

# Connectors and Switches

## Introduction

Compared to the sophistication of contemporary semiconductor electronics, the matter of connectors and switches appears simple. Nevertheless, it is important to be familiar with connectors and switches. They are the principal means by which users are most likely to fail and to require the attention of the user.

## Connectors

You ought to know about the following connectors and their properties. Then, when your first boss asks you to hand him a cable called “x”, you can respond appropriately.

[Note: Plugs are male; jacks (sockets) are female.]

### Banana and Double Banana

Banana connectors are inexpensive, big, and reliable. It is easy to fabricate equipment using both the plugs and the jacks. Plugs and jacks are often color coded, which helps avoid cabling errors. Banana jacks are found on panels. They are popular on equipment where neither of the two terminals for the input (or the output) is connected to the chassis. In this case one says, “Both sides float.” For instance, both sides of a multimeter float. Banana plugs are on cables. Hermaphrodite plugs also have an integral socket so that bananas can be stacked. That way, one output can be connected to several inputs.

Double bananas are simply two bananas on a single plug with fixed 3/4 inch spacing. In the absence of a double banana plug two singles will do. A double banana plug has a protruding key indicating the COMMON or GROUND connection. The key is important because one of the bad features of the double banana is that it is easy to reverse the contacts. Reversing the connector contacts can be damaging, especially in making connections to power supplies. The key is an attempt to help the user avoid mistakes. Banana plugs are entirely exposed. They can easily short to anything that is metallic.

## Five-way binding posts

Binding posts may be used with:

1. banana connectors
2. pin plugs
3. fork lugs
4. bare wires wrapped around the post
5. bare wires inserted in the hole

There, that makes five Maybe these are not the official five ways by which the five-way binding post gained its famous name, but they anyhow add up to five. Like banana jacks, posts are reliable and it is easy to build equipment using them. They protrude from the chassis rather more than one might like, and so they do not travel well. They are not used for connections that are intended to be permanent, except perhaps on loudspeakers. Making connections with binding posts can be tedious. Connections are made one at a time. Posts are not popular these days.

## BNC Connectors

Wise old birds like to say that BNC stands for Berkeley Nucleonics Corp. Perhaps they are right. In any event, BNC's are the most popular way to connect electronic test equipment. Like the double banana, the BNC makes two connections at once. Unlike banana jacks, the BNC socket normally has one side connected to the chassis. This tends to enforce a common connection in circuits that are attached to a BNC socket. BNC plugs are used with coaxial cables, and such cables can be used for high frequency signals. The outer connector is always connected to the outer shield of the cable. The center terminal is gold plated and is the hot side of the cable. Unlike the double banana, there is little danger of shorting the center terminal of the BNC, even when making a connection. BNC cables can be stacked by using T connectors and extended with barrel connectors. It is easy to build a BNC socket into a chassis. To attach a BNC plug to a coax cable requires a special tool. Normally one buys BNC cables and doesn't fabricate them.

## F Connectors

The F connector is a poor man's BNC. Like the BNC, it is used with coax cables and with high frequencies. It is the connector one sees on cable television equipment. To attach an F connector to a cable requires a special tool.

## Phono (RCA Phono) Connectors

The phono connector is the standard Connector for patching home stereo equipment. Like the BNC and the F, it makes two connections at a time. There is a hot terminal in the center and a shield. It is easy to short the center pin, but shorting can be avoided by care in making connections. The phono connector is moderately reliable and very inexpensive. An advantage of the phono connection tends to wipe oxide coatings off the contacts. The phono is not normally used for high frequency (megahertz) signals.

