APPLICATION NOTE

Understanding IEEE 1641—Using Loads

A discussion on how loads and impedances are represented in IEEE 1641

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Application Note 1002/ Issue 1, January 2010

Introduction

There are two completely different kinds of load within IEEE 1641. One is a BSC and the other is a property of the Physical class. In addition, 1641 may be used to define a signal of type Impedance, which adds a third possibility when a load is required.

The Load BSC provides an impedance, defined in terms of resistance and reactance, which be used to load a signal.

The load property represents the impedance, input or output, that is used when converting power, voltage and current values as is often required in RF applications.

This application note explains how and when to use the Load BSC, how and when the load property should be invoked and when an Impedance signal is required. This note also covers how to represent short circuits in 1641.

The Load BSC

The Load BSC is always used in conjunction with connectors. It is used to indicate that a load is required for the signal or UUT to operate correctly, i.e. it is information to the test implementer that a load is required at that point.

It is important to note that Load does not modify the signal (in the simulation sense) even though the signal may not be present or may not be correct if the load is not there. Although the Load is a Transformation BSC, it has a unity transfer function, i.e. the signal is not changed as it passes through the Load.

It may help to state where Load is **not** to be used in 1641—it is not an impedance element to be used for constructing networks.

The load property

The load property may be used with a signal of type Physical, e.g., a signal of type Voltage. In RF applications, it is common to express an input (or output) signal in dBm or dBW. In most cases it is a voltage or current signal that is actually required, but it is expressed as a power with reference to an input or output impedance. The load property allows the value of that impedance to be expressed.

A signal of type Impedance

It is possible to invoke a signal of type Impedance. For example a Constant BSC may be used as a source with type Impedance and amplitude in ohms. Theoretically, any source BSC may be of type Impedance, but in nearly every case the Constant BSC will be the most suitable.

Engineering use of loads in test

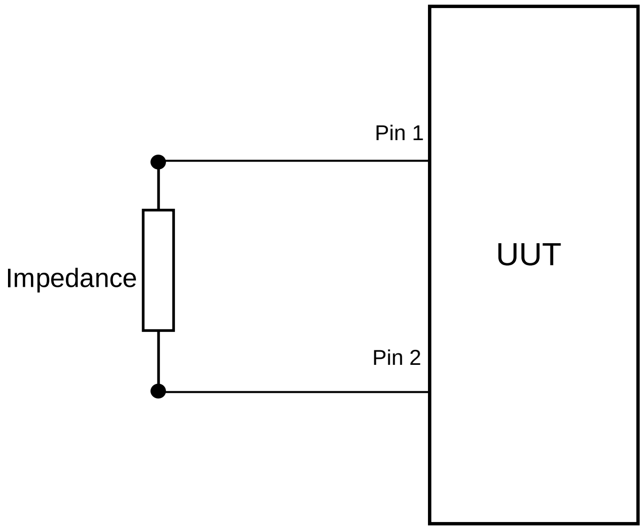
The simplest way to explain the use of loads is with a set of examples or use cases.

Quite often the use of the impedance element is there to provide information to the engineer implementing the test and is not *directly* related to the signal itself.

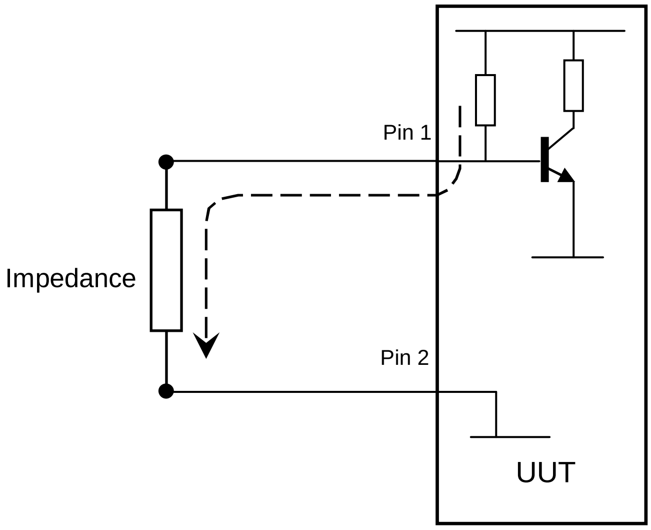
There are several different ways in which a load is used with UUTs when testing.

