Introduction

The analog signal pulse produced as a result of passage of radiation through a detector usually has very narrow width and amplitude and cannot be directly digitized or counted. Therefore, in most cases, the pulse must first be preamplified before being transferred to other processing units. A preamplifier is an electronic circuit that converts a weak electrical signal into an output signal strong enough to be noise-tolerant and further processed. Three are the main purposes of the preamplifier:

1. To amplify, if necessary, small signals from detectors
2. To shape signals for following signal processing
3. To match impedance between detector and signal chain

The preamplifiers are often placed as close as possible to the detector to reduce the effects of noise and interference. In this way, pick up of stray electromagnetic fields is reduced and cable capacitance, which reduces the signal-to-noise ratio, is minimized.

Different kinds of preamplifiers can be constructed to suit the specific detector and processing requirements. For example, the amplification required depends on the detector type:

- Photomultipliers in scintillation detectors provide gain, so usually no additional gain is required or, if yes, little amplification is necessary (≈ 5-20x)
- Semiconductor detectors, having smaller signals my require much more amplification ~10^3-10^4

Also other parameters (signal-to-noise ratio, range of input signal, response time, power consumption, dynamic range) are considered when designing a preamplification unit and most of them have competing requirements. Another important parameter is the linearity which is required in order to preserve Energy vs. Charge/Voltage relashionship.

The preamplifiers used in radiation detection systems can be divided into three main categories**[1]**:

- voltage-sensitive preamplifier
- current-sensitive preamplifier
- charge-sensitive preamplifier

Voltage-Sensitive Preamplifiers

A voltage-sensitive preamplifier is the most basic type of preamplifier that can be used in radiation detection systems. Its function is to amplify the potential at its input stage by a gain factor that is defined by its components. For such a circuit (**Figure 1**) the voltage at the input stage of the amplifier *Va* is related to the signal voltage *Vs* through the relation

$$V_a = \frac{R_a}{R_s + R_a} V_s$$

where R represents resistance with subscripts *a* for preamplifier input and *s* for signal respectively. For such a preamplifier to work properly it is necessary that it does not draw any current from the source, since any current drawn by it would decrease the potential drop across *Rs*.

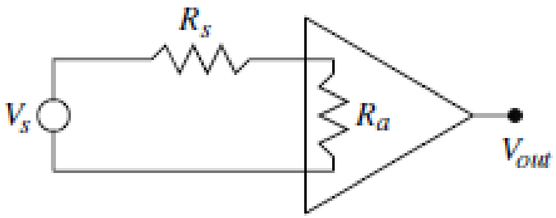

Figure 1: Principle design of a voltage sensitive preamplifier connected to a source, such as a radiation detector output. The input impedance Ra of the preamplifier is kept very large so that it draws minimal current from the source. Picture from **[1].**

This would require its input resistance to be, in a good approximation, much higher then *Rs*. In this approximation *Va* ≈ *Vs* and since the output of a voltage sensitive linear amplifier should be proportional to the voltage at its input stage, we can write

$$V_{out} = A\,V_a \approx A\,V_s$$

where A is the gain of the amplifier..

However since real radiation detectors do possess some capacitance and are essentially charge producing devices, this *Vs* voltage appears through the intrinsic detector capacitance plus any stray capacitance which may be in the input circuit (
Figure 2).

$$V_s = \frac{Q}{C_d}$$

where Q is the charge collected by the readout electrode and *Cd* is the combined detector and stray capacitance. Hence we can conclude that the voltage at the output of a realistic preamplifier, to a good approximation, is given by

$$V_{Out} \approx A\frac{Q}{C_d} \text{ assuming A } >> {}^{R_2}/_{R_1}$$

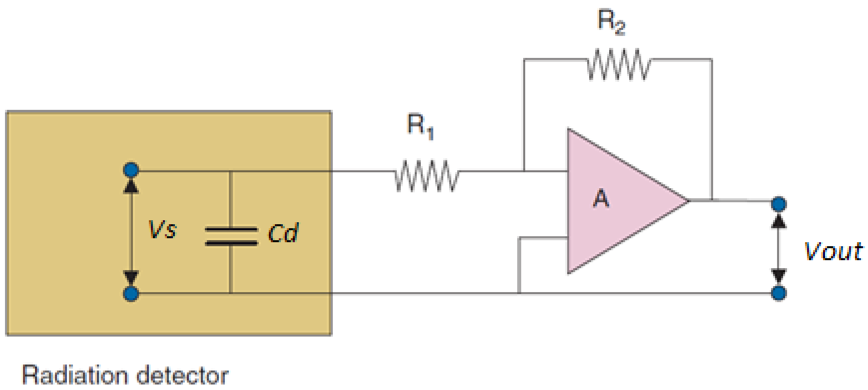

Figure 2: Design principle of a voltage-sensitive preamplifier connected to a source, such as a radiation detector output (left) and its equation (right). Picture from **[2].**

For majority of nuclear detectors, input capacitance is fixed, hence the output pulse of a voltage sensitive preamplifier is proportional to the charge Q released by the incident radiation. However, if the input capacitance varies then the output pulse will no more be proportional to the input charge. For example, in certain semiconduction detectors, the detector capacitance may vary with the operational parameters and in such case the voltage sensitive preamplifier cannot be used and charge sensitive preamplifier has to is the required equipment.

More details about voltage-sensitive preamplifier can be found in **[1]**.

