

## Choosing the Right Counting Solution

ORTEC offers a variety of instruments to configure counting systems for many applications, from simple to complex. The following descriptions and selection charts will help identify the functions and data interfaces needed for the application.

## The Basic Functions of Counting Systems

There are five general classes of counting systems: counters, timers, ratemeters, multichannel scalers and time digitizers, and digital signal averagers. Counters simply count the number of input pulses received during the counting period. ORTEC offers four of the five. Counters simply count the number of input pulses received during the counting period. Timers count pulses generated by an internal clock and are used to measure elapsed time or to establish the length of the counting period. Ratemeters provide a meter readout of the pulse count rate and convert this frequency to a DC voltage or current proportional to the average count rate per unit of time. This is normally expressed in counts per second (counts/s).

Two types of ratemeters are available from ORTEC: linear scale (Model 661), or combined logarithmic and linear scales (Models 449 and 9349). The Model 449 has positive and negative inputs with an optional audible alarm. The Model 9349 has a rear-panel, fast, negative input.

All ORTEC NIM timers contain preset controls to establish the duration of the counting period. When counting is initiated, the internal clock pulses are counted until the preset condition is reached; at that time, counting is stopped in all counters connected to the common gate line of the master timer. If the external input is used, the preset control will apply to counting of the pulses at the external input and will result in preset count operation.

Multichannel Scalers counts the number of events that occur during the time interval  $t$  to  $t + \Delta t$  as a function of time. The interval  $\Delta t$  is called the dwell time. The time  $t$  is quantized into channels or bins by the relation  $t = i \Delta t$ , where  $i$  is the bin number (an integer). Dwell times can be selected from fractions of a nanosecond to hours, and the total number of bins ranges from 4 to 67 million. When the scan is started, the MCS begins counting input events in the first channel of its digital memory. At the end of the selected dwell time the MCS advances to the next channel of memory to count the events. This dwell and advance process is repeated until the MCS has scanned through the preset number of memory channels. The display shows a graph of counts versus dwell channels from zero time on the left to end of the scan on the right.

Time digitizers measure the arrival time of individual events with a quantization precision,  $\Delta t$ , selectable from picoseconds to nanoseconds. The time spectrum is represented by  $t = i \Delta t$ , where  $i$  is the bin number (an integer). The number of bins is typically on the order of 65,000 to 67 million. Time digitizers can measure the time spectrum with a quantization precision that is at least three orders of magnitude smaller than is offered by multichannel scalers. This exceptional advantage in time resolution is sometimes gained at the expense of pulse-pair resolution. For example, the MCS-pci delivers a 6.7-ns pulse-pair resolving time, whereas the Model 9308-pci time digitizer is limited by interpolator dead time to 50 ns.

Both multichannel scalers and time digitizers are triggered by a start pulse that defines zero time. Typically, the start pulse corresponds to the stimulation of a process. The "products" of the process are counted as a function of time by the MCS, or their emission times are measured by the time digitizer. In a single pass through the selected time span, both instruments can record multiple events. If the process is repeatable, the data from multiple passes through the time span can be summed to improve the statistical precision. The final result is a histogram showing the probability of observing the product events as a function of time.

Multichannel scalers often have the advantage over time digitizers when dwell times much larger than a few nanoseconds are required, particularly in applications that demand pulse-pair resolving times much better than 50 ns. A time digitizer is the preferred solution when the measurement demands sub-nanosecond time quantization.

The Model 9353 straddles the time digitizer and MCS functions. It behaves like a time digitizer with 1-ns pulse-pair resolving time for 100-ps digital resolution. For digital resolution  $>1$  ns it acts like an MCS, counting multiple stop pulses in a bin on each scan.

## MCS vs. a Counter and Timer

Although a computer-controlled counter and timer can also be used to record counting rate as a function of time, the MCS technology offers several important advantages. The time taken to read, clear, and start a conventional counter at the end of each counting interval can range from microseconds to milliseconds. This dead time causes significant gaps in the recorded data. High performance multichannel scalers have negligible dead time between counting intervals (channels), and this avoids blank regions in the recorded time profile. Conventional counters and timers rarely handle time intervals shorter than 10 ms, whereas multichannel scalers are available with minimum dwell times ranging from 2  $\mu$ s down to 5 ns. Furthermore, the MCS products in this section include standard operating software to acquire, display, and manipulate the data. With a conventional counter and timer one must develop custom software for the intended application.

