Target
14	–D6	``	44	–Select	Initiator/Target
16	–D7	``	**46**	**–Control/Data**	**Target**
18	–Parity	``	**48**	**–Request**	``
25	Not Used		50	–Input/Output	``

8 bit differential 50 pin header & high density Alt. 1A cable connector:

Pins 1, 2, 22, 23, 24, 27, 28, 31, 32, 49 & 50 are Ground.

Pin	**Designation**	**Source**	**Pin**	**Designation**	**Source**
3	+D0	Initiator/Target	25	Termination Power	
4	–D0	Initiator/Target	26	Termination Power	
5	+D1	Initiator/Target	29	+Attention Initiator	
6	–D1	Initiator/Target	30	–Attention	Initiator
7	+D2	Initiator/Target	33	+Busy	Initiator/Target
8	–D2	Initiator/Target	34	–Busy	Initiator/Target
9	+D3	Initiator/Target	35	+Acknowledge	Initiator
10	–D3	Initiator/Target	36	–Acknowledge	Initiator
11	+D4	Initiator/Target	37	+Reset	Initiator
12	–D4	Initiator/Target	38	–Reset	Initiator
13	+D5	Initiator/Target	39	+Message	Target
14	–D5	Initiator/Target	40	–Message	Target
15	+D6	Initiator/Target	41	+Bus Select	Initiator/Target
16	–D6	Initiator/Target	42	–Bus Select	Initiator/Target
17	+D7	Initiator/Target	43	+Control/Data	Target
18	–D7	Initiator/Target	44	–Control/Data	Target
19	+Data Polarity	Initiator/Target	45	+Request	Target
20	–Data Polarity	Initiator/Target	46	–Request	Target
21	Diff. SCSI Sense	Initiator	47	+I/O	Target
			48	–I/O	Target

8 bit Single-ended pseudo interface for Macintosh computers using a 25 way D:

Pin	Designation	Pin	Designation
1	Request	14	Ground
2	Message	15	Control/Data
3	Input/Output	16	Ground
4	Reset	17	Attention
5	Acknowledge	18	Ground
6	Busy	19	Select
7	Ground	20	Parity
8	DB0	21	D1
9	Ground	22	D2
10	D3	23	D4
11	D5	24	Ground
12	D6	25	Terminator Power
13	D7		

8 bit Single-Ended 50 pin (Centronics) Alt. 2, A-cable connector.

Pins 1 to 11, 15 to 25 plus 35, 36, 40, and 42 are ground. Each data line and a ground line form a twisted pair, the associated ground-line is attached to the facing data pin at the connector.

Pin	Designation	Source	Pin	Designation	Source
12	reserved		41	–Attention	Initiator
13	n.c.		43	–Busy	Initiator/Target
14	reserved		44	–Acknowledge	Initiator
26 to 33	–D0 to – D7	Initiator/Target	45	–Reset	Initiator
34	–Data Bus Polarity	Initiator/Target	46	–Message	Target
37	reserved		47	–Select	Initiator/Target
38	Terminal Power		48	–Control/Data	Target
39	reserved		49	–Request	Target
	(– indicates active low)		50	–Input/Output	Target

8 bit Differential 50 pin (Centronics) Alt. 2, A-cable connector:

±data and control line pairs are twisted together and connected to facing pins at the connector

Pin	Designation	Source	Pin	Designation	Source
1	Ground		26	Ground	
2 to 9	+D0 to +D7	Initiator/Target	27 to 34	– D0 to –D7	Initiator/Target
10	Data Bus Parity	Initiator/Target	35	– Data Bus Parity	Initiator/Target
11	Differential Sense	Initiator	36	Ground	
12	Reserved		37	Reserved	
13	Termination Power		38	Termination Power	
14	Reserved		39	Reserved	
15	+Attention	Initiator	40	– Attention	Initiator
16	Ground	Initiator	41	Ground	
17	+Busy	Initiator/Target	42	– Busy	Initiator/Target
18	+Acknowledge	Initiator	43	– Acknowledge	Initiator
19	+Reset	Initiator	44	– Reset	Initiator
20	+Message	Target	45	– Message	Target
21	+Select	Initiator/Target	46	– Select	Initiator/Target
22	+Control/Data	Target	47	– Control/Data	Target
23	+Request	Target	48	– Request	Target
24	*+In/Out*	*Target*	*49*	*– In/Out*	*Target*
25	*Ground*		*50*	*Ground*	

16 bit Single-Ended 68 pin High Density Alt 3, P-cable connector:

Pins 1 to 16, 22 to 25, 27, 29, 31 to 34, 54 & 56 are Ground.
Pins 19 to 21, 26, 28, 30, 49, 50 & 53 are not connected.

Pin	Designation	Source	Pin	Designation	Source
17	Term. Power		57	–Busy	Initiator/Target
18	Term. Power		58	–Acknowledge	Initiator
35 to 38	–D12 to – D15	Initiator/Target	59	Reset	Initiator
39	–Data Parity High	Initiator/Target	60	–Message	Target
40 to 47	–D0 to – D7	Initiator/Target	61	–Bus Select	Initiator/Target
48	–Data Polarity	Initiator/Target	62	–Control/Data	Target
51	Term. Power		63	–Request	Target
52	Term. Power		64	–Input/Output	Target
55	–Attention	Initiator	65 to 68	–D8 to – D11	Initiator/Target

16 bit Differential 68 pin High Density Alt. 3, P-Cable Connector.

Pin	Designation	Source	Pin	Designation	Source
1 to 4	+D12 to +D15	Initiator/Target	31 to 34	+D8 to +D11	Initiator/Target
5	+Data Parity	Initiator/target	35 to 38	–D12 to –D15	Initiator/Target
6	Ground		39	– Data Polarity	Initiator/Target
7 to 14	+D0 to +D7	Initiator/Target	40	Ground	
15	+Data Parity High	Initiator/Target	41 to 48	–D0 to –D7	Initiator/Target
16	Diff. Sense	Initiator	49	–Data Polarity High	Initiator/Target
17	Term. Power		50	Ground	
18	Term. Power		51	Term. Power	
19	Reserved		52	Term. Power	
20	+Attention	Initiator	53	n.c.	
21	Ground		54	–Attention	Initiator
22	+Busy	Initiator/Target	55	Ground	
23	+Acknowledge	Initiator	56	–Busy	Initiator/Target
24	+Reset	Initiator	57	–Acknowledge	Initiator
25	+Message	Target	58	–Reset	Initiator
26	+Bus Select	Initiator/target	59	–Message	Target
27	+Control/Data	Target	60	–Bus Select	Initiator/Target
28	+Request	Target	61	–Control/Data	Target
29	+Input/Output	Target	62	–Request	Target
30	Ground		63	–Input/Output	Target
			64	Ground	
			65 to 68	–D8 to –D11	Initiator/Target

Further information

www.shadownet.com/hwb/menu_cable.html
www.technick.net/homepage *(Go to pin-outs then connectors).*
http://global.his.com/ *(For technical publications).*
www.tiaonline.org/ *(Go to Find & Buy then Standards).*
www.cablingdirectory.com *(Go to Connectors then to Tutorials).*
Also see the sister publication: Electricity and Basic Electrical Circuits.