## Electronics Standards and Definitions

## NIM and CAMAC Standards for Modular Instrumentation

Most of the nuclear electronic instrumentation manufactured by ORTEC is designed in accordance with either the NIM standard or the CAMAC standard for modular instrumentation. Both of these international standards encompass a wide range of mechanical and electrical definitions to provide cost and convenience advantages to users of the instruments.

Two of the most important advantages of the NIM and CAMAC concepts are flexibility and interchangeability. The user may configure the optimum system for a particular application, and later easily restructure the instruments as required for different experiments or measurements. In addition, an existing system can be updated with a few new modules, thereby augmenting the value of instrumentation on hand. As experimental demands increase, or as advancing technology makes new instruments available, new modules can be added to the system with assurance of compatibility.

Both the NIM and CAMAC standards incorporate modular instruments that plug into a “bin” or “crate,” and derive their power from a standard power supply attached to the rear of the bin (crate). The CAMAC standard differs from the NIM standard in two important ways. First, the CAMAC crate has a built-in, digital data bus to provide computer communications with the modules. Second, the narrowest CAMAC modules are exactly half the width of the minimum NIM module width. Power plug adapters are available from several manufacturers to permit NIM modules to slide into a CAMAC crate and derive their power from the CAMAC power supply.

Some of the ORTEC products are manufactured in “bench-top” or “stand-alone” packages for applications that demand a specific solution. In such cases the unit typically draws power from 90 V ac, 117 V ac, or 240 V ac, and generates its own dc voltages internally. The rechargeable, battery-operated, field-portable spectrometers are an example of this packaging. For the stand-alone and bench-top packages the analog and digital signals also conform to the NIM, ECL, and TTL standards described on the following pages.

As a result of the popularity of personal computers, many of the NIM, stand-alone, and bench-top instruments provide their own interface to a personal computer. Such interfaces can be made via the IEEE-488, RS-232-C, Ethernet, USB, and printer-port standards, or by the ORTEC Dual-Port Memory Interface. A number of the data control and acquisition products are also available on cards that plug into the ISA or PCI bus inside the personal computer.

### NIM Standard

All ORTEC NIM instrumentation conforms to the May 1990 Revision of the NIM standard [formerly TID 20893 (Rev) and NIM/GPIB]. Please refer to DOE/ER-0457T, U.S. NIM committee, May 1990; Standard NIM Instrumentation System, NTIS, U.S. Department of Commerce, Springfield, Virginia 22161.

**CAMAC Standard**
All ORTEC CAMAC instrumentation conforms to the CAMAC standard: IEEE Standard 583-1982, reaffirmed 1994, IEEE Standard Modular Instrumentation and Digital Interface System (CAMAC), Institute of Electrical and Electronics Engineers, Inc., P.O. Box 1331, 445 Hoes Lane, Piscataway, NJ 08855-1331.

**Linear and Logic Signal Standards and Connections**
Because many ORTEC instruments utilize both linear and logic signals, it is important to distinguish between linear and logic connections when setting up the equipment. The amplitude of a linear signal contains information about the charge or energy deposited by a detected event. Therefore, linear signals vary over a range of amplitudes. The analysis of linear signal amplitudes from an instrument reveals the pulse-height spectrum of the detected events. In contrast, logic signals have a fixed amplitude and shape. They are used to count events, provide timing information, and to control the function of subsequent instruments in a system. Both linear and logic signal connections are made by coaxial cables and standard BNC, LEMO, or SMA connectors. Some logic signal connections are made with ribbon or multi-wire cable terminated in multi-pin connectors.

**Slow Linear Signals**
Slow linear signals generally have rise times longer than 50 ns, and durations ranging from 0.5 to 100 μs. In ORTEC modules, these signals conform to the NIM-Standard Preferred Practices for 0 to 10-V spans. Slow linear signals may be unipolar and positive in polarity, or bipolar with the positive polarity occurring first. In either case, it is the range from 0 to +10 V that is analyzed for pulse amplitude information.

Standard polarity and span do not apply to the linear signal between the preamplifier and the amplifier. This signal must be variable in span and polarity to accommodate particular applications. However, ORTEC charge-integrating pre-amplifiers typically furnish a 50-μs (or greater) time-constant tail pulse to the main amplifier. The main amplifier accommodates this standardized input pulse with a compatible pole-zero cancellation circuit. In addition, ORTEC main amplifiers designed for energy or pulse-height spectroscopy accept either positive or negative input polarities.

Most ORTEC instruments provide the slow linear output signals through a very low source impedance, typically <1 Ω. The low impedance allows connection of almost any load without loss of signal amplitude. For example, a 100-Ω load may be driven to the full 10-V span. The low-impedance outputs are simple to use, because they permit paralleled multiple loads without loss of span. A 93-Ω coaxial cable, such as RG-62A/U, is normally used to connect slow linear signals between modules.

