Interfaces

Interface

An interface is the connection between two circuits, pieces of equipment, or systems. It is the place where the outputs of one circuit meet the inputs to another circuit. It is also the place where the signals in a system are transferred from one place to another.

Interfaces are typically a formally defined interconnection subsystem. They consist of connectors, wire or cable, and printed circuit board conductors. These interfaces are usually designed to carry either analog signals or digital signals.

Every IC, subassembly, or piece of equipment has one or more interfaces to facilitate the connection of input and output signals and to make it fast and convenient to connect one circuit or product to another. Most common interfaces are standardized so that equipment from different manufacturers can connect to one another and perform to specifications.

Interface Standards

There are three types of interfaces, power, analog, and digital. Digital interfaces are the most common. Most are standardized to specific mechanical and electrical characteristics. All have certain specifications such as impedance, frequency response, data speed, and physical characteristics.

Interfaces are categorized as follows power connection interfaces, analog signal interfaces, or digital interfaces. Digital interfaces are either parallel buses or serial buses

Power Connection Interfaces

Power connections are those interfaces that transfer AC and/or DC power from some power to another or from the power source to equipment. Some examples are the AC power cord or the cable and connectors that attach the output of a personal computer power supply to the mother board or disk drives.

Power interfaces are the least standardized and are usually optimized for the application. They are made up of wire of sufficient size to carry the voltage and current and matching connectors. While AC power line plugs and sockets are standardized, the DC power connections are not. They range from simple two-wire cables to large multi-conductor cables with multi-pin connectors.

Another type of power interface is a power bus that distributes DC power to multiple circuits, modules, or racks of equipment.

Analog Interfaces

Analog signals are voltages like audio, video, or sensor variations. They can be AC or DC. These signals originate at microphones, video cameras, sensors, antennas, and test generators. The frequency range is from DC (0 Hz) to 10 GHz or more. The frequency of the signal determines the interface. Here are a few examples and their interface.

Signal	Interface
Audio	Shielded cables to minimize noise pickup
Telephone	Twisted pair cable
Sensor	Twisted pair cable
Video	Coax or fiber optic cable
Radio frequency (RF)	Coax cable

Two Types of Analog Signal Interfaces

The two categories of analog signal interfaces are low frequency connecting wires and transmission lines.

The type of interface and cable is determined by the frequency of the signals. If the signals are at low frequencies (below about 100 kHz such as AC power, audio, and sensor signals, the wires, cables and connectors are less critical in terms of length and size. For example, speaker wires need no special characteristics other than a wire large enough to adequately carry the current. The same with AC power lines. Sensor wiring is non-critical as well. The most important consideration in such low frequency connections is noise pick up on long lines carrying small signals that can be masked by the noise. In such cases, shielded or twisted pair wires are used and differential rather than single-ended connections are used to minimize common mode noise.

Transmission Lines

If the length of an analog signal connection becomes longer than about one tenth of a wavelength at the operating frequency, that connection will act as a transmission line. Remember that wavelength (λ) is calculated with the expression:

$\lambda = 300/f_{MHz}$ where f is frequency in MHz and λ is in meters.

$\lambda = 984/fMHz$ where f is frequency in MHz and λ is in feet.

The wavelength of a 4 MHz video signal is:

$\lambda = 984/4 = 246$ feet

One tenth of 246 feet is 24.6 feet.

If the interconnections are greater than this, the cabling will act as a transmission line rather than just a pair of wires carrying voltage and current.