## Quarter-inch Phone Connectors

The phone plug originated when telephone operators at switchboards manually made connections amongst subscribers. Phone plugs are the fastest form of connect/disconnect, and they are popular in patching audio equipment where high speed patching can become an element of live performance. They are often shielded, and they make reliable connections. The plug is 1/4 inch in diameter. There are two-circuit phone plugs (tip-shield) and three-circuit phone plugs (tip-ring-shield or TRS). The shield is ground or common. When a TRS plug is used for two-channel audio the tip is for the left channel and the ring is for the right. The TRS connector can also be used for balanced lines, but it is not as good for this purpose as the XLR (see below). When a plug is inserted into a jack, the tip (and ring if there is one) is always momentarily shorted to ground. There are inline plugs and jacks; there are chassis-mount jacks. It is not hard to build with either the plugs or the jacks, though the three-circuit plugs can be tricky. Special phone jacks called “switching jacks” make or break connections depending on whether a plug is inserted in the jack. Therefore, input jacks can be “normalled.” The switching allows the input to device B to be normally the output of device A unless a plug is inserted in the jack. The plug then provides an alternative signal into device B. One says that A is “normalled” to B.

## Miniature Phone Connectors

Miniature phone jacks (3.5 mm) and micro phone jacks (2.5 mm) Are small versions of the quarter-inch phone jack. There are two-circuit and three circuit versions. Switching jacks are available. In contrast to the quarter-inch phone jacks, which are reliable, miniature phone jacks are highly unreliable. In fact, they are guaranteed to fail. Unfortunately, they appear with increasing frequency as audio connectors for sound cards and other small applications. Discovering a miniature phone jack on a piece of test equipment is reason enough for a potential user to reject the equipment and look elsewhere.

## XLR Connectors

The XLR connector can have three or four or five pins, but the three-pin versions are the only popular kind. The three-pin XLR is the standard balanced-line connector. Normally pin 2 is positive, pin 3 is negative, and pin 1 is shield. A balanced-line feeds a differential input circuit that amplifies the difference between positive and negative inputs. Any signal that is common to positive and negative inputs is cancelled in the differencing operation. Therefore, balanced-line systems enjoy a unique immunity to electrically noisy environments. Therefore, the XLR is the favorite microphone connector. The XLR is shielded, and the plug is keyed to prevent mistakes. Because the connector is physically large, it is a very reliable and easy to work with. (Note: the shell set screw has a left-hand thread.) Male and female connectors are available in both inline and chassis mount versions. They all tend to be expensive, partly because connectors have latches that prevent accidental disconnect. Typically, outputs appear at male connectors and inputs go in through female connectors. The pins of the XLR are not easily shorted in use.

## D-Sub Connectors

D-Sub connectors, DB37, DB25, DB15, DB9, with 37, 25, 15, and 9 pins respectively, are popularly used for serial communication in computers, e.g. keyboard, mouse, serial printer. DB25 Cables (AKA RS-232) have become so inexpensive that they are attractive to the experimenter for many applications where massive numbers of connections must be made. They cannot carry much current, however. Male and female inline connectors and male and female chassis mount connectors are available. So are gender changes, which have saved more lives than most paramedics. Although it is possible to solder half a dozen connections on a DB25 plug or socket, soldering a major fraction of all 25 is not recommended. Within a chassis one can use D-Sub connectors with flat ribbon cable already connected. Alternatively, one can attach ribbon cable to a D-sub having an insulation displacement connection.

## DIN Connectors

DIN stands for Deutsches Institut Fur Normung, the German standards organization. A DIN plug has pins equally spaced over part of the periphery of a circle. (It makes a big smiling face). DIN was used for many years in automotive electronics. Then, the five-pin DIN became the standard connector for MIDI (Musical Instrument Device Interface) bringing the DIN out from behind the dash and into the bright lights of stardom. The mini DIN is now frequently used for computer keyboard and mouse interfaces.

## LEMO Connectors

The 1970's witnessed the development of a series of high-speed electronic modules for nuclear physics instrumentation. In order to squeeze a dozen modules into a 19-inch rack crate the manufacturers developed front panels for munchkins. Anyone with fingers of normal size was not allowed to play. Companies like Ortec and Canberra were major culprits. Munchkin panels leave little room for connectors, and after years of trying to fit 14 square inches of BNC connectors onto 10.625 square inches of panel space, the industry developed the LEMO. The Lemo is an attempt to negate the time-honored principle that when it comes to connectors, small means unreliable. LEMO connectors are costly and no one makes his own.

