General Description

The CR-200 is a single channel shaping amplifier, intended to be used to read out the signals from charge sensitive preamplifiers (e.g. Cremat CR-110 or equivalent). Gaussian shaping amplifiers (also known as pulse amplifiers, linear amplifiers, or spectroscopy amplifiers) accept a step-like input pulse and produce an output pulse shaped like a Gaussian function. The purposes of this are to filter much of the noise from the signal of interest and to provide a quickly restored baseline to allow high counting rates. The CR-200 is available in 4 different shaping times: 100 ns, 250 ns, 1 μs, and 4 μs. Each has a fixed gain of 10. If additional gain is desired, it is recommended that this be done with the application of an additional amplifier between the preamplifier and the CR-200 shaping amplifier. Cremat offers an evaluation board (CR-160) which includes a variable gain amplifier of appropriate bandwidth, as well as all necessary connectors.
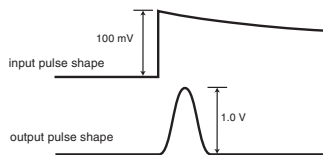

Figure 1. Comparison of sample input and output pulse shapes

Improvements in Revision 2

The new CR-200 'Revision 2' has been improved with a significant reduction in power consumption, reduced output offset, and an improved thermal coefficient of output offset. Revision 2 is pin-for-pin compatible with the previous revision of CR-200, however it should be noted that the labeling has been changed so that pin 1 appears on the left side of the label.

Definition of "Shaping Time"

The shaping time is defined as the time-equivalent of the "standard deviation" of the Gaussian output pulse. A simpler measurement to make in the laboratory is the full width of the pulse at half of it's maximum value (FWHM). This value is greater than the shaping time by a factor of 2.35. For example, a Gaussian shaping amplifier with a shaping time of 1.0 μs would have a FWHM of 2.35 μs.

Pole/Zero Correction

The decay time of the input pulse creates an offset in the baseline of the output pulse unless a pole/zero correction is utilized. This can be done by connecting a resistor between pin 1 (input) and pin 2 (P/Z). If the CR-200 is used to read out the Cremat CR-110 preamplifier, then this resistor value should be 300 kΩ (CR-200-100ns), 130 kΩ (CR-200-250ns and CR-200-1μs), and 43 kΩ (CR-200-4μs). If a different preamplifier is used, then the resistor value should be chosen so that it is equal to the decay constant (RC) of the preamplifier pulse divided by the CR-200 shaping amplifier input capacitor C_{in} (see table).

Package Specifications

The CR-200 circuit is contacted via an 8-pin SIP connection (0.100" spacing). Pin 1 is marked with a white dot for identification.
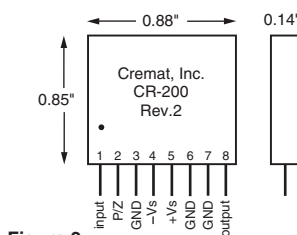

Figure 2.

Equivalent circuit diagram

Figure 3 shows an equivalent circuit. Pin numbers corresponding with the CR-200 preamplifier are shown. Input components C_{in} and R_{in} form a differentiating circuit. The following circuitry consists of two Sallen and Key filters, providing 4 poles of integration and signal gain. The numerous integration stages produce an output pulse that approximates a Gaussian function.
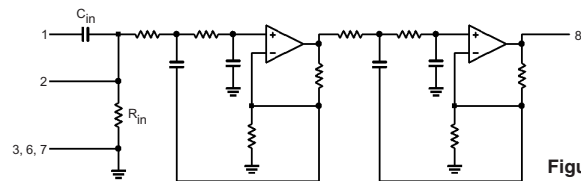

Figure 3.

part number	C_{in}	R_{in}	shaping time
CR-200-100ns	470 pF	220 Ω	100 ns
CR-200-250ns	1000 pF	240 Ω	250 ns
CR-200-1μs	1000 pF	1.0 kΩ	1.0 μs
CR-200-4μs	3300 pF	1.2 kΩ	4.0 μs