# Counters/Ratemeters/ Multichannel Scalers

## Multiple Stop Advantages over a Time-to-Amplitude Converter (TAC)

Both an MCS and a time digitizer can operate as a multiple-stop time spectrometer. On each scan through the selected time span, both instruments can record multiple stop events. In the case of the MCS this is achieved by counting "stop" events in the appropriate bin as they arrive. For the time digitizer, the arrival time for each event is recorded as the event occurs. Clearly, both instruments can record multiple stop events following each start trigger. In contrast, a time-to-amplitude converter (TAC) can record only one stop event for each start trigger. (See the Time-to-Amplitude Converters introduction.) The multiple stop capability allows the Model 9308-pci Picosecond Time Analyzer to acquire data at much higher rates than a TAC/MCA system for time spans >250 ns. The 9353 has this same advantage over a TAC for time spans  $\geq 50$  ns. **For example, on a time span of 81.92  $\mu$ s, a 9353 can acquire data 42,000 times faster than a TAC, and a Model 9308 picosecond TIME ANALYZER can exceed the TAC data acquisition rate by a factor of 1600.** These comparisons are based on minimizing spectrum distortion by maintaining <1% dead time losses. The advantages are even greater for longer time spans.

Multichannel scalers and time digitizers have an upper limit on the event rate as a result of the dead time caused by the pulse-pair resolving time. Generally, the probability of detecting a single event within the pulse-pair resolving time must be kept less than 2% during each scan, in order to limit the dead time losses and distortions to less than 1%. In the application Time-of-Flight Mass Spectrometry (TOF-MS) analyzing the output of a chromatograph (LC or GC), this places an unproductive limit on the ion rates that can be accommodated. As a result, TOF-MS spectra collected for 100-ms time intervals contain circa 20 counts in the largest peaks. This leads to statistical errors in excess of 22%, and correspondingly high detection limits. A Digital Signal Averager would be a much more appropriate solution for this type application.

## Accounting and Correcting for Dead Time Effects

With both multichannel scalers and time digitizers, dead times in the counting system can cause distortion of the measured time spectrum. One means of minimizing the distortion is to operate at counting rates low enough to keep dead time losses below 1%. Usually this strategy ensures that the spectrum distortion will be <1%. To achieve this goal one must know the equations linking counting rate, dead times, and dead time losses. Fortunately, these equations lead one to correction algorithms that can be applied in several practical cases to enable operation at significantly higher counting rates.

### Case 1: $\Delta t \ll T_d$

#### Cascaded Dead Times:

As explained in the introduction to the Fast Timing Discriminators section, the dead time experienced in the counting chain is typically composed of two cascaded components,  $T_e$  and  $T_{ne}$ .  $T_e$  is the extending dead time caused by the duration of the analog signal from the detector at the noise threshold of the timing (or counting) discriminator. It is an extending dead time because a second analog pulse occurring during a preceeding pulse extends the dead time by one pulse width from the arrival time of the second pulse. The non-extending dead time,  $T_{ne}$ , can be caused by the pulse width of the discriminator output driver, or it can be a longer dead time contributed by a circuit in the MCS or time digitizer. Sufficient accuracy<sup>1,2</sup> will be achieved if one chooses the longer of these two dead times to represent  $T_{ne}$ . A second pulse occurring during  $T_{ne}$  is ignored and does not affect the dead time. It is convenient to define the approximate dead time in the system as

$$T_d \approx T_e + U(T_{ne}-T_e) (T_{ne}-T_e) \quad (1)$$

where  $U(T_{ne}-T_e)$  is a unit step function defined by

$$\begin{aligned} U(T_{ne}-T_e) &= 1 \text{ for } T_{ne} > T_e \\ &= 0 \text{ for } T_{ne} \leq T_e \end{aligned} \quad (2)$$

Under that definition, the equations for Case 1 are valid if the quantization interval,  $\Delta t$ , is insignificant compared to  $T_d$ . This is the practical situation encountered in the Model 9308 picosecond TIME ANALYZER. For the Model 9308,  $T_d \approx 45$  ns and the maximum size of the bin width,  $\Delta t$ , is 2.5 ns.

Presume a time digitizer that has summed the repetitive spectra from  $n$  start triggers. The counts in the  $i$ th bin of the resulting spectrum (after suffering dead time losses) are defined to be  $q_i$ , and the time,  $t$ , is related to the bin number by

$$t = i \Delta t \quad (3)$$

<sup>1</sup>Jörg W. Müller, *Nucl. Instr. Meth.* 112, (1973), 47–57, Fig. 3.