Current-Sensitive Preamplifiers

The current-sensitive preamplifier is generally used with very low impedance devices, so they are not very frequently used with radiation detector. However, in certain applications it is desirable to measure the instantaneous current flowing through the detector. This can be done through a current-sensitive preamplifier, which converts the instantaneous current of the detector into a measurable voltage. Therefore, this device can also be called a current-to-voltage converter. Current sensitive amplifier can be constructed in the same way as a voltage sensitive amplifier with the exception that the input impedance in this case must be kept at the minimum to allow the current to flow through the amplifier **[1]**.

The basic scheme of a current-sensitive preamplifier is shown in **Figure 3.**
The current i_a flowing into the preamplifier of is related to the source current is by

$$i_a = \frac{R_a}{R_s + R_a} i_s$$

This equation implies that the requirement that the current flowing into the preamplifier is approximately equal to the source current can be fulfilled by making preamplifier input impedance very small as compared to source impedance

$$R_a << R_s \implies i_a \approx i_s$$

Since a linear current sensitive preamplifier is simply a current-to-voltage converter, therefore its output voltage is proportional to the source current

$$V_{out} \propto i_s$$

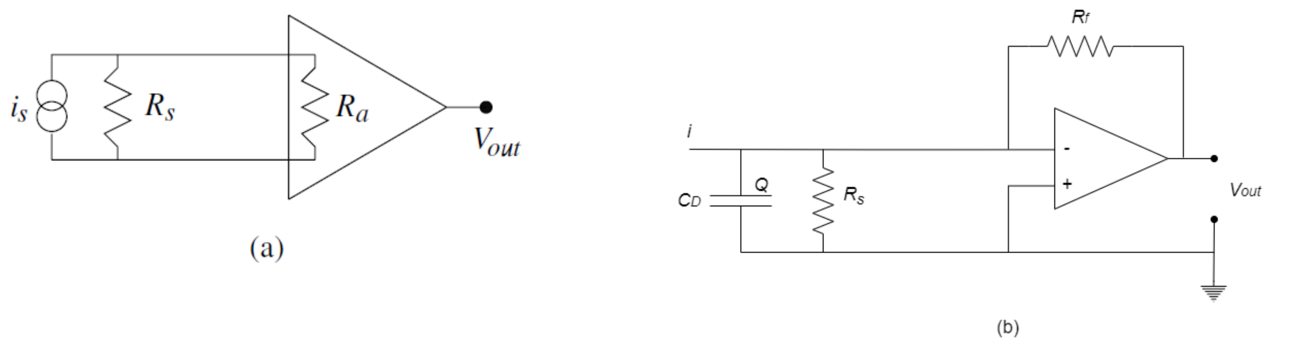

Figure 3: (a) Working principle of a current-sensitive preamplifier connected to a current source such as a radiation detector. A current-sensitive amplifier is a current-to-voltage converter. Its input impedance must be very small as compared to the detector

output impedance, to be able to measure instantaneous current. (b) A simplified but realistic current-sensitive preamplifier with feedback resistor R_f. C_d is the combined detector and stray capacitance and R_s is the combined impedance. Picture from **[1]**.

More details about current-sensitive preamplifier can be found in **[1]**.

Charge-Sensitive Preamplifiers

A charge-sensitive preamplifier is a current integrator that produces a voltage output proportional to the integrated value of the input current, or the total injected charge. Charge sensitive preamplifiers (CSPs) are often the best choice for radiation detectors. In this preamplifier, instead of directly amplifying the voltage or converting the current to voltage,

the electrical charge generated in the detector is all collected on the feedback capacitance of the preamplifier C_f (**Figure 4**). The output voltage V_{out} results proportional to the collected charge according to the relationship

$$V_{out} = \frac{Q_{in}}{C_f}$$

The great advantage of this circuit solution is that the measurement of charge is independent of the electrical parameters of the detector, such as its capacitance. Variations in the electrical parameters of the detector (as in the case of thermal variation or bias voltage variation) have a negligible impact on the charge measurement process. Moreover, the CSP, due to its integrational nature it provides an output proportional to the actual total charge created in the detector, whereas external sources of noise tend to give a zero average in signal post-processing.

For these reasons, charge sensitive preamplifiers are usually used in radiation detection applications, where individual detection pulses need to be measured with high precision.

