CR-Z-111 and **CR-Z-111-HV** CSP instruments: application guide

rev. 0.1, May 2014

Overview

The CR-Z-111 and CR-Z-111-HV are charge sensitive preamplifier (CSP) instruments, based on Cremat's CR-111 CSP module. The CR-Z-111 has BNC connections for detector input, test input, preamplifier output, and detector bias supply. The CR-Z-111-HV is identical to the CR-Z-111 except that SHV connectors are used in place of BNC connectors in the detector input and detector bias supply connections. The CR-Z-111-HV is recommended when the applied detector bias exceeds +/- 500V. Maximum detector bias voltage using the CR-Z-111-HV is +/- 2000V.

Preamplifier Specifications

Assume temp =20 °C, unloaded output

		units
Equivalent noise charge (ENC)*	630	electrons RMS
	0.1	femtoCoul. RMS
Equivalent in silicon detector:	6	keV (FWHM)
Equivalent in CdZnTe detector:	7	keV (FWHM)
ENC increase per added input capacitance	3.7	electrons RMS /pF
Gain	0.13	V / picoCoul.
	5.8	mV / MeV(Si)
Rise time **	5	ns
Decay time constant	150	µs
Maximum charge detectable per event	1.3 x10^8	electrons
	21	picoCoul.
Operating temperature	-40 to +85	°C
Output impedance	50	ohms
Output voltage swing	-3 to +3	volts

* Measured with input unconnected, using Gaussian shaping amplifier with shaping time =1 µs. With a detector attached to the input, noise induced by the detector capacitance, leakage current, and dielectric losses will add to this figure.

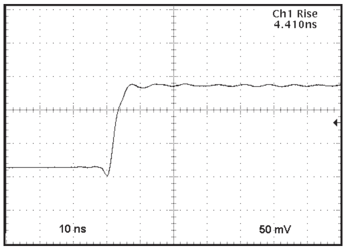
** Pulse rise time (defined as the time to attain 90% of maximum value) and increases with increasing input capacitance. Value cited in the table assumes zero added input capacitance.

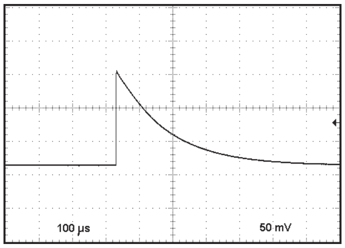
Preamplifier operation

Charge sensitive preamplifiers (CSPs) can be used when radiation is detected as a series of discrete detection events. These events generally produce brief pulses of current flowing into the CSP input, which has a low impedance at the frequencies of the detection signal. Depending on the type of detector, this burst of current may be very brief (<1 ns) or as long as a few µs. CSPs are integrating in nature, and integrate the current from each pulse to produce an output pulse proportional to the ionized charge from the detector flowing into the preamplifier input from each event. For an idealized detection current pulse into the input taking the form of a delta function, the detected charge (time integral of the input current) will take the form of a step function. The output waveform of an actual charge sensitive preamplifier is of course not exactly a step function and will have a non-zero rise time: for the CR-111 this figure is approximately 3 ns. Furthermore, capacitance at the preamplifier input (i.e. detector capacitance) will further slow the rise time at a rate of 0.11 ns / pF. The added capacitance of the diode protection circuit (D1 & D2) results in a pulse rise time of 5 ns for the CR-Z-111 instrument.

The output rise time may also be limited by the speed of the detector. For example, the detection current pulse from a CsI(Tl)/photodiode scintillation detector has a duration of approximately a couple µs, so in this case the expected rise time of the charge sensitive preamplifier output will be at least that long.