A potential problem with the low-impedance output is oscillation caused by reflection from unterminated cables more than 1.5 meters in length. For this reason, long 93-Ω coaxial cables should be terminated at the receiving end by a 93-Ω load. This is usually accomplished by adding a Tee connector and a 100-Ω terminator on the input to the module at the receiving end. The 100-Ω terminator in parallel with a 1000-Ω or larger input impedance in the module provides adequate termination of the 93-Ω cable.

An alternative solution to the oscillation problem is to use the 93-Ω output. This slow linear output is provided, in addition to the low-impedance output, on many ORTEC instruments. The receiving end can be left unterminated. The 93-Ω output provides termination of the cable at the signal source. The 93-Ω output can be used for full-span signal transfer only if the impedance of the load at the receiving end is very large compared to 93 Ω. If the 93-Ω source must drive a 93-Ω or 100-Ω load, half the span will be lost. The chief virtue of the 93-Ω output is stability against oscillation for variable cable conditions.

ORTEC preamplifiers for energy spectroscopy usually employ a 93-Ω output impedance to facilitate the use of long cables between the preamplifier and the main amplifier. Normally a 93-Ω cable should be used on these preamplifiers, and the 100-Ω terminator should be omitted at the receiving end.

**Fast Linear Signals for Timing**

Fast linear signals for timing measurements typically have rise times less than a few nanoseconds, and durations less than 1 μs. Historically, these signals were often derived from the anode of a photomultiplier tube, and this usage dictated the convention of using a negative polarity signal. The amplitude span for these signals may be 0 to –1 V, 0 to –5 V, or 0 to –10 V, depending on the device generating the signals. Because of the fast rise time, interconnections between modules are always made with a 50-Ω coaxial cable, and the cable is always terminated with a 50-Ω load at the receiving end. Modules intended for use with these signals normally have a 50-Ω input impedance. For modules with a high input impedance, a Tee and 50-Ω terminator can be added at the input to properly terminate the cable. Devices generating the negative, fast, linear signals can have either a very high output impedance (current source) or a very low output impedance (<1 Ω). An example of the very high output impedance is the anode output of a photomultiplier tube. At the opposite extreme, fast amplifiers for use with these signals commonly have an output impedance of <1 Ω.

Signals exhibiting rise times >1 ns can employ any of a variety of 50-Ω coaxial cable types and BNC or LEMO connectors. However, signals with sub-nanosecond rise times demand high-quality RG-58A/U coaxial cable terminated in SMA connectors in order to maintain the rise time. Cable length can also be important in avoiding degradation of signal rise time. For example, the total length of the RG-58A/U cable must be restricted to <1.7 meters to preserve the 350-ps rise time from a Model 9306 Preamplifier delivering signals from a microchannel plate detector. For signals having 2-ns rise time, significant degradation of the rise time is experienced for coaxial cable lengths longer than 4 meters. In general, the limiting rise time of a coaxial cable is proportional to the square of its length.

**NIM-Standard Positive Logic Signals**

The NIM-standard, positive logic signal is used for slow-to-medium-speed logic signals with repetition rates from dc to 1 MHz. The NIM-standard Preferred Practice provisions define this signal by the following amplitude limits:

| | Output (must deliver) | Input (must respond to) |
|---|---|---|
| Logic 1 | +4 to +12 V | +3 to +12 V |
| Logic 0 | +1 to –2 V | +1.5 to –2 V |

In addition, ORTEC imposes the following further standards on the NIM-standard, positive logic signals:

| | |
|---|---|
| Pulse width: | nominally 0.5 μs |
| Source impedance: | nominally ≤10 Ω |
| Input impedance: | nominally ≥1000 Ω |

Connection of the NIM-standard, positive logic sources and loads should be made with 93-Ω coaxial cable. RG-62A/U cables with UG-260/U (BNC) connectors are recommended. For cable lengths under 1.5 m, impedance-matching cable termination is not usually required, because reflections are not a problem. With longer cable lengths, proper termination with a 100-Ω terminator at the receiving end is advisable to prevent cable reflections.

**NIM-Standard Fast Negative Logic Signals**

The NIM-standard, fast negative logic signal is normally used when rise time or repetition rate requirements exceed the capability of the positive logic pulse standard. The NIM Preferred Practice provisions define this signal as one that is furnished into a 50-Ω impedance with the following characteristics:

| | Output (must deliver) | Input (must respond to) |
|---|---|---|
| Logic 1 | –14 to –18 mA | –12 to –36 mA |
| Logic 0 | –1 to +1 mA | –4 to +20 mA |

Because of the fast rise time, the fast negative logic signal must be used with properly terminated cables to prevent reflections. Therefore, 50-Ω cables terminated in 50 Ω at the receiving end must be used. RG-58A/U cables with UG-88/U (BNC) connectors, or RG-174 cable with LEMO connectors, are recommended. Most inputs that are designed to accept the NIM fast negative logic pulse have a 50-Ω input impedance. For inputs with a high input impedance, proper termination can be achieved using a Tee and a 50-Ω terminator on the module input.