The basic scheme of a charge-sensitive premaplifier is shown in **Figure 4.**

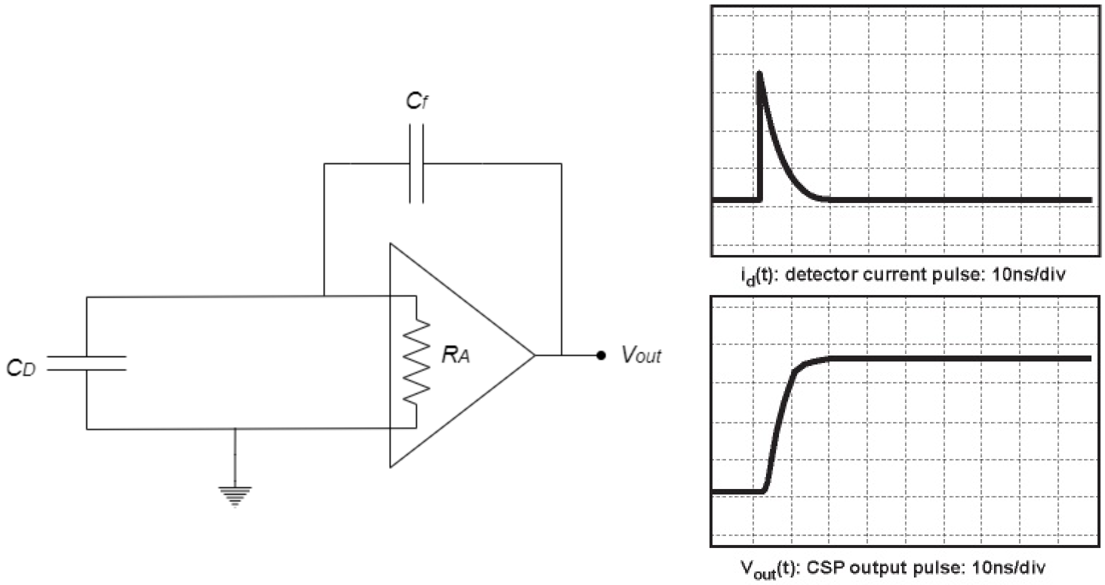

Figure 4. Basic principle of a charge-sensitive preamplifier. The charge accumulated on the detector capacitance C_d is then integrated on a feedback capacitor C_f. The voltage at the output is proportional to the input charge. Pictures from **[1]**.

A feedback capacitor C_f between the input and output stores the charge from the detector, and sets the Charge Sensitivity of the preamplifier as

$$\frac{V_{out}}{Q_{in}} = \frac{1}{C_f}$$

Each pulse of current from the detector causes the output of the charge sensitive preamplifier to step, the output being the time integral of the detector current. The Charge Sensitivity of a CSP is given in units of output volts over input charge (e.g. volts/picocoulomb). Sometimes the Charge Sensitivity of a CSP is given in units of output volts per MeV input (e.g. mV/MeV)[1].

The output voltage is then given by

$$V_0 \propto \frac{Q_d}{C_f} \; or \; V_0 \propto \frac{Q_f}{C_f}$$

Q_d is the charge released at the detector by the incident radiation and accumulated on C_d, which is proportional to the charge Q_f integrated on the feedback capacitor. The condition that $Q_f \approx Q_d$ can only be achieved if no current flows into the input of the preamplifier. This implies that the input of the preamplifier input impedance should be very large (i.e. $R_A \to \infty$).

The charge-sensitive preamplifier in the above schematic has no way to be reset and the output will increase until the charge sensitive preamplifier reaches its maximum output. So, in order to have the charge-sensitive preamplifier able to respond to subsequent pulses, it has to be reset. The most common method to reset the charge sensitive preamplifier circuit is to place a high valued resistor in parallel with the feedback capacitor. The pulse response of the preamplifier is hence transformed into a tail pulse, where the rise time remains as shown in the figure above, but there is now a long decay time (with a time constant R_f C_f) as is shown in the figure below.

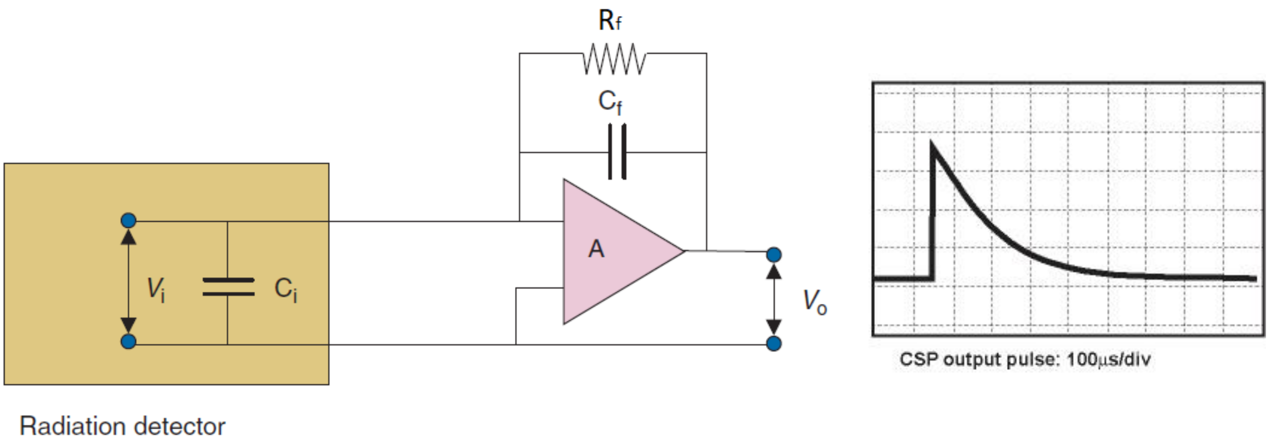

Figure 5: Design principle of a charge-sensitive preamplifier (with resistive feedback) connected to a source, such as a radiation detector output (left) and corresponding output pulse (right). Pictures from **[2]**.

[1] Assuming for a silicon detector an ionization energy for the creation of a charge carrier pair of 3.6 eV.