<sup>2</sup>D.R. Beaman, et al., *J. of Physics E: Sci. Instr.* (1972), 5, 767–776.

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By analogy to equation (3) it is convenient to define the quantized dead times,  $\tau_e$ ,  $\tau_{ne}$ , and  $\tau_d$ , by equations (4).

$$T_e = \tau_e \Delta t \quad (4a)$$

$$T_{ne} = \tau_{ne} \Delta t \quad (4b)$$

$$T_d = \tau_d \Delta t \quad (4c)$$

Note that  $i$ ,  $\tau_e$ ,  $\tau_{ne}$  and  $\tau_d$  are all rounded to integer values.

The number of counts that would have been recorded in bin  $i$  if the dead time were zero is defined to be  $Q_i$ . The distorted spectrum recorded in the measurement is represented by  $q_i$ , whereas  $Q_i$  is the undistorted spectrum that is sought.

When the counting rates are low enough to yield single-ion or single-photon counting, one can apply statistical sampling theory. Poisson Statistics can also be applied directly, provided the dead time losses are negligible<sup>3</sup>.

In equation (5),  $q_i/n$  is the probability of recording an event in the  $i$ th bin during a single pass through the time span. It is composed of three probabilities<sup>4</sup>, as described in the right hand side of the equation.

## Cascaded Dead Time Equation:

$$\frac{q_i}{n} = \frac{Q_i}{n} \exp \left\{ - \sum_{j=i-\tau_e}^{i-1} Q_j/n \right\} \left[ 1 - U(\tau_{ne} - \tau_e) \sum_{j=i-\tau_{ne}}^{i-\tau_e-1} Q_j/n \right] \quad (5)$$

The first term,  $Q_i/n$  is the probability that an event will arrive at the detector at a time suitable to be categorized in bin  $i$ . In order to be recognized as distinct from previous analog pulses there must be no pulses arriving at the detector in the time interval  $\tau_e$  preceding the pulse for bin  $i$ . That probability is given by the exponential term in equation (5). If a pulse had been counted by triggering the non-extending dead time in the time interval  $\tau_{ne}$  preceding the pulse for bin  $i$ , the pulse for bin  $i$  would be lost. Consequently, the term in the square brackets is the probability that no pulses are recorded in the preceding time interval  $\tau_{ne}$ . Note that the sum stops at  $j = i - \tau_e - 1$  because the exponential term already guarantees no pulses occurred in the time interval from  $j = i - \tau_e$  to  $i - 1$ .

Equation (5) can be rearranged to get the formula for computing the corrected spectrum,  $Q_i$ , from the distorted spectrum,  $q_i$ .

$$Q_i = \frac{q_i}{\exp \left\{ - \sum_{j=i-\tau_e}^{i-1} Q_j/n \right\} \left[ 1 - U(\tau_{ne} - \tau_e) \sum_{j=i-\tau_{ne}}^{i-\tau_e-1} Q_j/n \right]} \quad (6)$$

One applies the correction algorithm by starting at bin  $i = 0$ , while presuming that  $q_i$ ,  $q_j$ , and  $Q_j$  are all zero for negative values of  $i$  and  $j$ . For each  $i$ , the value  $Q_i$  is calculated from equation (6) using the recorded values  $q_i$  and  $q_j$  along with the  $Q_j$  values calculated for the previous values of  $i$ . This correction calculation is applied bin by bin until the maximum bin in the spectrum has been treated. At that point the list of  $Q_i$  values is the corrected spectrum.

If there truly were no counts to be detected for negative values of  $i$ , then the  $Q_i$  data near  $i = 0$  will represent the true spectrum before dead time losses. If the detector was actually responding to events for negative values of  $i$ , then  $Q_i$  will be underestimated until the bin number exceeds several times  $\tau_d$ . Frequently, this shortcoming can be eliminated by inserting a coaxial cable delay of the appropriate length between the detector and the stop input on the time digitizer.

