CR-200 Gaussian shaping amplifier: application guide

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General Description

The CR-200 is a Gaussian shaping amplifier module, and is used to read out the “tail pulse” signals such as from charge sensitive preamplifiers, PMTs, and other similar detection circuits. Gaussian shaping amplifiers are also known as ‘pulse amplifiers’, ‘linear amplifiers’, or ‘spectroscopy amplifiers’ in the general literature. They accept a step-like input pulse and produce an output pulse shaped like a Gaussian function (bell curve). The purpose of these amplifiers is not only to transform the shape of the event pulse from a tail pulse to a bell curve, but also to filter much of the noise from the signal of interest. Use of shaping amplifiers will reduce the fall time of the pulse signals, reducing the incidence of pulse ‘pile up’, and improve the signal-to-noise of the detection system.

The CR-200 is available in 8 different shaping times, from 50 ns to 8 μs. The gain and shaping times of these amplifiers are fixed. If additional gain is desired, it is recommended that this be done with the application of an additional broadband amplifier between the preamplifier and the CR-200 shaping amplifier. Cremat offers an evaluation board (CR-160-R7) which includes a multi-stage variable-gain amplifier, as well as all necessary connectors. More information on the CR-160-R7 evaluation board can be found at http://cremat.com

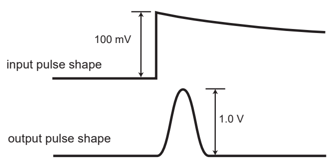


Figure 1. Comparison of sample input and output pulse shapes

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 2.4. For example, a Gaussian shaping amplifier with a shaping time of 1.0 μs would have a FWHM of 2.4 μs.

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.

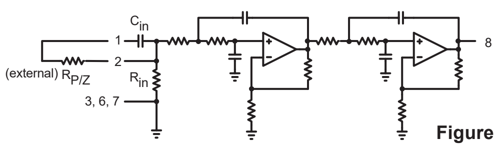


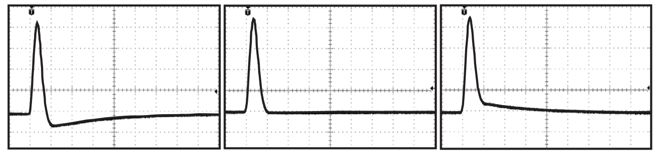
Figure 2

part #	shaping time	output pulse width (FWHM)	R_{in}	C_{in}	gain
CR-200-50ns	50 ns	120 ns	220 Ω	220 pF	8
CR-200-100ns	100 ns	240 ns	220 Ω	470 pF	10
CR-200-250ns	250 ns	590 ns	240 Ω	1000 pF	10
CR-200-500ns	500 ns	1.2 μs	510 Ω	1000 pF	10
CR-200-1μs	1 μs	2.4 μs	1.0 kΩ	1000 pF	10
CR-200-2μs	2 μs	4.7 μs	2.0 kΩ	1000 pF	10
CR-200-4μs	4 μs	9.4 μs	1.2 kΩ	3300 pF	10
CR-200-8μs	8 μs	19 μs	2.4 kΩ	3300 pF	10

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 so that $R_{P/Z} * C_{in}$ is equal to the decay time constant of the preceding charge sensitive preamplifier output signal. Use the equation $R_{P/Z} = R_f * C_f / C_{in}$ 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.

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.



$R_{P/Z}$ resistance too high $R_{P/Z}$ resistance proper $R_{P/Z}$ resistance too low

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):

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

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

To address this potential problem, Cremat offers the CR-210 baseline restorer. More information on this circuit can be found at the cremat.com web site.

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.

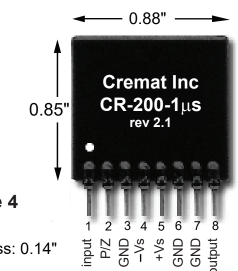


Figure 4

thickness: 0.14"

Typical Application

Figure 5 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. An optional CR-210 baseline restore circuit has been added as well.

