

# CR-200 Gaussian shaping amplifier:

# application guide

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## General Description

The CR-200 is a single channel shaping amplifier, intended to be used to read out the signals from charge sensitive preamplifiers. 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 for higher counting rates. The CR-200 is available in 7 different shaping times: 100 ns, 250 ns, 500 ns, 1  $\mu$ s, 2  $\mu$ s, 4  $\mu$ s, and 8  $\mu$ s. 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 multi-stage variable-gain amplifier, as well as all necessary connectors. More information on the CR-160 evaluation board can be found at <http://cremat.com>

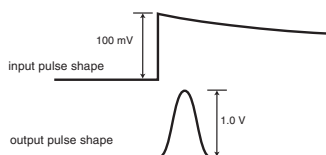


Figure 1. Comparison of sample input and output pulse shapes

## 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 its maximum value (FWHM). This value is greater than the shaping time by a factor of 2.4. For example, a Gaussian shaping amplifier with a shaping time of 1.0  $\mu$ s would have a FWHM of 2.4  $\mu$ s.

## Equivalent circuit diagram

Figure 2 shows an equivalent circuit. Pin numbers corresponding with the CR-200 shaping amplifier 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.

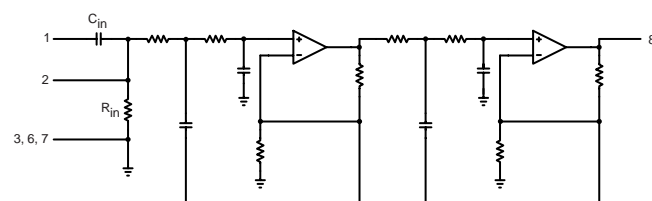


Figure 2

## Pole/Zero Correction

The long decay time of the input pulse creates a small overshoot in the shape of the output pulse unless a pole/zero correction is utilized. This can be done by connecting a resistor ( $R_{P/Z}$ ) between pin 1 (input) and pin 2 (P/Z). This resistor is in parallel with the input capacitor (internal to the CR-200 circuit) and creates a 'zero' in the amplifier's transfer function which cancels the 'pole' created by the charge sensitive preamplifier's feedback resistor. To achieve proper pole/zero cancellation,  $R_{P/Z}$  should be selected to be equal to  $R_f \cdot C_f / C_{in}$  where  $R_f$  and  $C_f$  are the feedback resistor and feedback capacitor of the charge sensitive preamplifier and  $C_{in}$  is the value of the input capacitor in the CR-200. The value of  $C_{in}$  for the CR-200 circuit can be found in the provided table.

Keep in mind that adding  $R_{P/Z}$  will likely affect the DC offset of the shaping amplifier output. This is because  $R_{P/Z}$  directly couples the DC offset from the charge sensitive preamplifier output into the shaping amplifier input. Some fraction of this DC offset is amplified along with the pulse. It is recommended that instrumentation which includes the CR-200 include a DC offset adjustment to be used to correct for this. An example of this can be found in the design of the CR-160 evaluation board found here: <http://www.cremat.com/CR-160schematic.pdf>

You may wish to realize  $R_{P/Z}$  as a potentiometer so to adjust the value precisely. The effect of  $R_{P/Z}$  on the pulse shape can be seen in the pulse waveforms shown in Figure 3.

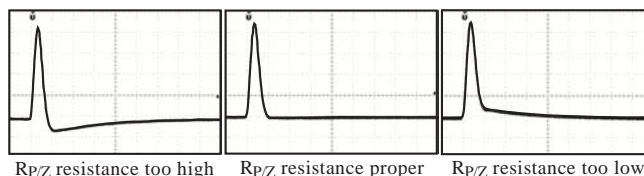


Figure 3

## Baseline Restoration (BLR)

The CR-200 does not contain active baseline restoration circuitry. For this reason there will be a negative 'baseline shift' (change in the output DC offset) at high counting rates. In order to determine whether this will be a problem for your application, use the equation (valid for small baseline shifts):

$$S/H = R \cdot \tau \cdot 2.5 \times 10^{-6}$$

where S is the negative baseline shift, H is the pulse height, R is the count rate (counts/sec), and  $\tau$  is the shaping time of the shaping amplifier (in  $\mu$ s). For example, using a 1  $\mu$ s shaping amplifier we would predict a 0.025 (2.5%) shift in the baseline at a count rate of 10,000 counts per second.