## Jones Connectors

If XLR connectors are limousines and LEMO connectors are sports cars then Jones connectors are trucks. Jones connectors have flat pins in a more or less regular array, which is deliberately made irregular (often by twisting a few pins by 90 degrees) so that the connection can only be made in one way. There may be as few as two pins, and the upper limit is more than 20. The flat pins of a Jones connector are large, sometimes very large, and can carry a lot of current. Inline and chassis mount connectors are both available in both genders. Jones connectors make look clunky but it is a treat to build (or repair) equipment using them.

## Switches

The switch is a convenient way to make and break electrical connections. There are a lot of considerations and a lot of different solutions.

### Push buttons

The simplest push button is the doorbell button. A springy metal strip forms one contact. Pushing on it bends the strip so that it touches the other contact, a fixed metal tab, thereby completing the circuit. When the finger pressure is released the springy metal strip resumes its normal shape, and the connection is broken. This kind of push button is called "normally open (NO)" and the "momentary." There are also normally closed (NC) buttons, where pressing the button breaks the electrical connection. The alternative to a momentary button is push-on push-off button, which retains its status until it is pushed again. Illuminated push buttons are nifty. They have a separate set of contacts for the lamp, independent of the operation of the button. The weak point of the push button is contact bounce. When the contact is initially made, it is not electrically stable. The contact

bounces, at least once, before a stable connection is complete. The contact may be alternately made and broken several times – over the course of microseconds – as the button is pressed. When the object is to ring a doorbell, contact bounce is of no consequence. When the push button is attached to digital logic, the bounce leads to an erratic signal. The best cure for contact bounce is a de-bouncing circuit made from two cross-coupled NAND gates. This circuit requires a push button with both NC and NO contacts.

## Toggle switch

A toggle is a mechanical contrivance that tends to enforce two-state behavior. A toggle switch employs toggling action to snap the switch status rapidly and reliably between open and closed. The simplest toggle switch is single-pole single-throw (SPST) meaning that there is a single circuit and the connection can be made or broken. An alternative is the single-pole double-throw (SPDT) where the center connector is either connected to the upper contact or to the lower contact. Hence a SPDT switch has three terminals where wires may be attached. A double-pole single-throw (DPST) switch is capable of switching two independent circuits with a single mechanical action. For example, it can turn on both positive and negative power supply voltages at once. Multipole switches are indicated on schematic diagrams with dashed lines indicating mechanical ganging. Also common is the DPDT switch, which has six terminals where wires may be connected. The list goes on. One can buy a 4PDT switch. Toggle switches come in two main sizes, standard and miniature. The miniature is more common on contemporary equipment because of munchkinizing. Standard toggle switches look and feel clunky in the present day. However, a standard toggle switch can be used for 120 VAC, and miniature toggles are NOT recommended for this purpose. Standard toggles can carry high currents. They can be found on aircraft and the space shuttle.

## Rotary switch

Whereas a toggle switch has two positions, a rotary Switch has many positions. Typically, positions are separated by 15 degrees. When you build equipment using a rotary switch, you set a stop to determine the number of positions that will be available. A rotary switch uses wafers on the shaft for the actual switch contacts. The number of wafers, hence the number of switching possibilities, is limited only by the length of the shaft, which may be considerable. You can see the utility of the rotary switch in classic oscilloscopes, made before the arrival of electronic switching. The time-base switch could be rotated to twenty different positions to set the sweep rate of the time base generator. Actually to change the time base

required switching half a dozen different circuits, but these could all be switched with different wafers on a single shaft. To avoid running long leads for electrical connections (thus avoiding capacitive coupling and lead self inductance) the makers ran the shafts from the front to the back of the oscilloscope and put the wafers where they were needed. Rotary switches may be make-before-break (MBB) or break-before-make (BBM). In a MBB switch the rotating contact is larger than the spacing between successive switched; e.g. if the terminals are separated by 15 degrees the rotating contact may occupy 20 degrees. The MBB switch is used to switch between two conditions without opening the switch in between. For instance, switching between two microphones in the input to an amplifier needs a MBB switch to avoid the hum that would occur if the input were open. On the other hand, a BBM switch is essential when switching among power supply voltages. On schematic diagrams the wafers are connected with dashed lines to indicate ganging.