Case 1—Load as in input to a UUT

The UUT requires an impedance element to be connected to two specified pins. No signal is to be applied and no measurements are to be made. This is just an element that the UUT needs in order to operate correctly.



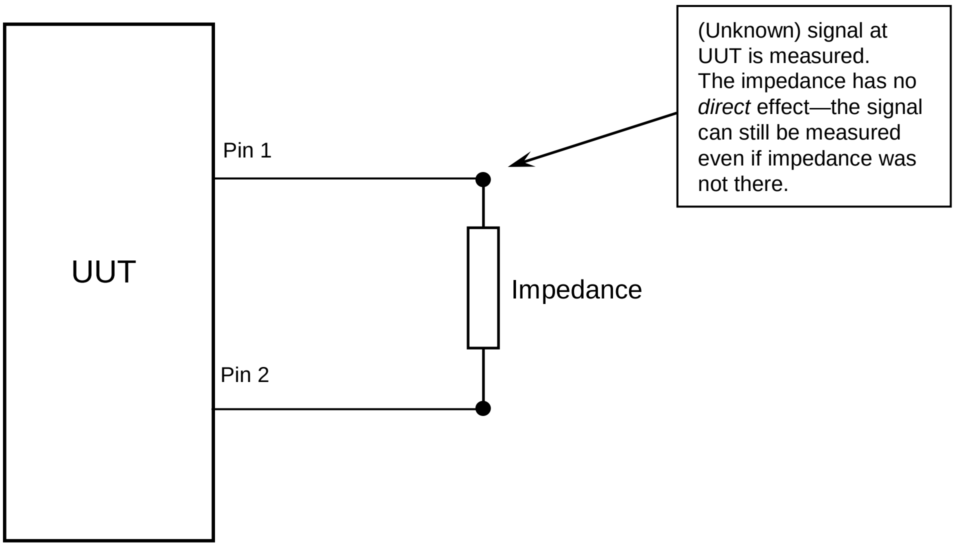
In the engineering sense the UUT is the source of an (unknown) signal which is being output into the load. What is actually happening is that a "signal" is being applied to the load by the UUT. This is true even if the impedance element is connected to an input of the UUT. An example is shown in the modified diagram below.



This could be represented by a Load BSC connected as in case 2 below, but it would be better to consider that the UUT requires the application of a signal, i.e. a Constant BSC with physical type *Impedance*. This remains true even for the special case of a (shorting) link, where the impedance is zero, although in the case of a simple link the two pins could just be connected together.

Case 2—Load as an output to a UUT

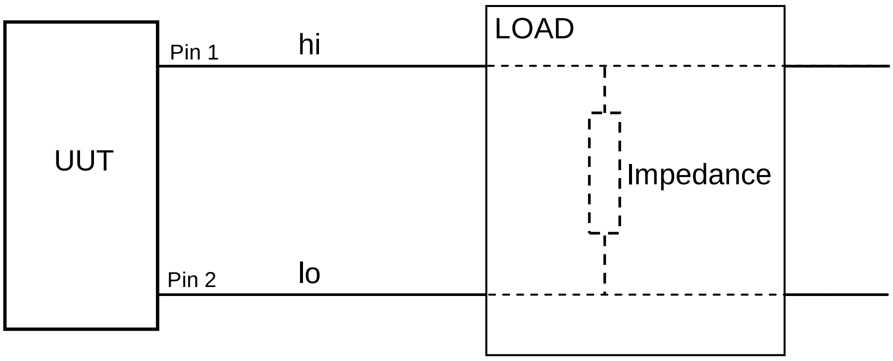
A UUT output requires a load to be applied to two pins. A measurement may be taken of (say) the voltage at those UUT pins. The load has to be there to ensure the UUT is operating correctly. The measurement is taken across the UUT pins. These two may be considered two separate unrelated actions (even though the lack of the load may result in an incorrect measured value).

