CSA4

Charge Amplifier

User Manual

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Germany

Version 1.0, December 4, 2009

Warranty

Equipment manufactured by FAST ComTec GmbH is warranteed against defects in materials and workmanship for a period of twelve months from date of shipment, provided that the equipment has been used in a proper manner as detailed in the instructions manuals. During the warranty period, repairs or replacement will be made at FAST ComTec's option on a return to factory basis. The transportation cost, including insurance to FAST ComTec is the responsibility of the Costumer except for defects discovered within 30 days after receipt of equipment where shipping expense will be paid by FAST ComTec.

The information in this manual describes the hardware and the software as accurately as possible, but is subject to change without notice.

Table of Contents

CSA4 Configuration Form

Preamplifier section:

type of preamp	(check one box)	(inverting)
	☐ CR110	1,4 V/pC
	☐ CR111	150 mV/pC
	☐ CR112	15 mV/pC
	☐ CR113	1,5 mV/pC

Shaping Amplifier section:

shaping time per stage (check one box in each line)

Shaper A	☐ 25ns	☐ 50ns	☐ 100ns	☐ 250ns	☐ 500ns	☐ 1μs	☐ 2μs	☐ 4μs	☐ 8μs
Shaper B	☐ 25ns	☐ 50ns	☐ 100ns	☐ 250ns	☐ 500ns	☐ 1μs	☐ 2μs	☐ 4μs	☐ 8μs
Shaper C	☐ 25ns	☐ 50ns	☐ 100ns	☐ 250ns	☐ 500ns	☐ 1μs	☐ 2μs	☐ 4μs	☐ 8μs
Shaper D	☐ 25ns	☐ 50ns	☐ 100ns	☐ 250ns	☐ 500ns	☐ 1μs	☐ 2μs	☐ 4μs	☐ 8μs

common for all stages: input polarity + / -

coarse gain x 1 x 10 x 100

individual for each stage: fine gain
pole zero cancelation
output offset control

output signal: positive, unipolar gaussian shaped

output impedance: 50 Ohm

output amplitude: 0... 8V into 1 kOhm

0... 4V into 50 Ohm

Power Connector section:

connector type: D-Sub 9 female

pin 1	GND
pin 2	GND
pin 4	+12V
pin 6	-24V
pin 7	+24V
pin 9	-12V

1. Introduction

1.1. General

Functionally, the Model CSA4 provides in a single width NIM module a preamplifier and a shaping amplifier with four shaping times simultaneously (selectable in the range from 100ns to 8µs: four values out of seven can be ordered : 100ns, 250ns, 500ns, 1µs, 2µs, 4µs, 8µs). A power connector (D-Sub 9 female) is also available at the front panel for the power supply of external preamplifiers.

1.2. Preamplifier section

The Model CSA4 provides a charge sensitive preamlifier. It is intended to be used in uncritical applications, where the detector / signal source needs no bias voltage supplied from the charge sensitive amplifier. (like integration of signals from PMT's)

In applications, where a detector bias is needed or the signal-to-noise ratio is important, an external charge sensitive preamplifier (like our model CSP10...13) close to the detector is recommended.