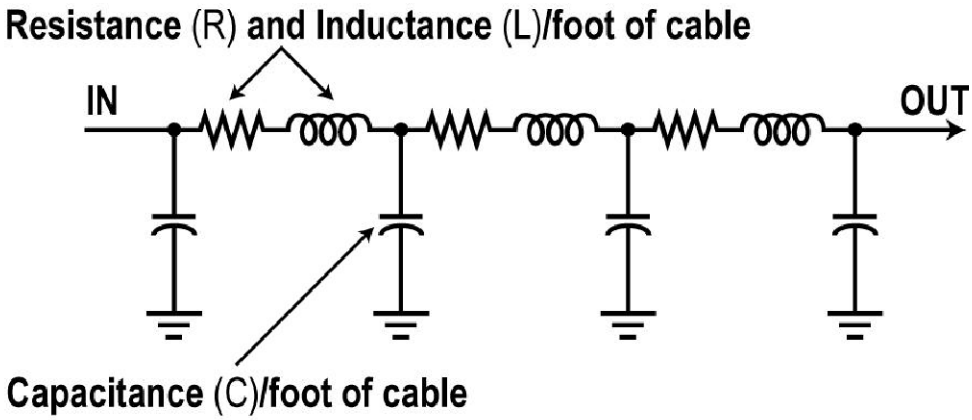
Transmission Lines Wavelength

The wavelength of 2.4 GHz (2400 MHz) wireless signal is:

λ = 984/2400 = 0.41 feet or 0.41 x 12 inches = 4.92 inches

Any connection longer than one tenth of 4.92 inches or just about one half inch will take on the characteristics of a transmission line with resulting consequences.

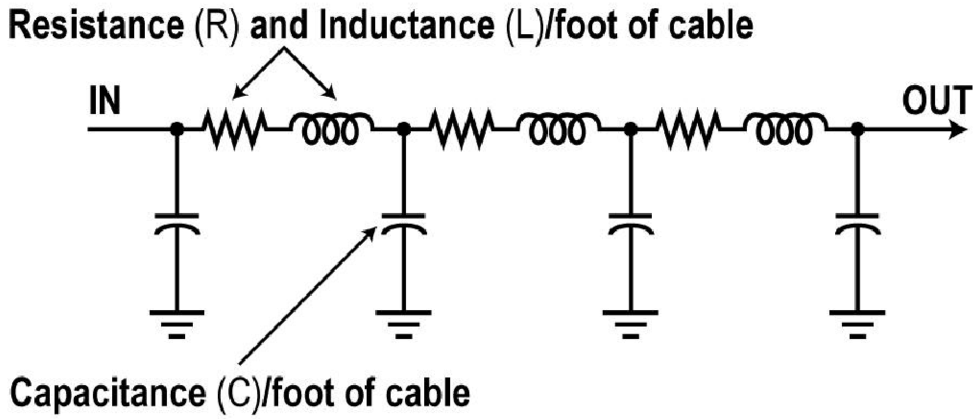
Transmission Line Behavior



Equivalent circuit of a transmission line (low pass filter)

At very high frequencies the two conductors that carry an analog signal such as video or RF act more like a complex inductive-capacitive circuit than just wires with a small resistance. Inductance of the wires have considerable reactance at the higher frequencies and become a major part of the cable performance.

Line Behavior



Equivalent circuit of a transmission line (low pass filter)

The capacitance between the conductors also exhibits low reactance that greatly affects signal attenuation and cable performance. In effect, the cable along with its resistance appears to be a distributed low pass filter. The cable therefore greatly affects signal attenuation and frequency response of the cable.

Transmission Line Impedance

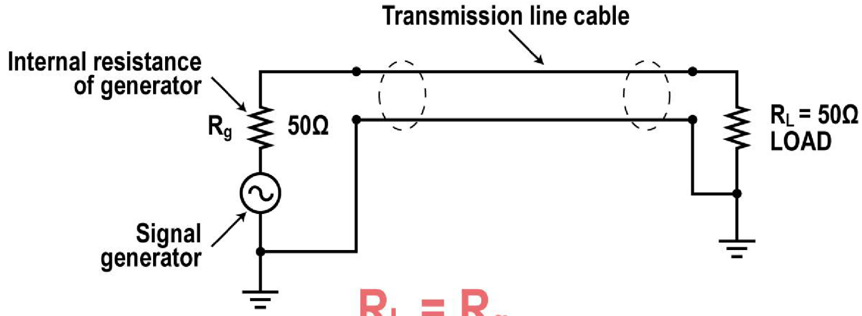
Cables acting as transmission lines at higher frequencies take on an impedance known as the characteristic impedance or surge impedance Z_o. This impedance is a function of the amount of capacitance and inductance per foot and is computed with the expression:

$$Z_o = \sqrt{(L/C)}$$

L and C are the inductance and capacitance per foot. Typical characteristic impedances are in the 50 to 600 ohm range. An infinite length of such a cable looks like a resistor of that value.

