CR-111-R2.1 charge sensitive preamplifier: application guide

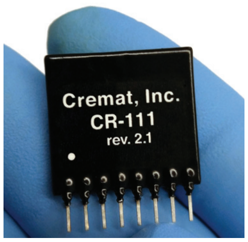
Oct. 2018

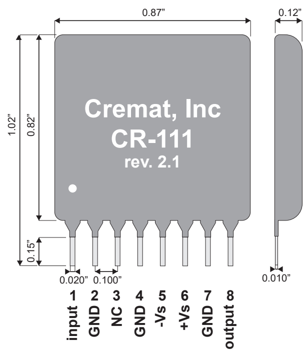
General Description

Cremat's CR-111-R2.1 is a single channel charge sensitive preamplifier module intended for use with various types of radiation detectors including semiconductor detectors (e.g. CdTe and CZT), p-i-n photodiodes, avalanche photodiodes (APDs), and various gas-based detectors. The CR-111-R2.1 is one of a series of four charge sensitive preamplifiers offered by Cremat, which differ from each other most notably by their gain. As with all Cremat's preamplifier modules, the CR-111-R2.1 is small (less than one square inch in area), allowing for compact multichannel detection systems to be constructed using a modular design.

Package specifications

The CR-111-R2.1 circuit is in an 8-pin SIP package (0.100" spacing). Pin 1 is marked with a white dot for identification.



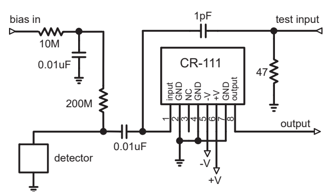


Detector coupling

The CR-111-R2.1 can be used either in a direct coupled (DC) mode or an AC coupled mode. If the detector current exceeds 100 nA, it is recommended that an AC coupled mode be used to prevent the resulting DC offset of the preamplifier output from saturating. more information can be found at:
http://www.cremat.com/applications/csp-application-notes/

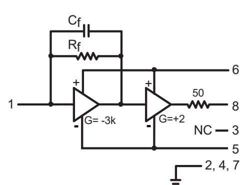
Typical setup

The CR-111-R2.1 is often AC-coupled to a detector in the way shown here. This circuit is available in the form of Cremat's CR-150-R5 evaluation board, providing a socket for the CR-111-R2.1 module, BNC connectors, and circuitry for powering the preamplifier. For more information see:
http://www.cremat.com/home/cr-150-r5-csp-evaluation-board/



Equivalent circuit diagram

This figure shows a simplified equivalent circuit diagram of the CR-111-R2.1, which is a two stage amplifier. The first stage is a high gain, charge sensitive preamplifier and the second stage is low gain voltage amplifier. Pin numbers corresponding with the CR-111-R2.1 preamplifier are shown. R_f (10 MΩ) and C_f (15 pF) are the feedback resistor and capacitor respectively. An LTspice model of the CR-111-R2.1 is available on the Cremat web site. LTspice is freeware computer software implementing a SPICE simulator of electronic circuits, produced by semiconductor manufacturer Linear Technology, now part of Analog Devices.

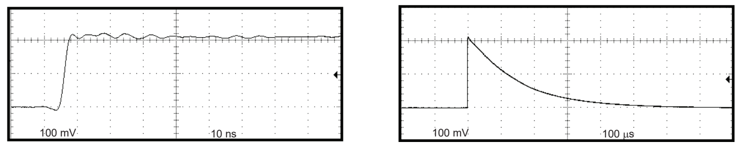


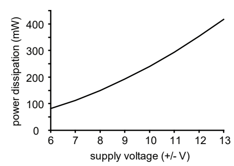
Input and output waveforms

Charge sensitive preamplifiers are used when radiation is detected as a series of pulses of current. These pulses of current flow into (or out of) the preamplifier input. Depending on the type of detector, these pulses are typically in the range of a few ns to a few µs in duration. Each current pulse is integrated by the feedback capacitor within the preamplifier resulting in a voltage pulse at the output that is proportional to the total charge in the pulse. The feedback resistor (in parallel with the feedback capacitor) slowly discharges (resets) the feedback capacitor, producing an exponential decay of each pulse with a time constant of 15pF x 10Mohms = 150µs. For this reason the pulses of current from the detector should be limited in duration to only a few microseconds as longer pulses see a distortion due to this exponential decay.

The rise time of the CR-111-R2.1 output pulses is approximately 2 ns, however the rise time may be further slowed by a couple of factors. Added capacitance at the preamplifier input (i.e. detector capacitance) slows the rise time at a rate of 0.05 ns/pF. The output rise time will 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 rise time of the charge sensitive preamplifier output will be at least that long.

The output waveform of the CR-111-R2.1 using a capacitively-coupled fast square wave pulser at the input is shown below in two figures. The rise time of the preamplifier is evident in the figure on the left. At long time domains, the 150 µs output decay is evident in the figure on the right. **Both figures below show the same preamplifier output.** They differ only in the time domain.





The power dissipation of the CR-111-R2.1 is shown to the left as a function of supply voltage. The minimum supply voltage for good operation is +/- 6V. Any supply voltage applied in excess of this figure does not change or improve CR-111-R2.1 performance, but instead results in unnecessary power dissipation.

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RoHS

Specifications

Assume temp =20 °C, V_s = ±6V, unloaded output

	CR-111-R2.1	units
Preamplification channels	1	
Equivalent noise charge (ENC)*		
ENC RMS	600	electrons
	0.1	femtoCoul.
Equivalent noise in silicon	5	keV (FWHM)
Equivalent noise in CdZnTe	7	keV (FWHM)
ENC slope	3.8	elect. RMS /pF
Gain	0.13	volts /pC
Rise time **	2	ns
Decay time constant	150	µs
Unsaturated output swing	-3 to +3	volts
Maximum charge detectable per event	1.3 x10^8	electrons
	21	pC
Power supply voltage (V_s)		
maximum	V_s = ±13	volts
minimum	V_s = ±6	volts
Power supply current (pos)	9	mA
(neg)	6	mA
Power dissipation with no load	85	mW
Operating temperature	-40 to +85	°C
Output offset	+0.2 to -0.2	volts
Output impedance	50	ohms

* Measured with input unconnected, using Gaussian shaping amplifier with time constant =1 µs. With a detector attached to the input, noise from 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) has a linear relationship with input capacitance. Value cited in the table assumes zero added input capacitance. To calculate pulse rise time for practical situations, use the equation: t_r =0.05 C_d + 2 ns, where t_r is the pulse rise time in ns, and C_d is the added capacitance (e.g. detector capacitance) in pF. Others factors within the detection system may further limit this value.