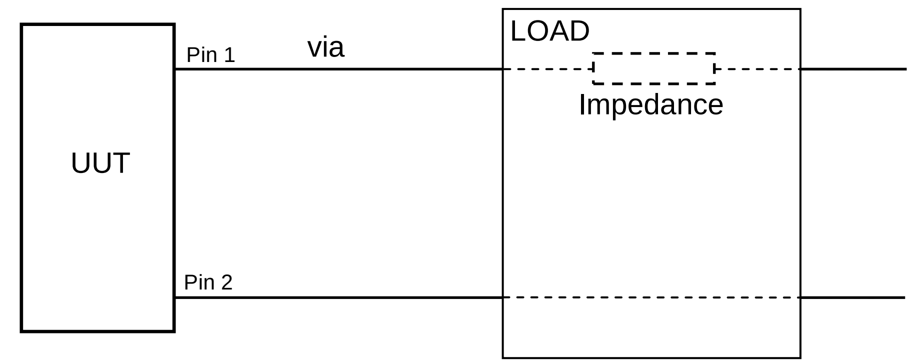


In practice, the lack of the impedance may affect the value of the signal measured, but when the impedance is present it doesn't *directly* modify the signal.

A common example is where it is used to indicate that the UUT requires a matching impedance, such as a measuring instrument with an input impedance of 50 Ω. Note that as the measuring instrument is physically adding a load to the output pins, a Load BSC is required to represent that load. If the measuring instrument also translates between voltage and power values, the load property will also be utilised (see Use of the load property—Summary).

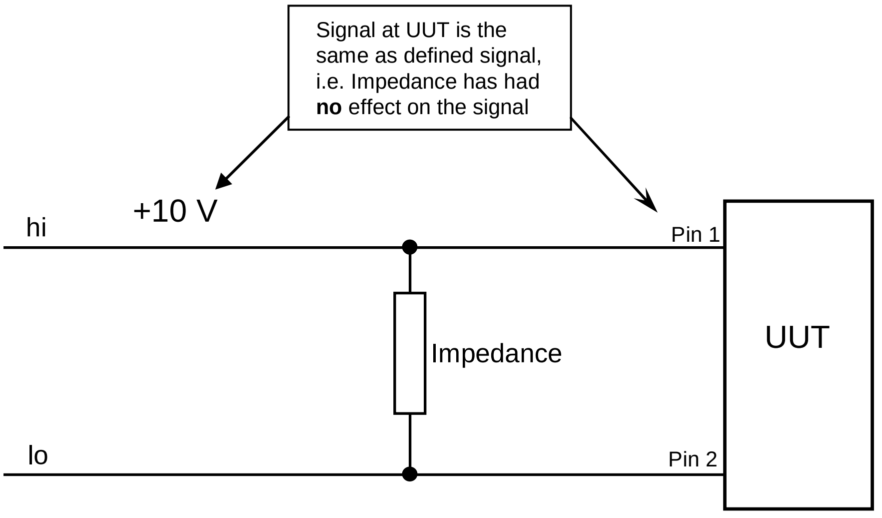
Although the Load BSC does not modify the signal, it is still a Transformation BSC and applies to the whole signal. It should not be thought of as a resistor with two terminals but as a complete load applied to a signal, however many terminals it has. This is illustrated by the two following diagrams:





Case 3—Load attached to an input to a UUT (parallel signal)