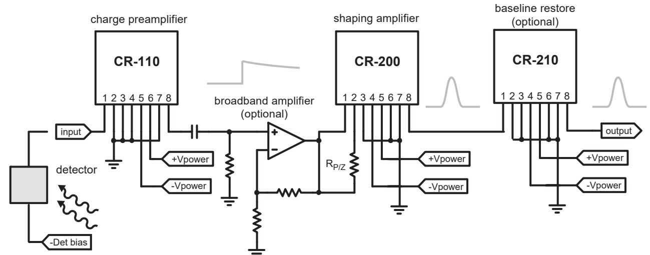


Figure 5

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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:

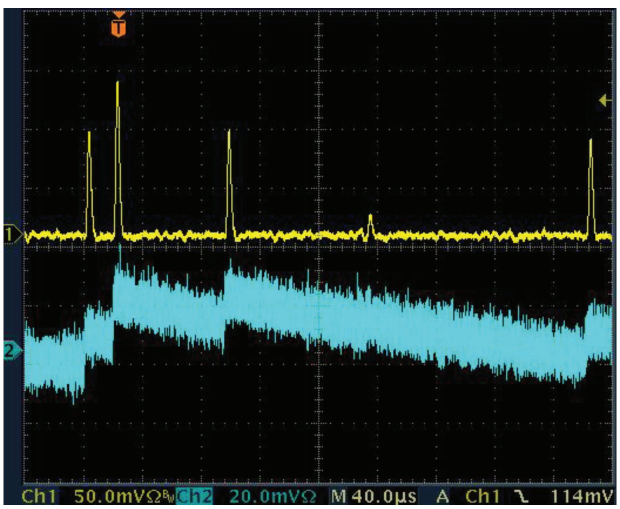
1. The shaping time must be long enough to collect the charge from the detector. This may be a limiting factor in slow detectors such as gas-based drift chambers or when collecting the light from slow-decay scintillators.

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. Many of these 'noise components' have different power spectra, 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. Keep in mind it may be difficult to precisely predict the shaping time at which the noise will be minimum. The surest method may be to determine this noise minimum experimentally by measuring the noise using a variety of shaping times.

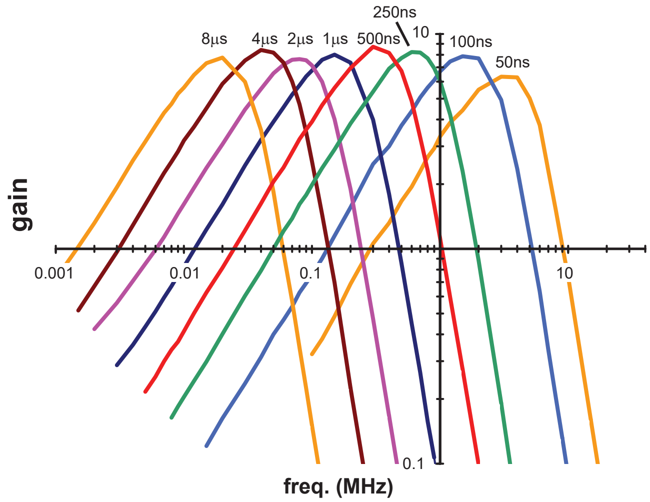
Example: Shaping Amplifier used in Nuclear Pulse Detection

Shown below are two oscilloscope traces: the input (blue) and output (yellow) of a Gaussian shaping amplifier (1µs shaping time) reading pulses from a charge sensitive preamplifier in the presence of noise. Not only does the shaping amplifier amplify the pulses, but the fall time is quickened, greatly reducing the problem of pulses 'piling up' on the tails of preceding pulses. Also, the filtering effects of the shaping amplifier significantly filters the noise. This allows for pulses to be clearly detected that would be otherwise buried within the noise.



Output Characteristics

The CR-200 shaping amplifiers have low output impedance (<5Ω) and can source/sink 20 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. There is an exception to this: the CR-200-50ns becomes somewhat non-linear for output pulses exceeding +/-6V.



CR-200 Bandpass filtering properties

Specifications

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

	CR-200	units
amplification channels	1	
polarity	non-inverting	
operating temperature range	-40°C to 85°C	
input noise voltage		
CR-200-50ns	115	µV RMS
CR-200-100ns	90	µV RMS
CR-200-250ns	60	µV RMS
CR-200-500ns	47	µV RMS
CR-200-1µs	36	µV RMS
CR-200-2µs	30	µV RMS
CR-200-4µs	24	µV RMS
CR-200-8µs	22	µV RMS
output impedance	<5	Ω
output offset	-40 to +40	mV
output temperature coefficient	-60 to +60	µV / °C
power supply voltage (V_s)		
absolute maximum	V_s = ±13	volts
minimum	V_s = ± 5	volts
quiescent power supply current	7	mA
maximum output current	20	mA
maximum output swing*	V_s-0.5	volts

* for CR-200-50ns maximum output is +/-6V or V_s-0.5, whichever is less.

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