With a practical length of cable, the cable will look like some complex impedance of the form R ± jX. In other words, the cable appears to be a complex circuit with an impedance that varies with frequency. Such a circuit will have an enormous and mostly detrimental effect on any signals that it carries.

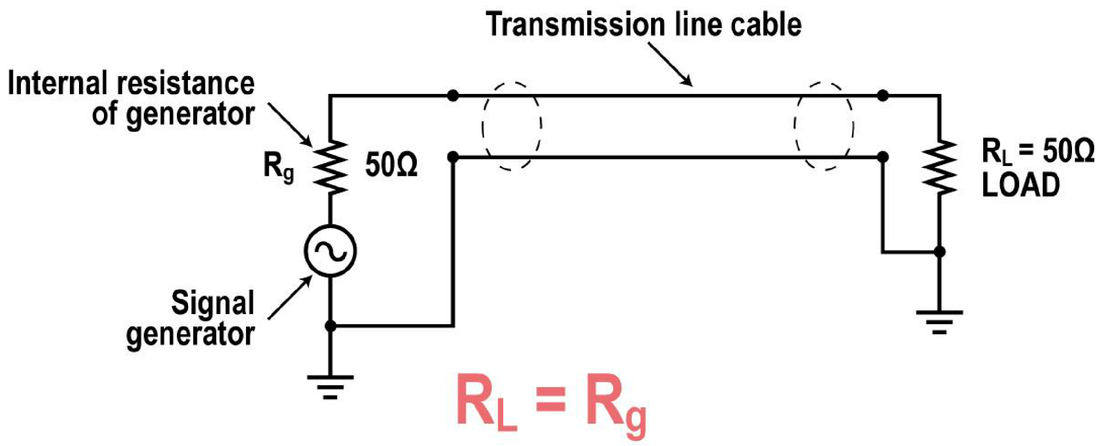
Signal Reflection



$R_L = R_g$

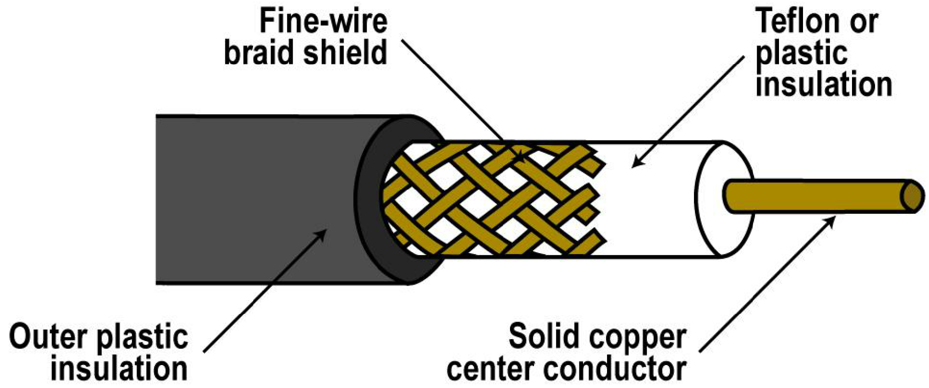
The primary effect of the transmission line on a signal is signal reflection. As the signal passes down the transmission line for voltage source to the load, it encounters the effects of the distributed inductance and capacitance. At the end of the transmission line, some of the signal is not usually absorbed by the load. So some of the signal will actually be reflected back toward the voltage source. This reflected signal will actually interfere (combine) with the original signal causing phase shifts, attenuation, and signal distortion.