The simplest solution to this possible problem is to implement a *bipolar* shape to the signals. Bipolar shaping is not susceptible to baseline offset shifts with increasing count rate. This can be easily done by differentiating the Gaussian output pulse using a 'C-R' filter. An example of this is shown in Figure 4. Suggested values for  $C_{out}$  and  $R_{out}$  are provided in the table presented on the following page. Keep in mind that making the pulse bipolar in this way will reduce the amplitude to less than half the original pulse height and reduce the width to half its previous value.

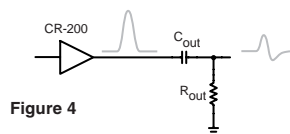


Figure 4

## 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.

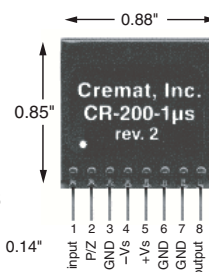


Figure 5

## Typical Application

Figure 6 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.

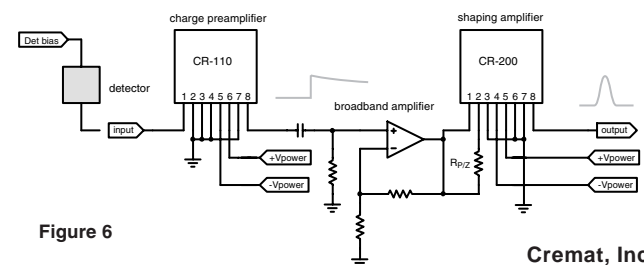


Figure 6

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## 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-decay scintillators.
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. Note that 'pile-up' will only be a problem at very high count rates; 'Baseline shift' will start to be a problem at somewhat lower count rates. See the previous section regarding 'Baseline Restoration'.
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 listed, 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. In terms of reducing the electronic noise, 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).

## Output Characteristics

The CR-200 shaping amplifiers have low output impedance ( $<5\Omega$ ) 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.

Specifications		Assume temp =20°C, $V_s = \pm 9V$ , 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	160	$\mu V$	RMS
CR-200-250ns	90	$\mu V$	RMS
CR-200-500ns	55	$\mu V$	RMS
CR-200-1 $\mu s$	45	$\mu V$	RMS
CR-200-2 $\mu s$	40	$\mu V$	RMS
CR-200-4 $\mu s$	35	$\mu V$	RMS
CR-200-8 $\mu s$	30	$\mu V$	RMS
output impedance	<5	$\Omega$	
output offset	-40 to +40	mV	
output temperature coefficient	-60 to +60	$\mu V / ^\circ C$	
power supply voltage ( $V_s$ )			
maximum	$V_s = \pm 12$	volts	
minimum	$V_s = \pm 6$	volts	
quiescent power supply current	7	mA	
maximum output current	10	mA	
maximum output swing	$\pm 8.5$	volts	

part #	shaping time	output pulse width (FWHM)	For optional bipolar shaping (see section on "Baseline Restoration" and Figure 4)	
			$R_{out}$	$C_{out}$
CR-200-100ns	100 ns	240 ns	50 $\Omega$	2200 pF
CR-200-250ns	250 ns	590 ns	50 $\Omega$	4700 pF
CR-200-500ns	500 ns	1.2 $\mu s$	50 $\Omega$	0.01 $\mu F$
CR-200-1 $\mu s$	1 $\mu s$	2.4 $\mu s$	50 $\Omega$	0.022 $\mu F$
CR-200-2 $\mu s$	2 $\mu s$	4.7 $\mu s$	50 $\Omega$	0.039 $\mu F$
CR-200-4 $\mu s$	4 $\mu s$	9.4 $\mu s$	50 $\Omega$	0.082 $\mu F$
CR-200-8 $\mu s$	8 $\mu s$	19 $\mu s$	50 $\Omega$	0.15 $\mu F$

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