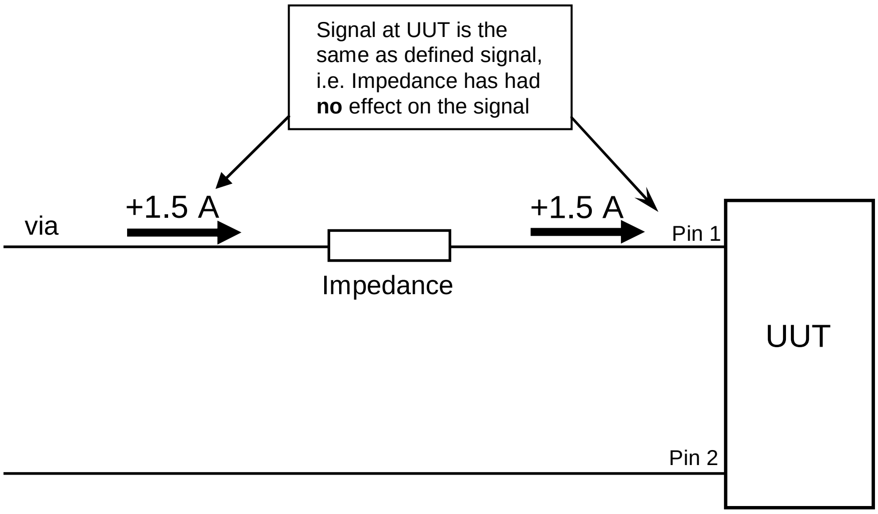
A load is connected to two input pins on the UUT and a signal is applied to those same input pins. Again, these two may be considered two separate unrelated actions. The lack of this element should not result in an incorrect input value when the signal applied is defined independently of the total load.



An example could be the situation where the impedance has to be there to ensure that the correct operation of the UUT or to prevent the input floating to an unsatisfactory value when the signal is inactive.

Case 4—Load attached to an input to a UUT (series signal)

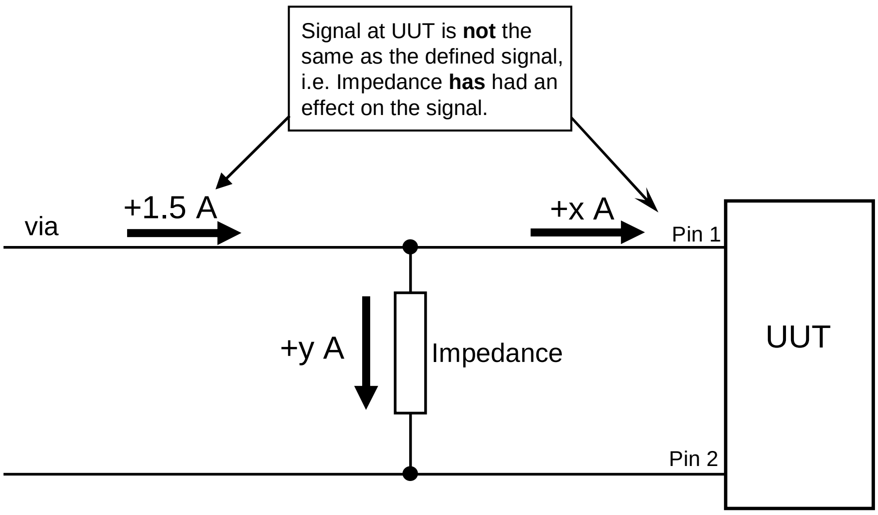
This is similar to case 3 (where the signal is not affected by the impedance element) but for a current signal. The whole of the current flows through both the element and the UUT, i.e. the current is not changed.



Case 5—Load attached to an input to a UUT (parallel network element)

In this case the signal applied *is* affected by the load. An example is where the signal is defined in terms of current and part of the current will flow through the element and part through the UUT.