## Single, Extending Dead Time:

For a system where the detector pulses are longer than any other dead times in the system ( $\tau_e > \tau_{ne}$ ), equation (5) simplifies to the equation for a single, extending dead time<sup>4</sup>.

$$q_i = Q_i \exp \left\{ - \sum_{j=i-\tau_e}^{i-1} Q_j/n \right\} \quad (7)$$

<sup>3</sup>Ron Jenkins, R.W. Gould, and Dale Gedcke, *Quantitative X-Ray Spectrometry*, Marcel Dekker, New York, (first edition), 1981, Chap. 4.

<sup>4</sup>D.A. Gedcke, Development notes and private communication, Nov.–Dec. 1996.

<sup>5</sup>P.B. Coates, *Rev. Sci. Instrum.* 63 (3), March 1992, 2084.

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## Single, Non-extending Dead Time:

The other extreme is a system in which detector pulse widths are negligible compared to the non-extending dead time in the MCS or time digitizer. In that case, equation (6) simplifies to<sup>4,5</sup>

$$Q_i = \frac{q_i}{1 - \sum_{j=i-\tau_{ne}}^{i-1} q_j/n} \quad (8)$$

## Accuracy of the Dead Time Correction:

It can be demonstrated by substituting known values into equations (6), (7) and (8) that all three equations yield predictions of  $Q_i / q_i$  that are within 1% of each other provided  $Q_i / q_i < 1.15$  (i.e., **a dead time correction < 15%**), and provided  $\tau_d$  is substituted for the single dead times in equations (7) and (8). This allows a simpler correction algorithm to be implemented using equation (8). In fact, the algorithm using equation (8) can start at the maximum value of  $i$  and proceed towards  $i = 0$ , while replacing  $q_i$  with  $Q_i$  in the data file. This is the procedure used in the **Model 9308** software.

Without the dead time correction algorithm, one would have to limit the counting rate to achieve <1% dead time losses in order to limit the spectrum distortion to <1%. By applying the dead time correction algorithm, one can typically operate at a factor of 10 higher dead time loss, while still achieving <1% spectrum distortion. This implies **a factor of 10 higher data rates**. However, the accuracy of the correction is limited by the factors discussed next.

If the time spectrum is constant across all bins, it is easy to show that a 10% error in the assumed value for the dead time in equations (6), (7), or (8) will lead to < 1% error in the corrected counts if  $Q_i / q_i < 1.10$ . A more serious case is a narrow peak centered at bin  $i$ , and preceded by an intense, narrow peak centered at bin  $j = i - \tau_d$ . A small error in the presumed value for  $\tau_d$  can result in either including or excluding the peak at bin  $j$  in the dead time corrections. This can make a large difference in the dead time correction applied to the peak at bin  $i$ . An additional issue is the error in rounding off the presumed dead time to the nearest integer value. This leads to round-off errors at the two limits of the sums in the equations. That effect can be restricted to an error <1% if one ensures that  $q_j/n < 0.005$  for all  $j$ . Clearly, it is important to use an accurately measured dead time in the correction formula.

By applying basic probability theory, it can be shown that the statistical variance in the recorded counts  $q_i$  is given by<sup>4</sup>

$$\sigma_{q_i}^2 = q_i (1 - q_i/n) \approx q_i \quad \text{for } q_i/n \ll 1 \quad (9)$$

Moreover, for the sum of the recorded counts in any number of bins, such as

$$M = \sum_{j=i-\tau}^{i-1} q_j \quad (10)$$

the statistical variance in the sum is

$$\sigma_M^2 = M = \sum_{j=i-\tau}^{i-1} q_j \quad (11)$$

A straight forward propagation-of-errors computation predicts the statistical variance in the corrected counts  $Q_i$  calculated from equation (8) to be<sup>4,5</sup>

$$\sigma_{Q_i}^2 = Q_i k_i \quad (12)$$

where  $k_i$  defines the magnification factor arising from the variances in the  $q_i$  and  $q_j$  in equation (8), i.e.,

$$k_i = (Q_i / q_i) + (Q_i / q_i)^2 [(Q_i / q_i) - 1] (q_i/n) \quad (13)$$

The effect of  $k_i$  is small for dead time corrections  $Q_i / q_i < 1.15$ , but the second term of  $k_i$  escalates rapidly for higher dead time corrections.<sup>5</sup>

# Counters/Ratemeters/ Multichannel Scalers

## Case 2: $T_d \ll \Delta t$ , with Counts Essentially Constant Across $\Delta t$

This solution is applicable to multichannel scalers. Typically the dead time  $T_d$  is  $< 20$  ns. If the dwell time is large compared to 20 ns (for example: 2000 ns) and the counting rate varies insignificantly during the dwell time of a bin, then one can transform equation (6) into the form that applies for approximately constant counting rate.<sup>4</sup> The result is