The output waveform of the CR-111 using a capacitively-coupled fast square wave pulser at the input is shown in the following scope traces. At long time domains, the output decays due to the discharge of the feedback capacitor through the feedback resistor within the CR-111 module, with an RC time constant of 150 µs. The pulse decay caused by the feedback resistor inside the CSP serves to reset the preamplifier. Although subsequent pulses may ride up on top of this decaying tail, this generally does not present a problem because the preamplifier output is usually not analyzed directly; it is usually routed through a shaping amplifier which considerably quickens the pulse decay. More information on this can be found in the product literature for Cremat's shaping amplifiers at http://cremat.com/CR-200.htm

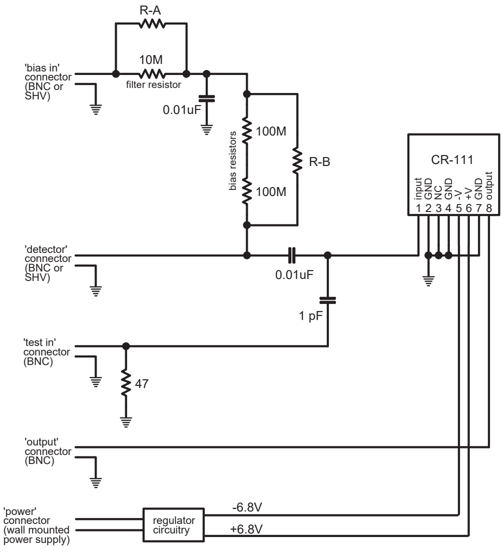




Equivalent circuitry

Cremat's CR-Z series of charge sensitive preamplifier instruments use 'AC-coupling' to connect the detector to the input of the preamplifier's amplification stage. This AC-coupling is evident in the simplified circuit diagram shown below. The detector must be a two-terminal device having one terminal at ground. The detector dark current flows into the preamplifier instrument through the 'bias in' connector, is filtered in a simple RC low pass filter (10M/0.01uF), then flowing through the bias resistor (200M ohms) and then through the detector to ground. The bias resistor serves as a high impedance to the detector signals, so the detector signal current passes instead through the relatively low impedance of the 0.01uF blocking capacitor to the preamplifier input.

In the event that the detector dark current exceeds approximately 10 nA, the user may consider reducing the value of the bias resistor in order to prevent the resulting voltage drop across the resistor from becoming too large. The voltage drop across the bias resistor (as well as the filter resistor) reduces the detector bias voltage by that same amount because they are in series. So if precise control of the detector bias is required and the detector current exceeds approximately 10 nA, we recommend reducing the value of the bias and filter resistors to keep these voltage drops small. It is for this reason that there are a couple unpopulated resistor positions on the main circuit board, labeled R-A and R-B, which can be used to shunt the filter and bias resistors respectively. A table of recommended values of R-A and R-B is shown below, based on the average detector current. Because most voltmeters cannot accurately measure voltage drops across very large resistances, the best method is to use your knowledge of the approximate detector current to calculate this voltage drop.

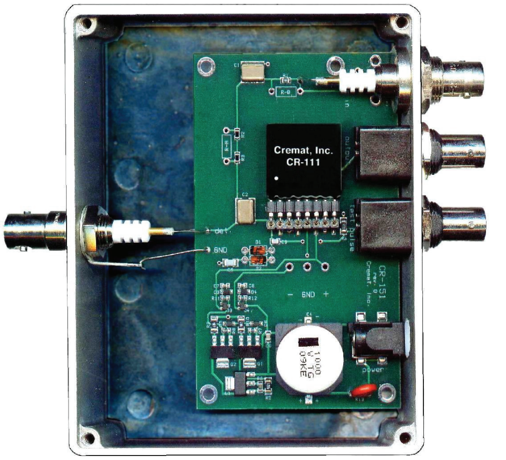


leakage current range:			R-A	R-B
0	to	10 nA	(left open)	(left open)
10 nA	to	30 nA	(left open)	22M
30 nA	to	100 nA	(left open)	10M
100 nA	to	300 nA	3.3M	3.3M
300 nA	to	1 µA	1M	1M
1 µA	to	3 µA	330k	330k
3 µA	to	10 µA	100k	100k
10 µA	to	30 µA	33k	33k

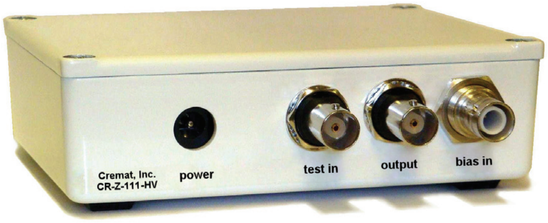
Cremat Inc, 950 Watertown St., Suite 3
West Newton, MA 02465 USA
+1(617) 527-6590
http://cremat.com