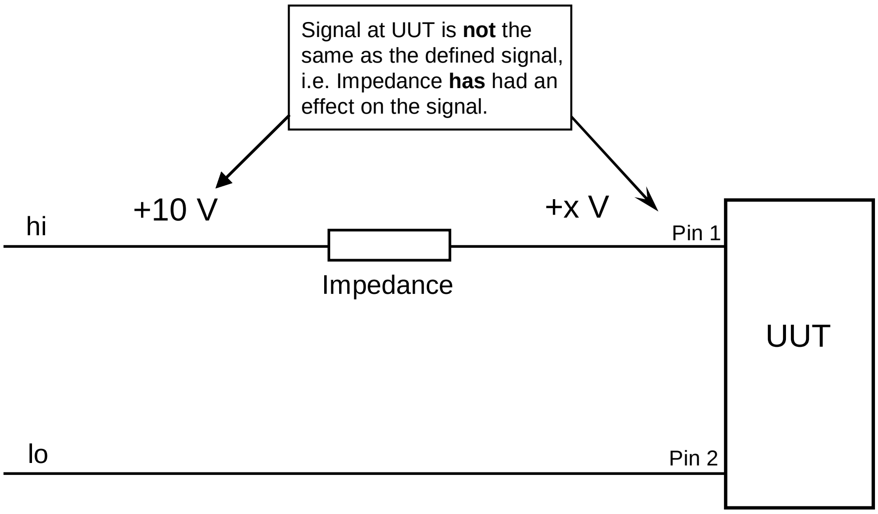
This is *not* a correct use of Load, as it is being used as a network element and the value of current flowing in the UUT (x amperes) is not known.



In this situation, a completely different model may need to be used according to the specific situation. For example, if the current into the UUT (x A) is much lower than the bypass current (y A) then the model may represent a voltage source which is programmed as a current. In such cases, the signal being applied to the UUT is a function of the initial signal and the impedance, which should be dealt with by creating a TSF with the appropriate function code in the TSF. However, this situation is likely to arise quite infrequently and each occurrence should be examined on its own merits.

Case 6—Load attached to an input to a UUT (series network element)

This is another example similar to case 5; a load is used in series in between the applied signal and the UUT. In this case the load element should be considered part of the source signal TSF or as part of the UUT, depending on the specific circumstances. A Load BSC is not appropriate as it is being used as a network element and the voltage at the UUT (x volts) is not known.



Instruments with significant output impedance

An example of case 6 is where the output impedance of a source instrument in significant. In many RF applications a UUT will have an input impedance of 50 Ω and the source instrument is assumed to have the appropriate output impedance. What is actually happening in this case is that the instrument sources a *current*, which is defined as a *voltage* translated according to the source instrument output impedance. These output or input impedances cannot be represented with a Load BSC.

A completely different model is required here, where a source current is programmed by a voltage divided by the source's output impedance. This conversion will be done mathematically in the source TSF. The effect of an incorrect UUT input impedance is then modelled correctly. In most cases, it is reasonable to assume that the UUT input impedance is correct (and is matched by the correct instrument output impedance) and that the effect of these impedances may be ignored.

Conversions between voltage and power will be done by invoking the load property of the physical signal.

Summary

Cases 2, 3 and 4 are similar in that the impedance does not *directly* affect the signal. In these cases the impedance has nothing to do with the signal definition, either for source or sensor. The impedance is only relevant to the requirements of the UUT. Therefore, in these cases a Load BSC may be used.

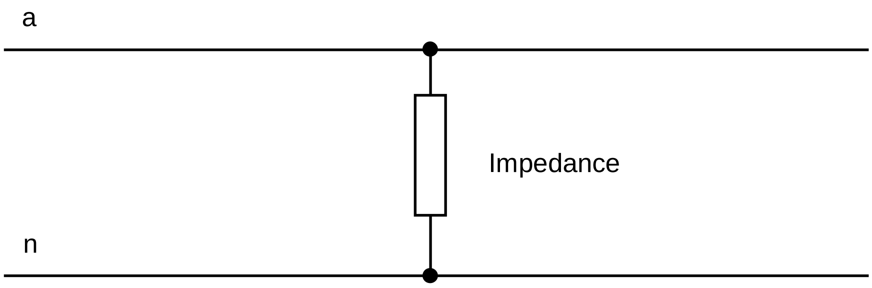
In case 1 the impedance itself may be considered to be the signal being applied. Therefore, in this case a Constant BSC of type Impedance may be used.