Transmission Line Effects



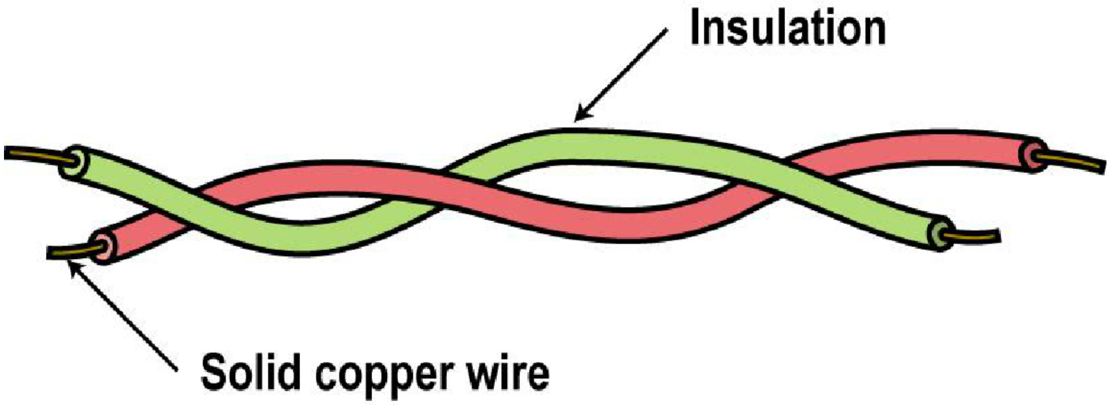
To eliminate the reflection, the transmission line must be driven by a generator or circuit whose output impedance is equal to the characteristic impedance of the line and the load must be resistive with a value equal to the transmission line impedance. The figure shows the correct connections for a transmission line. Any deviation will produce reflections and detrimental effects.

Types of Transmission Lines: Coax Cable



The most common type of transmission line is the coax cable which is like that shown here. It has a center conductor of copper surrounded by an insulator such as Teflon and that, in turn, is surrounded by a braided copper shield. The most common characteristic impedances are 50 ohms and 75 ohms. Most video cables are 75 ohms while most RF cables for antennas and other connections between equipment are 50 ohms.

Types of Transmission Lines: Twisted Pair

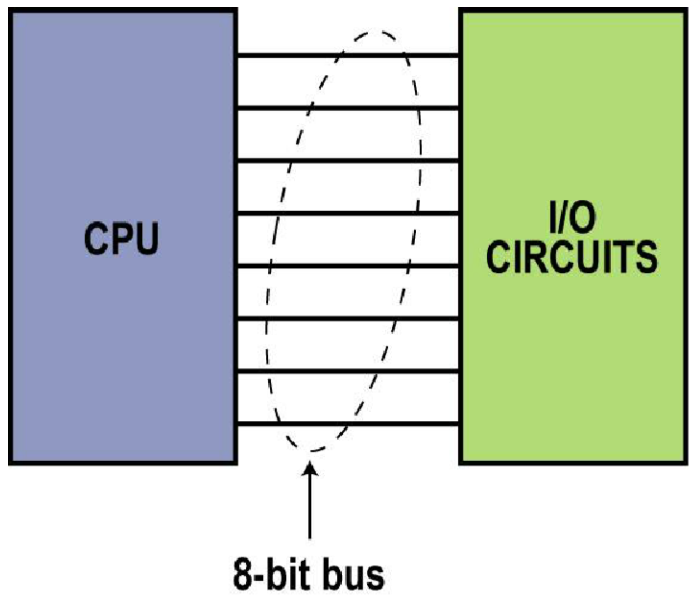


Twisted pair cable is also used as a transmission line to carry high frequency signals and digital data as in a network. The twisted pair characteristic impedance is in the 100 to 150 ohm range depending upon wire size and number of twists per inch.

In all cases, the driving generator and load must have a resistive value equal to the characteristic impedance.

Digital Interfaces: Parallel Buses

One type of digital interface is the parallel bus. A bus is a group of multiple conductors that carry a binary word with one bit per conductor. All bits of a word are transmitted simultaneously over the bus. The figure shows an 8-bit bus that carries one byte of data from one place to another.



Examples of Parallel Buses

Parallel buses are very fast but are limited in the distance over which signals can be carried. The greater the speed of the data transfer, the shorter the bus. At rates below several MHz, the maximum length is several feet. At higher speeds up to 200 MHz, the maximum length is several inches. Longer buses will take on the characteristics of a transmission line and cause complications as well as much greater expense.