Testing the preamplifier for proper operation

To test the CR-Z-111 CSP, connect a square wave pulser to the 'test in' BNC connection on the CR-Z-111 instrument, and an oscilloscope to the output. For best results you should properly terminate the coaxial cable at the oscilloscope. The square wave input should be in the range of 100 mV to 10V peak-to-peak amplitude, approximately 50% duty cycle, and a frequency of no more than 1000 Hz. Leave the 'detector input' and 'bias in' unconnected. Finally, apply power to the preamplifier by connecting the wall mounted power supply to the 'power' connection. The rise time of the square wave pulses from your test pulser should be no more than 5 ns, or the rise time of the preamplifier output will be limited by the rise time of the test pulser rather than by the preamplifier itself.



The preamplifier should produce a 'tail pulse' output in response to the square wave applied to the test input. A tail pulse is a pulse with a fast rise time and slow exponentially decaying fall time. An example of the output tail pulse waveform was shown previously in this document. With each change of state of the input square wave, a brief burst of current is injected to the preamplifier input through the 1 pF coupling capacitor (see the 'Equivalent circuitry' section). The CSP integrates the charge from this brief burst of current, producing a step function output. At long time domains, this step function can be seen decaying exponentially with a 150 microsecond time constant. This time constant is characteristic of the CR-111 module and is a result of the RC of the module's feedback resistance (10M) and feedback capacitance (15 pF). For example, if a 1 volt peak to peak square wave is applied to the test input, there is a 1 picocoulomb current pulse applied to the preamplifier input with every cycle change. The gain of the CR-111 module is 0.13 volts output per picocoulomb input. The output tail pulse response, therefore, has a peak-to-peak amplitude of 0.13 volts. Remember that the output impedance of the CR-111 module is 50 ohms, so if the coaxial cable to your oscilloscope is terminated by a 50 ohms termination then the measured output voltage will be halved to 75 mv. Also, the test input has a 50 input impedance so this load may alter the amplitude of your test input pulse. The tolerance of the 1 pF test capacitor is only +/- 25% so the precision of this measurement will likely be limited by this tolerance.



CR-Z-111-HV shown

There are a number of different methods used to measure noise; a commonly used method is to measure the width of a pulser peak in a pulse height spectrum as collected by a multi-channel analyzer. A disadvantage of this method is the requirement for both a multi-channel analyzer and pulser. A somewhat simpler method to measure noise that does not require access to a multi-channel analyzer is to use an instrument capable of measuring rms voltage. Many digital oscilloscopes have this capability. Besides this instrument you will also need a low noise shaping amplifier having 1 microsecond shaping time. Cremat offers such an instrument, however there are a number of different manufacturers offering suitable shaping amplifiers. To make this noise measurement, connect the output of the CR-Z-111 CSP to the input of the shaping amplifier, leaving the 'detector input', 'bias in', and 'test in' on the CR-Z-111 unconnected. Measure the rms noise of the shaping amplifier output, being careful to exclude any small DC offsets present (use 'AC coupling'). Using the known nominal gain of both your shaping amplifier and the CR-Z-111 CSP (0.13 volts per picocoulomb), you can divide the measured noise by these gains to obtain the input equivalent noise charge (ENC). Because of the great sensitivity of this instrument, there may be some pickup of the ambient RF at the open 'detector input' connector. Shielding this connector will be required to get an accurate measurement, which can be done with a non-shorting BNC cap.

DC offset at the CSP input and output

There is generally a small DC offset to the output of the CR-Z-111 preamplifier. This figure varies slightly from unit to unit, and for a given unit can also drift slightly with time and temperature. This is generally of no consequence in nuclear pulse measurements, in which the DC offset of the preamplifier is filtered from analysis. The DC offset of the preamplifier is within the range of -0.2V to +0.2V.

The potential at the input of the CR-Z-111 is not exactly at ground. This figure varies slightly from unit to unit and is due to the manufacturing spread of the input JFET used in the CSP circuit. The input potential is within the range of -1V to -0.2V.

Power supply

Included with all CR-Z series charge sensitive preamplifiers is a wall mounted power supply. This supply has 5 different interchangeable input blades in order to accommodate various wall sockets and wall voltages found internationally. Cremat does not recommend that other types or models of power supplies be used in place of this model.