The time variation of the output pulse from an ideal resistive feedback charge-sensitive preamplifier is given by

$$V_0 = \frac{Q_f}{C_f}$$

$$V(t) = V_0 e^{-t/R_f C_f}$$

This maximum value of the voltage occurs at t=0, which implies a step response of the circuit to the detector output. However, in real cases, the output voltage always takes some finite amount of time to reach its maximum value. It should be noted that V_0 is proportional to the detector pulse and is therefore a measure of the energy deposited by the incident radiation.
An interesting feature of resistive feedback preamplifiers is that they do not exhibit any dead time but suffer of pulse pileup at high count rates. Such a preamplifier will keep on amplifying even if the next pulse arrives during the pulse decay time, so the instantaneous voltage of the previous pulse will be added to the new one.
This condition can easily bring the CSP out into saturation in the case of high rates. Care must be taken in the right choice of the CSPs charge sensitivity by also considering event rates in addition to the maximum energy of the individual event. With the right choice of charge sensitivity, CSPs with its advantages can be used even at high rates, despite a moderate worsening of noise due to parallel noise contribution introduced by low feedback resistance values.
Pulsed reset preamplifiers provide an alternative mechanism for resetting the feedback capacitor after the pulse has reached its maximum value. This technique provides the main advantage of not having the noise of the Feedback Resistor, but introduces dead time during the reset phase. In addition, the active nature of this mechanism introduces complexity by requiring part that must decide when to trigger the reset mechanism. These reasons have relegated this technique to very specific applications.

More details about charge-sensitive preamplifier (resistive feedback and transistor reset) can be found in **[1]**.

Conversion factor table

The tables included in the next sections of this Application Note reports preamplifier sensitivities and noise values in different units considering the different application.

The sensitivity is generally expressed in mV per MeV of energy deposited in a given detector material. The charge released by the detector is a function of the photon or particle energy and the detector material, and is given by

$$Q_d = \frac{\mathrm{e}}{\varepsilon}\,\mathrm{E} \times 10^6$$

Where *e* is the charge of an electron (1.6×10^{-19} coulomb), E is the energy in MeV of the incident radiation, 10^6 converts MeV to eV, and ε is the amount of energy required to produce an electron-hole/ion pair in the detector. Some examples of such values are summarized in the following table **[4][5]**.

Semiconductor detectors	Energy required per e-/hole pair creation
Si	3.61 eV (300 K), 3.71 (77 K)
Ge	2.98 eV (77 K)
CdTe	4.46 eV (300 K)
Diamond	13 eV
AsGa	4.35 eV
Gas detectors (Proportional Counters)	**Energy required per e-/ion pair creation**
Argon	26.4 eV
Methane	29.2 eV

In case of a charge-sensitive preamplifier, considering

$$V_0 = \frac{Q_d}{C_f}$$

we have

$$V_0 = \frac{\mathrm{e}}{\varepsilon C_f}\,\mathrm{E} \times 10^6$$

Therefore, the preamplifier gain can be expressed as

$$\frac{V_0}{E} = \frac{\mathrm{e}}{\varepsilon C_f} \times 10^6$$

Considering the case of a preamplifier with feedback capacitor $C_f = 1 \times 10^{-12}$ F connected to a room-temperature silicon detector, the sensitivity is

$$\frac{V_0}{E} = \frac{(1.6 \times 10^{-19}) \times 10^6}{3.61\,(1 \times 10^{-12})} = 44\,\frac{mV}{MeV}$$

Similarly, considering so a feedback capacitor of 1 pF, the corresponding reference sensitivity values are:

- 55 mV/MeV (for Germanium detector)
- 36 mV/MeV (for CdTe detector)
- 38 mV/MeV (for HgI2 detector)
- 1 V/pC
- 0.16 µV/electron

From the same consideration, in terms of released charge we have

- 1 MeV (Si) = 4.4×10^{-2} pC
- 1 KeV (Si) = 4.4×10^{-5} pC = 275 e- (1 C ≈ 6,242×1018 e-)

These values have been used as conversion factors to provide sensitivity and noise values in the different units when required.

CAEN Preamplifier Selection Guide

The following tables show the correspondence of detector type and suggested CAEN preamplifier models Such tables are intended as selection guides only, for complete and precise specifications, please check the data sheet for each preamplifier model.

Detector wise selection guide

Silicon Detectors	
Application	**Recommended Preamplifier**
Energy or Timing Spectroscopy	Models **A1422[6]** and **A1422E/F[9]** are recommended. Final model choice depends on capacitance of detector and on the desired sensitivity. Model **A422A[8]** is useful in case of small single detector setup and it is more flexible due the multiple embedded sensitivity. Model **A1426[16]** is the recommended model in case of thin silicon detectors. It is recommended in case of use in hostile environment. The input impedance can be matched to a 50 Ohm transmission line, thus allowing to put the preamplifier far from the detector at a distance up to 100 m, without deteriorating its response in terms of equivalent noise. Model A1426 is also recommended in case of high-rate scenario thanks to its fast shaping of the signal, down to 12 ns, that allows working at a rate of few MHz without incurring in signal pile-up.
Energy or Timing Spectroscopy (integration in custom PCB)	Model **A1422H[7]**. Final model choice depends on capacitance of detector and on the desired sensitivity.

Segmented Silicon Detectors	
Application	**Recommended Preamplifier**
Energy or Timing Spectroscopy, Tracking and Imaging	Models **A1442[11]** or **A1429[12]** are recommended because of the high channel density and the combination with the **2740/2745[19]** digitizer family.

Silicon Photomultipliers (SiPM/MPPC)	
Application	**Recommended Preamplifier**
Energy or Timing Spectroscopy	Model **A1423[13]** is recommended for SiPM detectors. Flexible solution thanks to its selectable gain via a 16-position rotary switch.