Common parallel buses include the parallel port, the PCI bus, LVDS bus, GPIB bus, IDE bus, SCCI bus, and the PCMCIA bus. These are discussed in the following slides.

Common Parallel Buses

A parallel port is an 8-bit bus widely used to carry computer data to a printer. It has a standard speed, length, and connector.

The PCI bus is the most widely used bus in a personal computer to carry data from microprocessor to memory and I/O circuits. It carries 32 and 64 bits of data over very short conductors on a printed circuit board with appropriate connectors. Speeds of up to 133 MHz are possible.

Low voltage differential signaling (LVDS) is a parallel bus where the connections are differential rather than single-ended. Such buses are used to carry fast digital data from one IC to another on a printed circuit board or over short flat ribbon cables from one PCB to another. Transfer speeds can be up to 2 GHz.

General purpose interface bus (GPIB) is also referred to by its standard number IEEE 488. It is an 8-bit bus that carries digital data from one test instrument to another and to a data acquisition system.

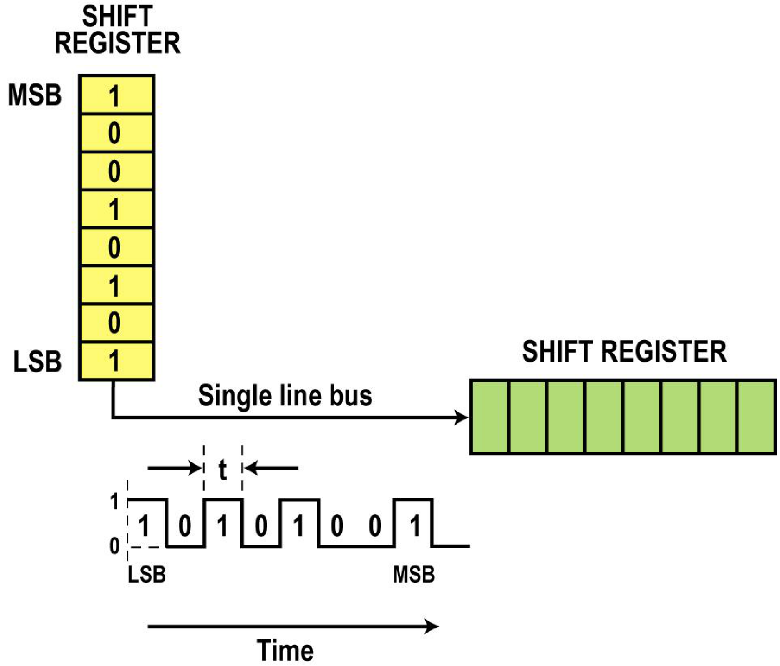
Additional Parallel Buses

The integrated drive electronics (IDE) bus is also known as the Advanced Technology Attachment (ATA) bus. It is an 8 or 16-bit bus used to carry digital data to and from internal disk drives over short flat ribbon cables. Data speeds range up to 133 MegaBytes per second (MB/s).

The small computer system interface (SCSI) is also referred to by its nickname “scuzzy” bus. It is an 8 or 16-bit bus for carrying data to and from external disk drives. Its length is 3 to 12 meters with data rates to 320 MB/s.

The personal computer memory card international association (PCMCIA) bus is also known as the Card bus. It is a 16 or 32-bit bus used for attaching credit card sized interfaces to laptop computers including flash memory, modems, network interfaces, and wireless transceivers.

Serial Interfaces



A serial interface is one that carries digital data in serial format, that is, one bit at a time over a pair of conductors. The figure shows how the parallel binary number is transmitted serially where the LSB is transmitted first and MSB last.

Serial Interface Operation

Serial data transfers are generally considered to be slower because unlike parallel buses they do not transmit all bits of a word simultaneously. However, serial data speeds have been increased over the years making them just as fast as some parallel buses.

Serial connections only use one wire for data (plus a ground) so are simpler and less expensive.

Furthermore, serial data transfers can be transmitted over much greater distances than parallel buses if they the signals are carried on coax or twisted pair transmission lines or fiber optic cable.