Typical Application

Figure 4 shows the CR-200 in a typical application, coupled to a detector via a CR-110 charge sensitive preamplifier. Depending on the requirements of your application, an AC-coupled amplifier may be added between the preamplifier and shaping amplifier to further increase the signal size.
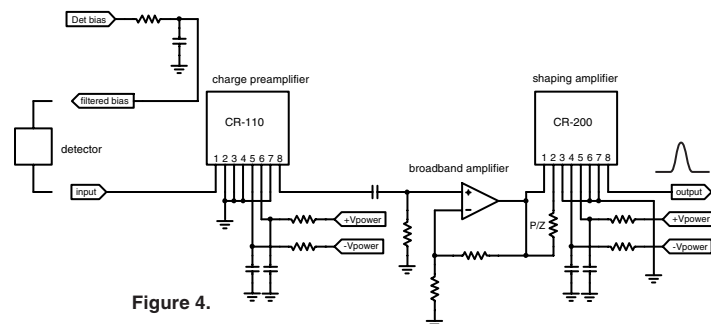

Figure 4.

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Specifications

Assume temp =20°C, V_s = ± 9V, unloaded output

	CR-200	units
amplification channels	1	
gain	10	
polarity	non-inverting	
operating temperature range	-40°C to 85°C	
input noise voltage		
CR-200-100ns	90	μV RMS
CR-200-250ns	90	μV RMS
CR-200-1μs	45	μV RMS
CR-200-4μs	30	μV RMS
output impedance	<5	Ω
output offset	-20 to +20	mV
output temperature coefficient	-60 to +60	μV / °C
power supply voltage (V_s)		
maximum	V_s = ±12	volts
minimum	V_s = ± 6	volts
power supply current	7	mA
maximum output current (with loaded output)	10	mA
maximum output swing	±8.5	volts

Achieving the Desired Gain

The CR-200 series of amplifiers have a fixed gain of 10. It is expected that many users will want a gain greater than this for their application. This should be done by adding one or more amplification stages between the preamplifier and the shaping amplifier. The noise level of this voltage amplification stage should be kept reasonably low in order to take full advantage of the low noise of the preceding preamplifier stage. Assuming the CR-110 charge sensitive preamplifier is used in the application, a noise voltage of 10 nV / $\sqrt{Hz}$ is adequate. Because there is typically a DC offset at the preamplifier output, this amplifier should be AC coupled to preamplifier. The bandwidth of these amplifiers should span ranges at least as wide as that shown in the following table in order to make optimal use of the signal:

part number	f_{low}	f_{high}
CR-200-100ns	1 kHz	15 MHz
CR-200-250ns	1 kHz	6 MHz
CR-200-1μs	1 kHz	1.5 MHz
CR-200-4μs	1 kHz	400 kHz

The Cremat CR-160 evaluation board accepts the CR-200 shaping amplifier as a plug-in module and also contains a low noise variable gain amplifier and the appropriate connectors needed for the user to easily evaluate the CR-200 shaping amplifier. A schematic diagram of the amplifier on the CR-160 board is included, and this can serve as a template for users to design and build their own amplifier for the CR-200 in their own applications.

Choosing the Optimal Shaping Time for your Application

There are a number of considerations in the choice of the optimal shaping time for your application. Consider:

1. The shaping time must be long enough to collect the charge from the detector. This may be a limiting factor in slow detectors such as gas-based drift chambers or when collecting the light from slow scintillator materials.

2. The shaping time must be short enough to achieve the high counting rates you require. Assuming randomly spaced pulses, long-shaped pulses have a higher probability of 'piling up' than short pulses.

3. Choose a shaping time that filters as much of the electronic noise as possible. Electronic noise at the preamplifier output is created by a number of different aspects of the detection system. Some of these 'noise components' have different frequency distributions, allowing us to use the filtering capability of the shaping amplifier to choose a shaping time that minimizes the noise for the particular detection system under design. The principal sources of electronic noise in a detection system are **a)** the thermal noise of the input JFET in the preamplifier (which is proportional to the total capacitance to ground at the input node), **b)** the thermal noise of the feedback resistor and any 'biasing' resistor attached to the detector, **c)** the 'shot noise' of the detector leakage current, **d)** the electrical contact-related 1/f noise of the detector and preamplifier input JFET, and **e)** the 'f noise' caused by the proximity of lossy dielectric material near the preamplifier input node.