Diamond Detectors	
Application	**Recommended Preamplifier**
Energy or Timing Spectroscopy	Model **A1423B[13]** is recommended for diamond detectors. It gives a flexible solution thanks to its selectable gain via a 16-position rotary switch. Model **A1425[15]** is optimized for high-speed single MIP particle detection with diamond detectors, where the signal integrated charge is extremely small. Designed for spectroscopy applications, it can be used for sub-nanosecond measurements of particle time-of flight. Model **A1426[16]** is the recommended model in case of use in hostile environment. The input impedance can be matched to a 50 Ohm transmission line, thus allowing to put the preamplifier far from the detector at a distance up to 100 m, without deteriorating its response in terms of equivalent noise. Model A1426 is also recommended in case of high-rate scenario thanks to its fast shaping of the signal, down to 12 ns, that allows working at a rate of few MHz without incurring in signal pile-up.

Proportional Counters and Ionization Chambers	
Application	**Recommended Preamplifier**
Energy Spectroscopy or Counting	Model **A1422[6]** is recommended for multichannel application. Final model choice depends on desired sensitivity based on the detector pulse charge. Model **A422A[8]** is useful in case of small single detector setup and it more flexible to due the multiple embedded sensitivity.

Photomultiplier Tubes, Scintillation Detectors	
Application	**Recommended Preamplifier**
Time Spectroscopy	Model **A1424[14]** with Fast Output (rise time < 2.3 ns). Model **A1423[13]** is recommended for very fast scintillator especially if they do provide very small pulses. It gives a flexible solution thanks to its selectable gain via a 16-position rotary switch.
Energy and Time Spectroscopy	Model **A1424[14]** is the recommended model. It is a very flexible unit thanks to the selectable gain via a 10-position rotary switch. Thanks to the presence of both an Energy and Fast output, it allows the user to do at the same time Energy and Timing spectroscopy measurements.

Resistive Plate Chamber	
Application	**Recommended Preamplifier**
Energy or Timing Spectroscopy	Model **A1426[16]** is the recommended model in case of high-rate scenario thanks to its fast shaping of the signal, down to 12 ns, that allows the user to work at a rate of few MHz without incurring in signal pile-up. It is recommended in case of use in hostile environment. The input impedance can be matched to a 50 Ohm transmission line, thus allowing to put the preamplifier far from the detector at a distance up to 100 m, without deteriorating its response in terms of equivalent noise.

GEM Detectors	
Application	**Recommended Preamplifier**
Energy and Time Spectroscopy	Models **A1442[11]** or **A1429[12]** are recommended because of the high channel density and the combination with the **2740/2745[19]** digitizer family.

He3 Tubes, BF3 detector	
Application	**Recommended Preamplifier**
Energy and Time Spectroscopy	Model **A1422[6]** is a general purpose solution. Final model choice depends on desired sensitivity based on the detector pulse charge.
Position sensitive measurements	Model are **A1422CD[10]** is recommended thanks to its RJ-45 output that allows an easy integration with the **R5560[20]** digitizer in case of distributed setups with detector located in different positions. Model **R1443[18]** it is specifically designed for operating with neutron detectors as 3He or BF3 tubes and it provides a complete solution in combination with the **R5560[20]** digitizer.
Passive and active interrogation counting	Model **A1421[22]** features a preamplification, shaping and discrimination stage that makes it perfectly for operating with neutron detectors as 3He or BF3 tubes in passive and active interrogation measurement in combination **with R7771 Neutron Pulse Train Recorder[23]** and **R7780 Neutron Coincidence Analyzer, Multiplicity analyzer, Shift Register and Pulse Train Recorder[24].**

Fission Chamber and Proton Recoil Detector	
Application	**Recommended Preamplifier**
Energy, Time Spectroscopy and Counting	Model **A1427FC[17]** is the recommended model for Fission Chamber as specifically designed for such detector. It can be used in combination with the **A1428FC[21]** Discriminator. Model **A1427PR[17]** is the recommended model for Proton Recoil as specifically designed for such detector. It can be used in combination with the **A1428PR[21]** Discriminator.