Serial Data Rate

The speed of serial data transmission depends upon the bit time of the serial signal. If the bit time is t, the data rate is:

Data rate in bits per second (bps) = 1/t

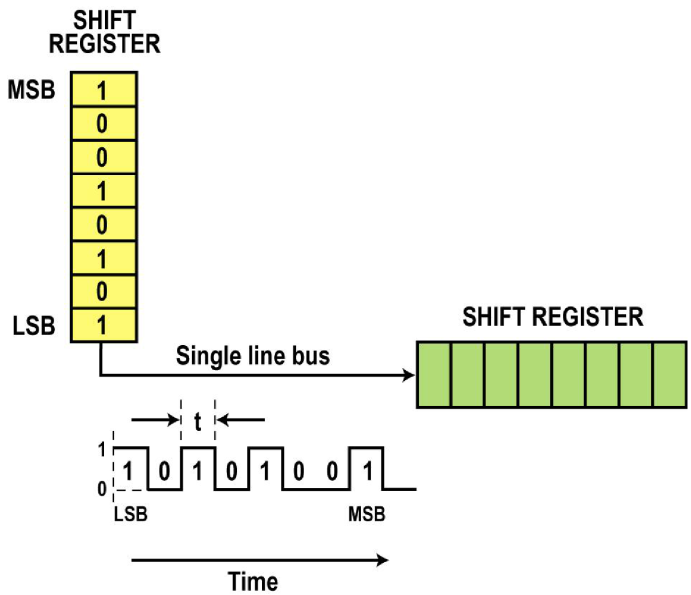
For example, if the bit time is 100 nanoseconds, the data rate is:

Data rate = $1/100 \times 10^{-9}$ = 10,000,000 bits per second or 100 Mbps

The bit time is (t) is the reciprical of the data rate or t = 1/bps.

What is the bit time of a serial signal with a data rate of 128 kbps?

t = 1/bps = $1/128 \times 10^{3}$ = 7.81 µS



Common Serial Interfaces

A serial interface is one that carries digital data in serial format, that is, one bit at a time over a pair of conductors. The most common examples of serial interfaces are the serial port, the universal serial bus, the serial peripheral interface, the I^2C bus, Ethernet, the RS-485. Others that are used are the IEEE 1394, synchronous optical network, iSCSI, serial ATA, RS-422/423, microwire, controller area network, and local interconnect network. There is a brief explanation for each of these on the following pages.

Examples: RS-232, USB, and SPI

The serial port is also known by its standard number RS-232. It carries low speed digital data in the form of sequential bytes at a rate up to about 115 kbps at distances up to about 50 feet. It has standard voltage levels, cables, connectors.

The universal serial bus (USB) is the most widely used interface for peripherals such as printers on personal computers. It has a data rate of up to 12 Mbps with standard connectors, cables, etc. The newer version has a data rate to 480 Mbps.

The serial peripheral interface (SPI) is used for transmitting data between ICs on a printed circuit board with speeds to 10 Mbps.

Examples: I^2C, Ethernet, and RS-485

The I^2C bus is a slow serial interface for transmitting control data from one IC to another on a PCB or over short cables. The data rate is up to 400 kbps.

Ethernet is the serial bus used in most local area networks (LANs). Most of them use category 5 (CAT5) twisted pair cable to get data rates of 10, 100 or 1000 Mbps up to a range of 100 meters.

The RS-485 is a differential serial bus that uses twisted pair cable to carry sensor and control data in industrial control systems. The data rate is up to 10 Mbps over a range of 4000 feet.

Other Serial Interfaces

IEEE 1394 is a super fast serial bus (to 400 Mbps) for carrying digital video in consumer electronics products.

Synchronous optical network (Sonet) is a fiber optic system for carrying serial data at rates to 40 Gbps.

iSCSI is a serial version of the small computer system interface (SCSI) parallel bus using Ethernet.

Serial ATA is a serial version of the IDE/ATA bus.

RS-422/423 is a variation of the RS-232 and RS-485 interfaces.

Microwire is a subset of SPI.

Controller area network (CAN) is used widely in industrial machines and cars.

Local interconnect network (LIN) is a serial bus used in cars and trucks.

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