In cases 5 and 6 the impedance *does* affect the signal at the UUT directly. The defined signal is not applied to the UUT; i.e. the impedance has modified the signal before it is applied to the UUT. In these cases the Load BSC cannot be used as 1641 does not support the use of Loads to build networks. The solution is to examine the case in detail and to create a TSF that outputs the required signal using the appropriate function code in the TSF

Different kinds of load

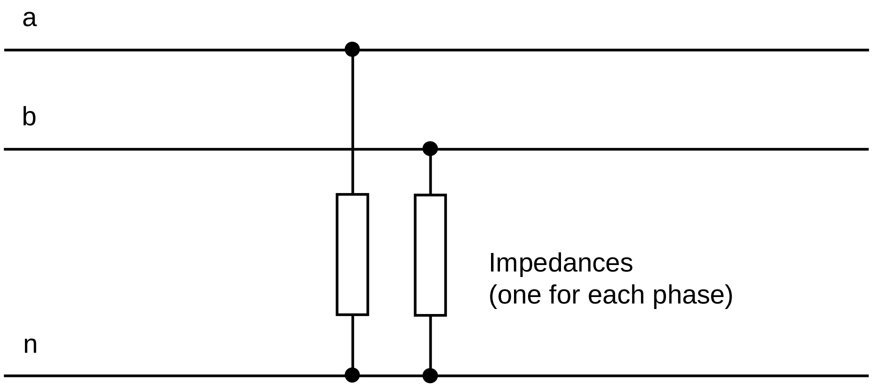
The examples shown above are all related to the "TwoWire" use of a load. In engineering terms we use many special configurations of loads. These include three phase loads of different types (which may be balanced or unbalanced), plus other configurations for synchros, resolvers and busses. Several of these are illustrated below. Many of them are either the same as the two wire example, or multiple instances of the two wire example.

SinglePhase



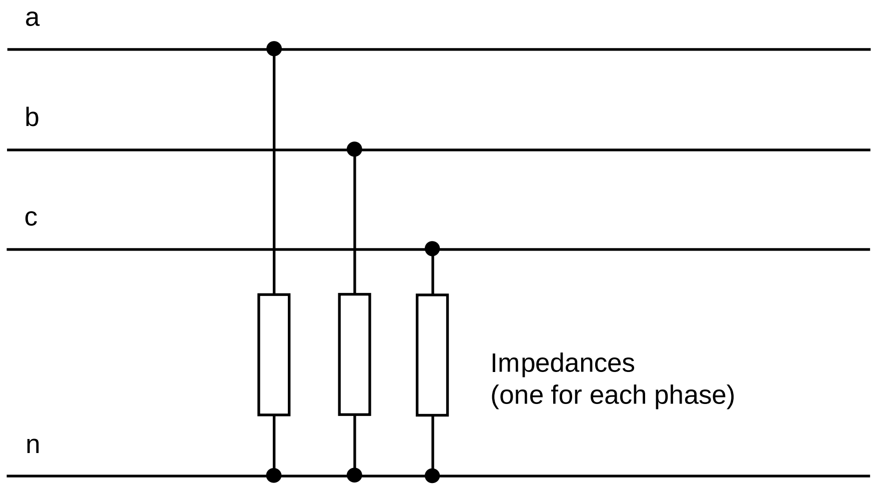
same as TwoWire (hi, lo) and TwoWireComp (true, false)