Application wise selection guide

Charged-Particle Spectroscopy with Semiconductor Detectors

Model	Detector Type	Features	Number of inputs (X)	Range of Input Capacitance	Sensitivity (mV/MeV)	Equivalent Input Noise (FWHM)* Energy (keV at pF)	Rise Time (ns at pF)	Decay Time (us)	Output Linear range	E2CRP (MeV^2/s)*	Detector Bias Resistor (MΩ)	Maximum Detector Bias Voltage (Volts)
A422A	Si	Good timing and low noise. Small size and low cost	1	<1000 pF	5/30/60	< 4 @ 0 < 5 @1000 (5 mV/MeV) < 2 @ 0 < 17.5 @1000 (30/60 mV/MeV)	Min 14 ns (Fast Out) Min 50 ns (Energy Out)	300	±8 V	N.A.	100	5000
A1422X005F2	Si	Good timing and low noise. Small size and low cost	A = 1 B = 4 C = 8	<200 pF	5	< 4.7 @ 0 < 7.6 @200	< 5 @ 0 < 15 @200	100	±10 V (1 kΩ) ±4.5 V (50 Ω)	1.57×10^{10}	100	2000
A1422X045F2	Si	Good timing and low noise. Small size and low cost	A = 1 B = 4 C = 8	<200 pF	45	< 2.2 @ 0 < 4.3 @200	< 5 @ 0 < 15 @200	100	±10 V (1 kΩ) ±4.5 V (50 Ω)	1.57×10^{8}	100	2000
A1422X090F2	Si	Good timing and low noise. Small size and low cost	A = 1 B = 4 C = 8	<200 pF	90	< 2.2 @ 0 < 4.2 @200	< 10 @ 0 < 25 @200	50	±10 V (1 kΩ) ±4.5 V (50 Ω)	7.86×10^{7}	100	2000
A1422X400F2	Si	Low noise, small size and low cost	A = 1 B = 4 C = 8	<200 pF	400	< 2.2 @ 0 < 4.1 @200	< 70 @ 0 < 110 @200	27	±10 V (1 kΩ) ±4.5 V (50 Ω)	7.00×10^{6}	100	2000
A1422X450F2	Si	Low noise, small size and low cost	A = 1 B = 4 C = 8	<200 pF	450	< 2.2 @ 0 < 4.1 @200	< 70 @ 0 < 110 @200	27	±10 V (1 kΩ) ±4.5 V (50 Ω)	7.00×10^{6}	100	2000
A1422X001F3	Si	Good timing and low noise. Small size and low cost	A = 1 B = 4 C = 8	<1000 pF	1	< 10.5 @ 390 < 21.5 @1000	< 20 @ 390 < 40 @1000	100	±10 V (1 kΩ) ±4.5 V (50 Ω)	1.57×10^{10}	100	2000
A1422X005F3	Si	Good timing and low noise. Small size and low cost	A = 1 B = 4 C = 8	<1000 pF	5	< 10.5 @ 390 < 21.5 @1000	< 20 @ 390 < 40 @1000	100	±10 V (1 kΩ) ±4.5 V (50 Ω)	1.57×10^{10}	100	2000
A1422X045F3	Si	Good timing and low noise. Small size and low cost	A = 1 B = 4 C = 8	<1000 pF	45	< 5.8 @ 390 < 13.2 @1000	< 25 @ 390 < 50 @1000	100	±10 V (1 kΩ) ±4.5 V (50 Ω)	1.57×10^{8}	100	2000

A1422X090F3	Si	Good timing and low noise. Small size and low cost	A = 1 B = 4 C = 8	<1000 pF	90	< 5.5 @ 390 < 13.2 @1000	< 45 @ 390 < 100 @1000	50	±10 V (1 kΩ) ±4.5 V (50 Ω)	7.86×10^7	100	2000
A1422E/F	Si	Good timing and low noise for silicon detectors with wide surface and high capacitance	E = 2 F = 4	< 330	200	< 2.8 @ 0 < 6.8 @330	< 5.4 @ 0 < 60 @330	22	±10 V (1 kΩ) ±4.5 V (50 Ω)	1.57×10^6	100	750
A1422H	Si	Good timing and low noise. Small size and low cost	PCB mounted unit	< 1000 pF	1/5/45/90/400/450	Same as corresponding A1422 boxed module					10	800
A1426	Si	Fast, suitable for high rate and remotization with hostile environments	1	N.A.	Up to 220	7	Input pulse width 100 ps to 8 ns		0 ÷ 1 V (open circuit) 0 ÷ 0,5 V (50 Ω)	N.A.	N.A.	1000

*Energies are referenced to 3.62 eV/e-h pair in silicon detectors and 2.96 eV/e-h pair in germanium detectors.

Charged-Particle Spectroscopy and Tracking with Semiconductor Detectors

Model	Detector Type	Features	Number of inputs (X)	Range of Input Capacitance	Sensitivity (mV/MeV)	Equivalent Input Noise (FWHM)* Energy (keV at pF)	Rise Time (ns at pF)	Decay Time (us)	Range (MeV)	E2CRP (MeV²/s)*	Detector Bias Resistor (MΩ)	Maximum Detector Bias Voltage (Volts)
A1442X020	Si	Good timing, low noise and High density	A = 16 B = 32	200 pF	20/100 (x1/x5)	< 5 KeV @ 0 < 28 eV/pF slope	< 20 @ 0 < 60 @200	50	200 @ 1X 40 @ 5X	-	22	400
A1429x020	Si	Good timing, low noise and very high density	64	200 pF	20	< 5 KeV @ 0 < 28 eV/pF slope	< 20 @ 0 < 60 @200	50	225	-	22	400
A1429x045	Si	Good timing, low noise and very high density	64	200 pF	45	< 5 KeV @ 0 < 28 eV/pF slope	< 20 @ 0 < 60 @200	100	100	-	22	400
A1429x090	Si	Good timing, low noise and very high density	64	200 pF	90	< 5 KeV @ 0 < 28 eV/pF slope	< 20 @ 0 < 60 @200	50	50	-	22	400
A1429x200	Si	Good timing, low noise and very high density	64	200 pF	200	< 5 KeV @ 0 < 28 eV/pF slope	< 20 @ 0 < 60 @200	22	22	-	22	400
A1429x400	Si	Good timing, low noise and very high density	64	200 pF	400	< 5 KeV @ 0 < 28 eV/pF slope	< 20 @ 0 < 60 @200	11	11	-	22	400

*Energies are referenced to 3.62 eV/e-h pair in silicon detectors and 2.96 eV/e-h pair in germanium detectors.