Of the noise components mentioned above, the noise from factor (a) is more heavily filtered with longer shaping times. More precisely, the electronic noise due to this factor is inversely proportional to the shaping time. The electronic noise due to factor (b), on the other hand, is proportional to the shaping time, as is factor (c). Factors (d) and (e) are generally difficult to predict, which means it is difficult to predict the exact noise performance of a detection system. Fortunately, both of these factors are independent of shaping time, so they have no impact on the determination of the optimal shaping time. The optimal shaping time can be predicted by considering only factors (a), (b) and (c). The subject of noise in detection systems using charge sensitive preamplifiers is addressed in more detail in these articles:

Bertuccio G; Pullia A; "A Method for the Determination of the Noise Parameters in Preamplifying Systems for Semiconductor Radiation Detectors", Rev. Sci. Instrum., 64, p. 3294, (1993).

Radeka V; "Low-Noise Techniques in Detectors", Ann. Rev. Nucl. Part. Sci., 38, p. 217, (1988).

Goulding FS; Landis DA; "Signal Processing for Semiconductor Detectors", IEEE Trans. Nuc. Sci., NS-29, p. 1125, (1982).
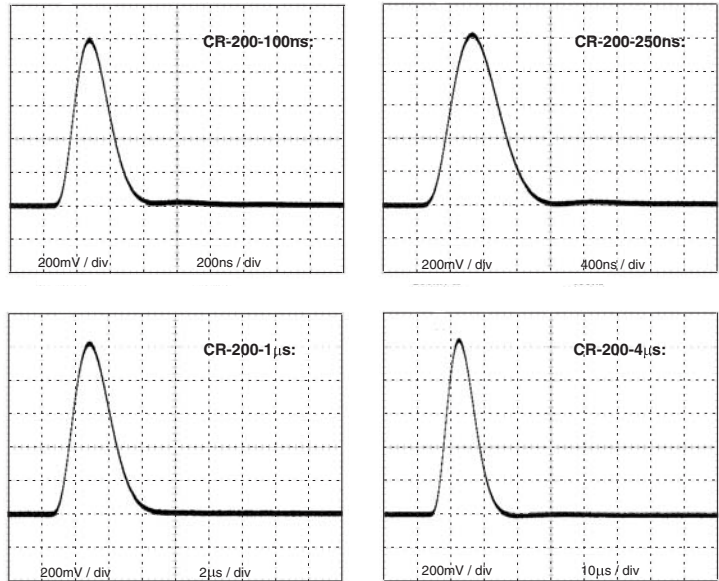
Electronic Noise (continued)

The following equation can be used to estimate the noise level in a detection system based on the CR-110 charge sensitive preamplifier. Estimates have been made for factors (d) and (e) mentioned previously, assuming short traces on an FR-4 circuit board (such as those found on Cremat's CR-150-AC-C evaluation board). This equation may be useful in allowing the user to calculate the optimal shaping time (τ in μs) minimizing the electronic noise (ENC in electrons rms) for a given detector capacitance (C_{in} in pF) and detector leakage current (I_d in pA).

$$\text{ENC} := \sqrt{\frac{43 \cdot (C_{in} + 15)^2}{\tau} + 8 \cdot \tau \cdot (I_d + 800) + 50000}$$

Output Pulse Shapes

The following scope traces were recorded using the four different models of the CR-200. In each case the input pulse was a 100 mV step.

CR-200-100ns; 200mV / div, 200ns / div

CR-200-250ns; 200mV / div, 400ns / div

CR-200-1μs; 200mV / div, 2μs / div

CR-200-4μs; 200mV / div, 10μs / div

Output Characteristics

The CR-200 shaping amplifiers have low output impedance (<5Ω) and can source/sink 10 mA of output current. This may not be sufficient to drive a terminated cable in your application, depending on the size of the signal. For this reason it is best to use a cable driver circuit at the CR-200 output to make maximum use of the CR-200 output voltage swing capability. The unloaded output voltage swing comes to within 0.5 volt of the power supply rails.