TwoPhase

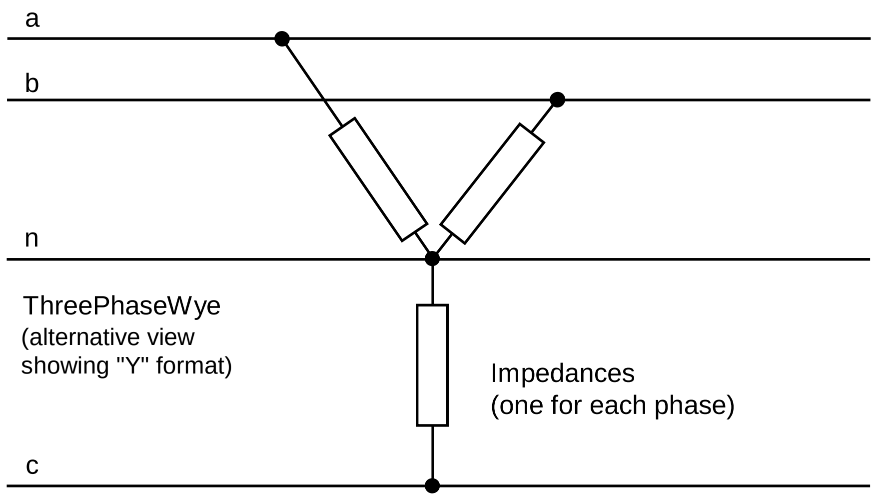


same as ThreeWireComp (true, false, lo)

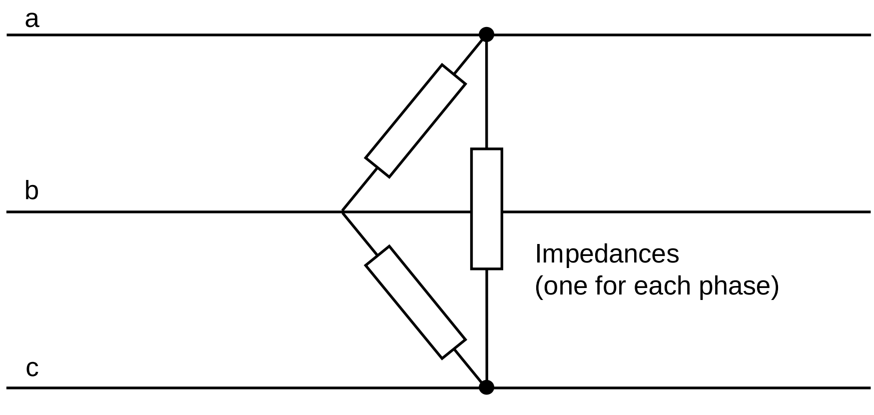
ThreePhaseWye



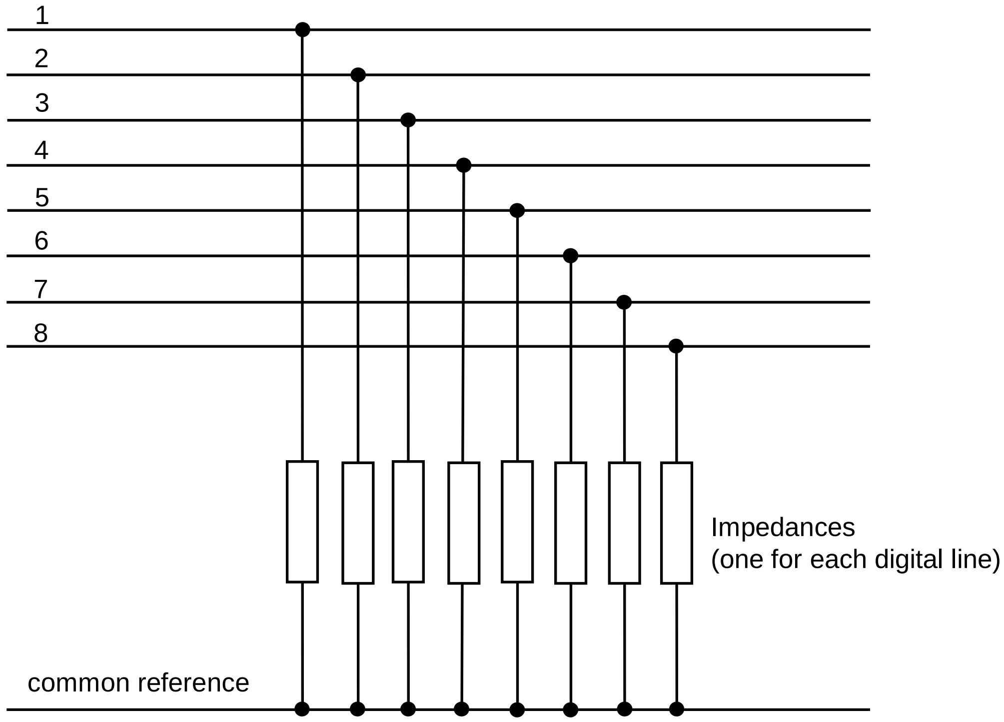
ThreePhaseWye (cont.)