Spectroscopy with Proportional Counters and Ionization Chamber										
Model	**Detector Type**	**Features**	**Number of inputs (X)**	**Sensitivity (V/pc)**	**Equivalent Input Noise FWHM* (Electrons at pF)**	**Rise Time (ns at pF)**	**Decay Time (ns)**	**Output Linear Range(V)**	**Detector Bias Resistor (MΩ)**	**Maximum Detector Bias Voltage (Volts)**
A1422X005F2	PC/IC	Good timing and low noise. Small size and low cost	A = 1 B = 4 C = 8	0.1	< 1293 @ 0 < 2090 @200	< 5 @ 0 < 15 @200	100	±10 V (1 kΩ) ±4.5 V (50 Ω)	100	2000
A1422X045F2	PC/IC	Good timing and low noise. Small size and low cost	A = 1 B = 4 C = 8	1	< 605 @ 0 < 1183 @200	< 5 @ 0 < 15 @200	100	±10 V (1 kΩ) ±4.5 V (50 Ω)	100	2000
A1422X090F2	PC/IC	Good timing and low noise. Small size and low cost	A = 1 B = 4 C = 8	2	< 605 @ 0 < 1155 @200	< 10 @ 0 < 25 @200	50	±10 V (1 kΩ) ±4.5 V (50 Ω)	100	2000
A1422X400F2	PC/IC	Low noise, small size and low cost	A = 1 B = 4 C = 8	9	< 605 @ 0 < 1128 @200	< 70 @ 0 < 110 @200	27	±10 V (1 kΩ) ±4.5 V (50 Ω)	100	2000
A1422X450F2	PC/IC	Low noise, small size and low cost	A = 1 B = 4 C = 8	10	< 605 @ 0 < 1128 @200	< 70 @ 0 < 110 @200	27	±10 V (1 kΩ) ±4.5 V (50 Ω)	100	2000
A1422X001F3	PC/IC	Good timing and low noise. Small size and low cost	A = 1 B = 4 C = 8	0,02	< 2888 @ 390 < 5913 @1000	< 20 @ 390 < 40 @1000	100	±10 V (1 kΩ) ±4.5 V (50 Ω)	100	2000
A1422X005F3	PC/IC	Good timing and low noise. Small size and low cost	A = 1 B = 4 C = 8	0.1	< 2888 @ 390 < 5913 @1000	< 20 @ 390 < 40 @1000	100	±10 V (1 kΩ) ±4.5 V (50 Ω)	100	2000
A1422X045F3	PC/IC	Good timing and low noise. Small size and low cost	A = 1 B = 4 C = 8	1	< 1595 @ 390 < 3630 @1000	< 25 @ 390 < 50 @1000	100	±10 V (1 kΩ) ±4.5 V (50 Ω)	100	2000
A1422X090F3	PC/IC	Good timing and low noise. Small size and low cost	A = 1 B = 4 C = 8	2	< 1513 @ 390 < 3630 @1000	< 45 @ 390 < 100 @1000	50	±10 V (1 kΩ) ±4.5 V (50 Ω)	100	2000

*Conversion between KeV (Si) and electrons have been considering the conversion factors reported in **Conversion factor table**.

Energy Spectroscopy with Scintillation Detectors, PMTs

Model	Detector Type	Features	Sensitivity (mV/pc)	Noise (rms)	Rise Time (ns)	Decay Time (us)	Output Linear Range (V)
A1424	PMTs	Low noise, fast response and high counting rates preamplifier with selectable sensitivity.	0.8, 0.9, 1.1, 1.3, 1.5, 1.7, 2.5, 3, 5, 10 selectable via Rotary Switch	3.2 fC at 10 mV/pC 8.5 fC at 0.8 mV/pC	ENERGY Out < 60 ns FAST Out < 2.3 ns	50	Range: ± 8V (on 1 kΩ)

Fast Timing and Fast Counting with Scintillation Detectors, Photomultiplier Tubes

Model	Detector Type	Features	Gain	Input Impedance(Ω)	Noise	Output Rise Time (ns)	Coupling	Output Linear Range (V)	Maximum Detector Bias Voltage (Volts)
A1423B	PMTs	Very fast rise time for use with PMTs. High flexibility with selectable gain.	from +18 dB to +54 dB Selectable via 16 position Rotary Switch	50	7dB @ 1GHz	< 1 ns	AC	± 1	750
A1425	PMTs	Fast and low noise preamplifier with AC coupled input. Designed for spectroscopy applications can be combined with sub-nanosecond measurements of particle time-of flight	3.6 mV/pc	50	0.16 fC (1000 e)	< 1 ns	AC	1	1000

Energy and Time Spectroscopy with SiPM

Model	Detector Type	Features	Gain (db)	Input Impedance(Ω)	Noise figure	Output Rise Time (ns)	Coupling	Output Linear Range (V)	Maximum Detector Bias Voltage (Volts)
A1423B	SiPM/MPPC	Very fast rise time for use with PMTs. High flexibility with selectable gain. Wide bandwidth.	from +18 dB to +54 dB Selectable via 16 position Rotary Switch	50	7dB @ 1GHz	< 1 ns	AC	± 1	750

Energy and Time Spectroscopy with Diamond detectors

Model	Detector Type	Features	Gain	Input Impedance (Ω)	Noise	Output Rise Time (ns)	Coupling	Output Linear Range (V)	Maximum Detector Bias Voltage (Volts)
A1423B	Diamond	Very fast rise time for use with PMTs. High flexibility with selectable gain.	from +18 dB to +54 dB Selectable via 16 position Rotary Switch	50	7dB @ 1GHz	< 1 ns	AC	± 1	750
A1425	Diamond	Fast and low noise preamplifier with AC coupled input. Designed for spectroscopy applications can be combined with sub-nanosecond measurements of particle time-of flight	3.6 mV/pc	50	0.16 fC (1000 e)	< 1 ns	AC	0 ÷ 1	1000
A1426	Diamond	Fast and low noise preamplifier with AC coupled input. Its input impedance can be matched to a 50 Ohm transmission line, thus allowing to put the preamplifier far from the detector at a distance up to 100 m, without deteriorating its response in terms of equivalent noise	5 mV/pc	50	0.3 fC (2000 e)	< 1 ns (total width max 8 ns)	AC	0 ÷ 1 V (open circuit) 0 ÷ 500 mV (50 Ω termination)	1000