### Cascaded Dead Times:

$$Q_i = \frac{q_i}{\exp\left\{\frac{-Q_i T_e}{n \Delta t}\right\} \left[1 - U(T_{ne} - T_e) q_i \left(\frac{T_{ne} - T_e}{n \Delta t}\right)\right]} \quad (14)$$

Note that  $Q_i$  appears on both sides of the equation. So equation (14) must be solved by iteration. If one substitutes the instantaneous counting rates defined by equation (15) in equation (14), the constant counting rate formula in the Fast Timing Discriminator section are generated.

$$R_i = \frac{Q_i}{n \Delta t} \quad (15a)$$

$$r_i = \frac{q_i}{n \Delta t} \quad (15b)$$

In some applications the detector pulse width will exceed the non-extending dead time ( $T_e > T_{ne}$ ) leading to

### Single, Extending Dead Time:

$$q_i = Q_i \exp\left\{\frac{-Q_i T_e}{n \Delta t}\right\} \quad (16)$$

If the detector pulse width is negligible compared to the non-extending dead time, equation (14) becomes

### Single, Non-extending Dead Time:

$$Q_i = \frac{q_i}{1 - (q_i/n)(T_{ne}/\Delta t)} \quad (17a)$$

or

$$q_i = \frac{Q_i}{1 + (Q_i/n)(T_{ne}/\Delta t)} \quad (17b)$$

As in Case 1, it is convenient and adequate to use equation (17a) when the dead time losses are less than 15%, provided  $T_{ne}$  is replaced with  $T_d$ . Most of the caveats in Case 1 concerning accuracy apply here as well. The one exception is the statistical variance in the recorded counts  $q_i$  which is given by<sup>3</sup>

$$\sigma_{q_i}^2 = q_i (q_i / Q_i)^2 \quad (18)$$

for the case of non-extending dead time. The statistical variance in the  $Q_i$  calculated from equation (17a) is given by<sup>3</sup>

$$\sigma_{Q_i}^2 = Q_i (Q_i / q_i) \quad (19)$$

Note that large dead time corrections magnify  $\sigma_{Q_i}$  (the standard deviation in the corrected counts) by the square root of the correction factor,  $Q_i / q_i$ . Equations (18) and (19) are valid if  $\Delta t \gg T_d$  and  $\Delta t$  is large compared to the mean spacing between pulses. The expressions for the  $\sigma_{q_i}$  and  $\sigma_{Q_i}$  corresponding to extending dead time are approximately the same as equations (18) and (19) for  $Q_i / q_i < 1.1$ , but diverge wildly from the non-extending case for large correction factors<sup>3</sup>. This provides an incentive for limiting dead time losses to  $< 10\%$ .

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## Case 3: $T_d \sim \Delta t$

In this case there is not a practical algorithm for making accurate dead time corrections in the time histogram. However, one can use the equations above and the equations in the Fast Timing Discriminators section to predict the severity of the dead time losses and to determine the limitations on the counting rates that guarantee negligible dead time losses.

## Case 4: Counting Rates Vary Significantly Across $\Delta t$

The statements under Case 3 apply.

## Software Programmer's Toolkits

Each multichannel scaler and time digitizer includes a complete software package to operate the instrument in virtually all applications. Occasionally, it is advantageous to integrate the instrument into a software program specific to a unique application. ORTEC offers the Programmer's Toolkits summarized in the table below to facilitate special programming.

### Software Programmer's Toolkits

Toolkit	Supports	Operating Environment
A11-B32 (CONNECTIONS Programmer's Toolkit)	MCS-pci	Windows 2000/XP
A69-BX (pTA Software included with each 9308-pci)	9308-pci pTA	Windows 2000/XP
9353-B32 (included with each 9353)	9353	Windows 2000/XP