The rise time of the NIM fast negative logic pulse is not specified in the NIM Preferred Practice provisions. In ORTEC instruments the rise time is typically 2 ns. The leading edge is normally used for all triggering, and pulse width is unimportant except for repetition rate considerations.

In systems that mix the use of NIM fast negative logic and ECL logic, the NIM fast negative logic is sometimes referred to as a NIM output.

**ECL Logic Signals**

In experiments employing a very large number of identical detectors, duplication of the functions in each detector channel makes mass connection of the similar signals desirable. Instruments developed for such applications usually incorporate up to 16 channels of the same function in a single module. A convenient method of interconnecting these channels from module to module incorporates a 34-pin (in two 17-pin rows) connector, and either a ribbon cable or a cable containing 100-Ω twisted pairs. The standard used for fast logic signals with this system is the ECL standard. The signal standard for ECL logic at 25°C is:

| | Output (must deliver) | Input (must respond to) |
|---|---|---|
| High state | –0.81 to –0.98 V | –0.81 to –1.13 V |
| Low state | –1.63 to –1.95 V | –1.48 to –1.95 V |

The ECL output driver provides complementary outputs. As one output switches from the high state (nominally –0.9 V) to the low state (nominally –1.8 V), the complementary output switches from the low state to the high state. Usually, differential receivers are used for ECL inputs to a module to take advantage of the complementary outputs from the ECL output driver. This has the benefit of avoiding ground loops between modules, and minimizing common mode noise interference. ECL signals have rise times less than 2 ns. Therefore, the twisted pair of wires conveying the complementary signals must be terminated at the receiving end with a 100-Ω resistor connected between the pair of wires. When several modules are driven through connectors placed part way along the cable, the 100-Ω termination should be included only in the last module at the receiving end of the cable.

**TTL Logic Signals**

The slow logic functions inside the instruments are usually designed with integrated circuits employing the TTL logic standard. The standard signal levels for TTL logic are:

| | Output (must deliver) | Input (must respond to) |
|---|---|---|
| Logic 1 | +2.4 to +5 V | +2 to +5 V |
| Logic 0 | 0 to +0.4 V | 0 to +0.8 V |

Comparison of the signal definition tables show that TTL logic levels are not guaranteed to be compatible with the NIM-standard positive logic levels. For this reason the TTL levels are normally converted to the NIM positive logic standard for the module's inputs and outputs. Pragmatically, one often finds that the NIM positive inputs or outputs have been designed in such a way that they will work with the TTL logic levels. In fact, suppliers of NIM modules have counted on that situation to eliminate the expense of NIM inputs and outputs on the instrument. In such cases the user should be cautious and check to ensure compatibility under all operating conditions.

Of course, TTL logic levels are frequently used for interconnections occurring on proprietary buses between modules. An example is the bus used in the ORTEC Dual-Port Memory Interface.

**Detector Bias Voltage Cables and Connectors**

The detectors used for photons, ions, and other charged particles normally require a bias voltage in order to function properly. Detector bias voltages range from a few volts up to several thousand volts, depending on the type of detector. For photomultiplier tubes, the bias voltage is applied to the cathode, dynodes, and anode through the resistive network in a photomultiplier tube base. Other types of detectors receive their bias voltage through a filter network built into the preamplifier assembly. For voltages up to 5 kV dc, the connection from the bias power supply to the preamplifier, or to the photomultiplier tube base, is made with RG-59A/U coaxial cable and SHV connectors.

With detectors that receive their bias voltage via the preamplifier input connector, several types of cables and connectors are used. The choice of cable and connectors is usually controlled by voltage limits, and by the connectors offered on the detector and the preamplifier. For detectors with Microdot connectors, a 100-Ω Microdot cable (Microdot 293-3913) with compatible connectors is normally employed. Although this cable can handle voltages up to 2500 V dc, the preamplifier input rating normally limits the bias to less than 1000 V dc. Frequently, an adapter to convert from the Microdot connector to a BNC connector is necessary in order to accommodate the preamplifier input connector. For bias voltage up to 1000 V dc, RG-62A/U cable with BNC connectors can be used. This is particularly convenient for detectors and preamplifiers equipped with BNC connectors. For bias voltages from 1 to 5 kV, RG-59A/U cable with SHV connectors must be used. Consequently, preamplifiers that are rated for bias voltages above 1 kV have SHV input connectors.

A long cable connection between the detector and the preamplifier adds input capacitance, and also makes the electronics more susceptible to picking up environmental noise. Both effects can cause a degradation of the amplitude resolution and the timing performance. Therefore, the detector-to-preamplifier connection should be kept as short as possible. Because of noise considerations and the high voltages involved, cables delivering bias voltages are not terminated in their characteristic impedance.