Energy and Time Spectroscopy with GEM and MicroMegas detector

Model	Detector Type	Features	Number of inputs (X)	Sensitivity (µV/Electron) – (V/pc)	Equivalent Input Noise (FWHM)* Energy (electrons at pF)	Rise Time (ns at pF)	Decay Time (us)	Range (MeV(Si))
A1442X020	GEM/MM	Good timing, low noise and high density	A = 16 B = 32	0,073/0,36 - 0,45/2,28 (x1/x5)	< 1375 @ 0 < 7,7 e/pF slope	< 20 @ 0 < 60 @200	50	200 @ 1X 40 @ 5X
A1429x020	GEM/MM	Good timing, low noise and very high density	64	0,073 – 0,45	< 1375 @ 0 < 7,7 e/pF slope	< 20 @ 0 < 60 @200	50	225
A1429x045	GEM/MM	Good timing, low noise and very high density	64	0,16 – 1	< 1375 @ 0 < 7,7 e/pF slope	< 20 @ 0 < 60 @200	100	100
A1429x090	GEM/MM	Good timing, low noise and very high density	64	0,32 – 2	< 1375 @ 0 < 7,7 e/pF slope	< 20 @ 0 < 60 @200	50	50

A1429x200	GEM/MM	Good timing, low noise and very high density	64	0,73 – 4,54	< 1375 @ 0 < 7,7 e/pF slope	< 20 @ 0 < 60 @200	50	22
A1429x400	GEM/MM	Good timing, low noise and very high density	64	1,45 – 9,1	< 1375 @ 0 < 7,7 e/pF slope	< 20 @ 0 < 60 @200	50	11

*Conversion between KeV (Si) and uV/Electron have been considering the conversion factors reported in **Conversion factor table**.

Energy and Time Spectroscopy and Counting with Fission Chamber and Proton Recoil detector

Model	Detector Type	Features	Gain	Noise (rms)	Rise Time (ns)	Width	Dynamic Range (V)	Detector Bias Resistor (kΩ)	Maximum Detector Bias Voltage (Volts)
A1427FC	FC	Fast and low noise current preamplifier with AC coupled input.	700÷2500	≤ 40 mV p.p. (measured with gain = 1000 on FOUT) ≤ 7 mV p.p. (measured with gain = 1000 on EOUT)	Eout ≤ 19; Fout negative lobe ≤12;	Eout: Width Out 50 ns FWHM; Fout: Total duration = 120 ns, Width Out negative lobe: 27.5 ns FWHM,	Eout = 0÷-350 mV max; Fout = -2 V÷+1.3 V max;	200	3000
A1427PR	PR	Fast and low noise current preamplifier with AC coupled input.	500÷1500	≤ 30 mV p.p. (measured with gain = 700 on FOUT) ≤ 4 mV p.p. (measured with gain = 700 on EOUT)	Eout ≤ 19; Fout negative lobe ≤12;	Eout: Width Out 50 ns FWHM; Fout: Total duration = 160 ns; Width Out negative lobe: 40 ns FWHM;	Eout = 0÷-350 mV max; Fout = -2 V÷+1.3 V max;	200	3000

Energy and Time Spectroscopy and Counting with He3 tubs and BF3 detector										
Model	**Detector Type**	**Features**	**Number of inputs (X)**	**Sensitivity (V/pC)**	**Equivalent Input Noise FWHM* (Electrons at pF)**	**Rise Time (ns at pF)**	**Decay Time (ns)**	**Output Linear Range(V)**	**Detector Bias Resistor (MΩ)**	**Maximum Detector Bias Voltage (Volts)**
A1422CD	He3/BF3	Fast, low noise inverting preamplifier. Complete solution with R5560 Pulse Processor.	4	0.1	< 1293 @ 0 < 2090 @200	< 5 @ 0 < 15 @200	50	±5 V (1 kΩ) ±2.5 V (100 Ω)	100	2000

*Conversion between KeV (Si) and electrons have been considering the conversion factors reported in **Conversion factor table**.

Position Sensitive measurements with He3 tubs and BF3 detector									
Model	**Detector Type**	**Features**	**Number of inputs (X)**	**Sensitivity (V/pC)**	**Total Gain (V/pC)**	**Rise Time (ns)**	**Decay Time (us)**	**Input Charge Dynamics (pC)**	**Maximum Detector Bias Voltage (Volts)**
R1443X	He3/BF3	Rack mountable, fast, high density and high-rate preamplifier. Complete solution with R5560 Pulse Processor.	A = 16 B = 32 C = 32 with individual HV	1 V/pc	2.25 V/pc	< 20 ns	1	± 0.8 pC	3000

Passive and active interrogation counting measurements with He3 tubs and BF3 detector									
Model	**Detector Type**	**Features**	**Number of inputs (X)**	**Sensitivity (V/pC)**	**Total Gain (V/pC)**	**Rise Time (ns)**	**Decay Time (us)**	**Input Charge Dynamics (pC)**	**Maximum Detector Bias Voltage (Volts)**
A1421	He3/BF3	Fast preamplifier, shaper and discriminator with analog and TTL output. Complete solution with R771 and R7780.	1	1	28 V/pc	Total width: 700 ns		± 0.1 pC	3000

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