## MCS Selection Guide

Feature	MCS-pci
<b>Package</b>	Plug-In PC Card
<b>Bus</b>	PCI
<b>Dwell Time</b>	
Minimum	100 ns
Maximum	1300 s
<b>Memory Length (channels)</b>	65,536
<b>Time Span (Full Memory Length)</b>	
Minimum	6.55 ms
Maximum	2.7 years
<b>Inputs and Rates</b>	
Fast +/- Discriminator	150 MHz
SCA	1 MHz
<b>SCA or Discriminator Controls</b>	Computer
<b>SCA Sweep Mode</b>	Yes
<b>Dead Time Between Channels</b>	Zero
<b>End-of-Pass Dead Time</b>	Zero
<b>Ramp</b>	Standard. Sawtooth or Triangular with Computer Adjustable Start/Mid/End Points
<b>Software Base</b>	Microsoft® Windows™
<b>User-Defined Calibration of Horizontal Axis</b>	Linear, Quadratic, or Cubic
<b>Programmer's Toolkit</b>	A11-B32

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## Time Digitizer Selection Guide

Feature	Model 9308-pci picosecond TIME ANALYZER	Model 9353 100-ps Time Digitizer/MCS
<b>Package</b>	2-wide NIM Module with PCI-bus interface	Plug-in PCI Card
<b>Time Quantization</b>		
Minimum	1.221 ps	100 ps
Maximum	2.5 ns	13 $\mu$ s
<b>Memory Length (bins)</b>	65,536	67,000,000
<b>Time Span</b>		
Minimum	80 ns	51.2 ns
Maximum	163.84 $\mu$ s	6.7 ms
<b>Time Offset</b>		
Minimum	0 ns	0 ns
Maximum	324.92 $\mu$ s	6.7 ms
<b>Input and Rates</b>	Fast Negative NIM: 20 MHz burst; 2 MHz continuous	Positive or Negative: 1 GHz burst; >10 MHz continuous
<b>End-of-Pass Dead Time</b>	<1 $\mu$ s	0
<b>Software Base</b>	Microsoft Windows	Microsoft Windows
<b>User-Defined Calibration of Horizontal Axis</b>	Linear, Quadratic, or Cubic	Linear, Quadratic, or Cubic; Least Square Fit
<b>Dead Time Correction</b>	Included in Software	Included in Software
<b>Programmer's Toolkit</b>	Included	Included
<b>Operating Modes</b>	Histogramming or List Modes	Histogramming List, Chromatograph, and Trend Modes

## Ratemeters Selection Guide

Model	Type	Full Scale Ranges		Input Types	Pulse-Pair Resolution	Audible Output	Recorder Output	Package and Width	Special Feature
		Minimum	Maximum						
449	Log/Linear	10 counts/s	10 <sup>6</sup> counts/s	+/-Logic pulses >3 V high & >50 ns wide	<100 ns, or <1% of average pulse spacing	449-2 option	YES	NIM-2	0 to 100% zero suppression
661	Linear	25 counts/s	10 <sup>7</sup> counts/s	Positive discriminator; Negative NIM	<40 ns	NO	YES	NIM-1	Fast Response circuit
9349	Log/Linear	10 counts/s	10 <sup>6</sup> counts/s	Negative NIM >4 ns wide	<100 ns, or <1% of average pulse spacing	NO	YES	NIM-2	0 to 100% zero suppression

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## Counters and Timers Selection Guide

Feature	Model Number				
	871	974	994	995	996
Timer (T) and/or Counter (C)	Dual T and C	Quad T and C	Dual T and C	Dual C	T and C
Number of Counters	2 or 1	3 or 4	2	2	1
Number of Timers	0 or 1	1 or 0	1	0	1
Max Rate (MHz)	25	100	100	100	100
Positive Input	Y	Y	Y	Y	Y
Negative Input	Y	Y	Y	Y	Y
Discriminator	Y	Y	Y	Y	Y
Digits Displayed	8	8	8	8	8
Time Base	1 MHz	1 MHz	10 MHz		10 MHz
Gate	Y	Y	Y	Y	Y
+6 V Required		Y	Y*	Y*	Y
Computer Controllable		Y	Opt	Opt	Opt
IEEE-488		Y	Opt	Opt	Opt
RS-232-C (20 mA)		Y	Opt	Opt	Opt
NIM Width	2	2	2	2	1

NOTE: BLANKS INDICATE "NO" or "NONE."

\*Internal +6 V option available (Option 99X-4).

Specifications subject to change  
050207

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[www.ortec-online.com](http://www.ortec-online.com)

Tel. (865) 482-4411 • Fax (865) 483-0396 • [ortec.info@ametek.com](mailto:ortec.info@ametek.com)  
801 South Illinois Ave., Oak Ridge, TN 37831-0895 U.S.A.  
For International Office Locations, Visit Our Website

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