ThreePhaseDelta



DigitalBus



The above examples are treated as multiple versions of the cases given in the first section. This means that the Load BSC is suited for use where the impedances are used in the same way as illustrated in cases 2, 3 and 4. All the impedances have the same value, which is that given to the instance of the Load BSC. The values of the impedances may well be the same, but this is not always the case in practice. For example, the three phase loads may be unbalanced, where the individual impedances have different values

In many cases, it would not matter if the impedance values were the same or different as the value has no direct effect on the signal. The problem is that there is no way of expressing different values in a Load BSC, as only one value may be given. When it is required to represent different values for multiple impedances in a Load, this is achieved by separating the signal into its component channels and using individual TwoWire Loads for each channel.

Implementing Shorts in 1641

There are two ways in which a Short can be implemented. The first being the application of a constant source impedance of zero ohms, the second being the connection of a Load to two pins. One is used on the input of a UUT and the other is used on the output of a UUT. In both cases they are used to indicate that a short is required on the UUT.

Short on UUT input

In this case the Constant BSC is used as a source of impedance. This may be set to zero ohms and applied (as with any other source) to the UUT pins (see case 1).

It would also be possible to apply a signal of zero volts between the UUT pins. This would have the same effect as short always has a potential of zero volts across it. This would not work if the short has a tolerance or is not precisely zero ohms, or if the UUT pins floated above zero volts.

The Load BSC should not be used as a load on the input of a UUT as it is a transformation BSC and itself expects an input.

Short on UUT output

This may be implemented by using the Load BSC. The UUT is the input to the Load BSC as illustrated in case 2. The Load is set to zero ohms and connected to the UUT pins. The Load BSC does not require an output as no measurement is likely to be taken and the signal will not normally be passed to another element, both of which would be pointless after a short.

Note that the Load BSC will not actually change the output from the UUT so a simulation will not give a representative output in this situation.

It would always be possible to treat the UUT output as an input and use the Constant BSC as a source of impedance. This would be set to zero ohms and applied to the UUT pins as in the previous UUT input example. In this case the result of a simulation may or may not provide a representative result because effectively two signals of different types are being connected in parallel.

Use of the Load BSC—Summary

1. The Load BSC (as defined by the SML) has no effect on a signal.
2. It may not be used as a network element.
3. It is used in association with a connector BSC listing the UUT pins. In simple terms, the Load is usually the first BSC immediately after the connector which lists the UUT pins.
4. It indicates that a Load is required to be connected to ensure the correct operation of a signal (1641 is a *signa*l definition standard).
5. A Load BSC can only have a single impedance value, which applies to all impedances in a Load.
6. If different impedance values are required, separate model into multiple two wire loads.
7. If Load does not seem to fit the application, a different model entirely may be required.

Use of a source BSC of type Impedance—Summary

1. It is used as an input to a UUT.
2. It applies a *signal* of type Impedance, i.e. no assumptions may be made about a voltage or current at the UUT pins where it is connected.
3. The Constant BSC is normally used. This applies an impedance signal on two terminals which may be considered a model of a impedance element such as a resistor.
4. Any source BSC (e.g., Sinusoid, WaveformRamp) may be of type Impedance but many may not be realisable by real instruments.

Use of the load property—Summary

1. It is used when expressing a **value** of a signal of type Physical.
2. It is used to provide the appropriate impedance value for translation between valid units, i.e. between Power and Voltage.