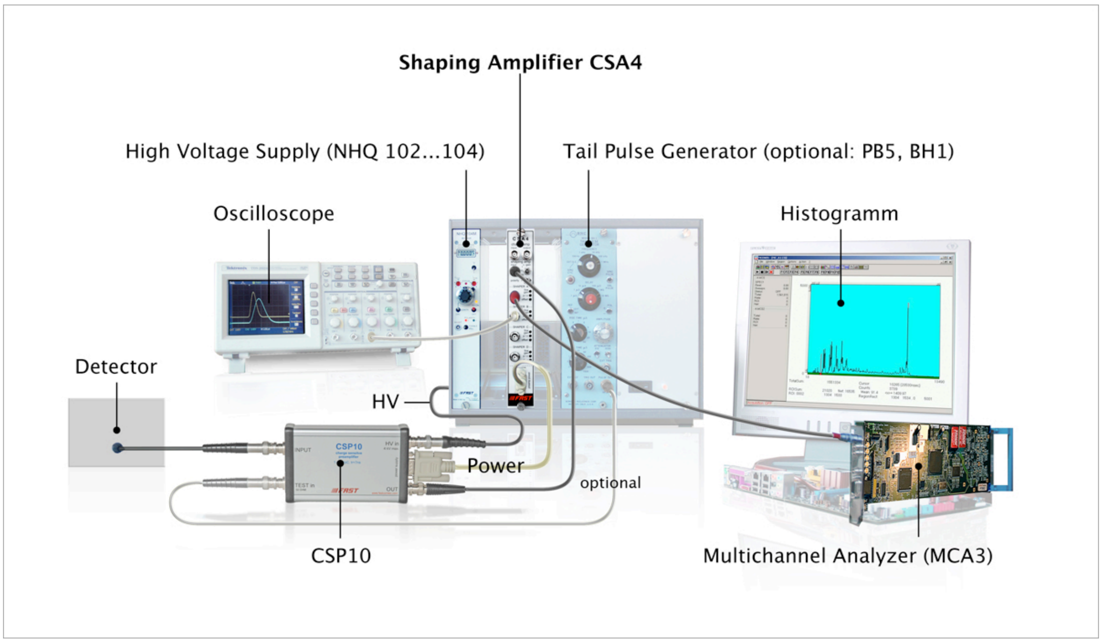
1.3. Typical Setup

The Model CSA4 Shaping Amplifier with its selection of shaping time constants can be used in surface barrier, proportional counter, NaI and Ge(Li) detector applications. The choice of shapings also allows the best possible performance by tailoring the system for the conflicting requirement of optimum signal to noise ratio and high count rate performance. The excellent stability and low noise contribution enhances the use of this amplifier in most applications.

It is intended to be used to read out the signals from a charge sensitive preamplifier (first CSA4 section, CSP1x ... or equivalent).

Gaussian shaping amplifiers (also known as spectroscopy amplifiers, shaping amplifiers, linear amplifiers or pulse amplifiers) accept a step-like input pulse (fast rise time, slow fall time) and produce an output pulse shaped like a gaussian function.

The purpose of this are to filter much of the noise from the signal of interest and provide a quickly restored baseline to allow high count rates.



2. Specifications

2.1. Inputs

INPUT - Accepts positive or negative pulses from a associated preamplifier; ± 8 volts divided by selected gain, ± 10 volts maximum; rise time, less than SHAPING TIME constant; decay time constant, 40 µsec to ∞ for 0,1, 0.25, 0.5, 1, and 2 µsec shaping time constants, 100 µsec to ∞ for 4, and 8 µsec shaping time constant; input impedance, approximately 1k ohms; input BNC connectors located on front panel.

2.2. Outputs

UNIPOLAR OUTPUTS - Provide positive, linear active filter, near-Gaussian shaped pulses; amplitude linear to +8 volts @ R_l > 1kOhm, +4 volts @ R_l = 50 Ohm , 10 volt max.; output dc level adjustable, front panel output impedance approximately 50 ohms; BNC connectors located on front panels.

2.3. Performance

GAIN RANGE - Continuously variable x1 to x2500, product of COARSE and FINE GAIN controls.

OPERATING TEMPERATURE - 0 to 50° C

GAIN DRIFT - Less than or equal to ± 0.0075%/° C

DC LEVEL DRIFT - Less than or equal to ± 0.1mV/° C

INTEGRAL NON LINEARITY - Less than or equal to ±0.05%, over total output range, for 2 µsec shaping.

OVERLOAD RECOVERY - UNIPOLAR output recovery to within ±2% (±1%) of full scale output from X1000 overload in 2.5 (2.0) non-overloaded pulse widths, at full gain, any shaping time constant and pole/zero cancellation properly set.

NOISE CONTRIBUTION - Less than or equal to 3.4 µV true rms, referred to input, 3 µsec shaping and amplifier gain greater than or equal to 100.

PULSE SHAPING - Near-Gaussian shape; one differentiator, two active filter integrators; time to peak, 2.35 x shaping time; pulse width FWHM: 2,4 x shaping time; time to peak, pulse width measured at 0.1 % of full scale output; 1 µsec SHAPING center frequency, 150 kHz; band width, 180 kHz; f_c and BW for other shapings are multiples of that given for 1 µsec.

2.4. Connector Types

With the exception of the PREAMP POWER connector, all signal connectors are BNC type.

PREAMP POWER – Amphenol type 17-10070

2.5. Power Requirements

+12 V dc 200 mA + current drawn from the preamp power connector

- 12 V dc 100 mA + current drawn from the preamp power connector

+24 V dc 0 mA + current drawn from the preamp power connector

- 24 V dc 0 mA + current drawn from the preamp power connector

2.6. Physical

Size–Standard single-width NIM module 3.41 x 22.13 cm (1.35 x 6.71 inch)

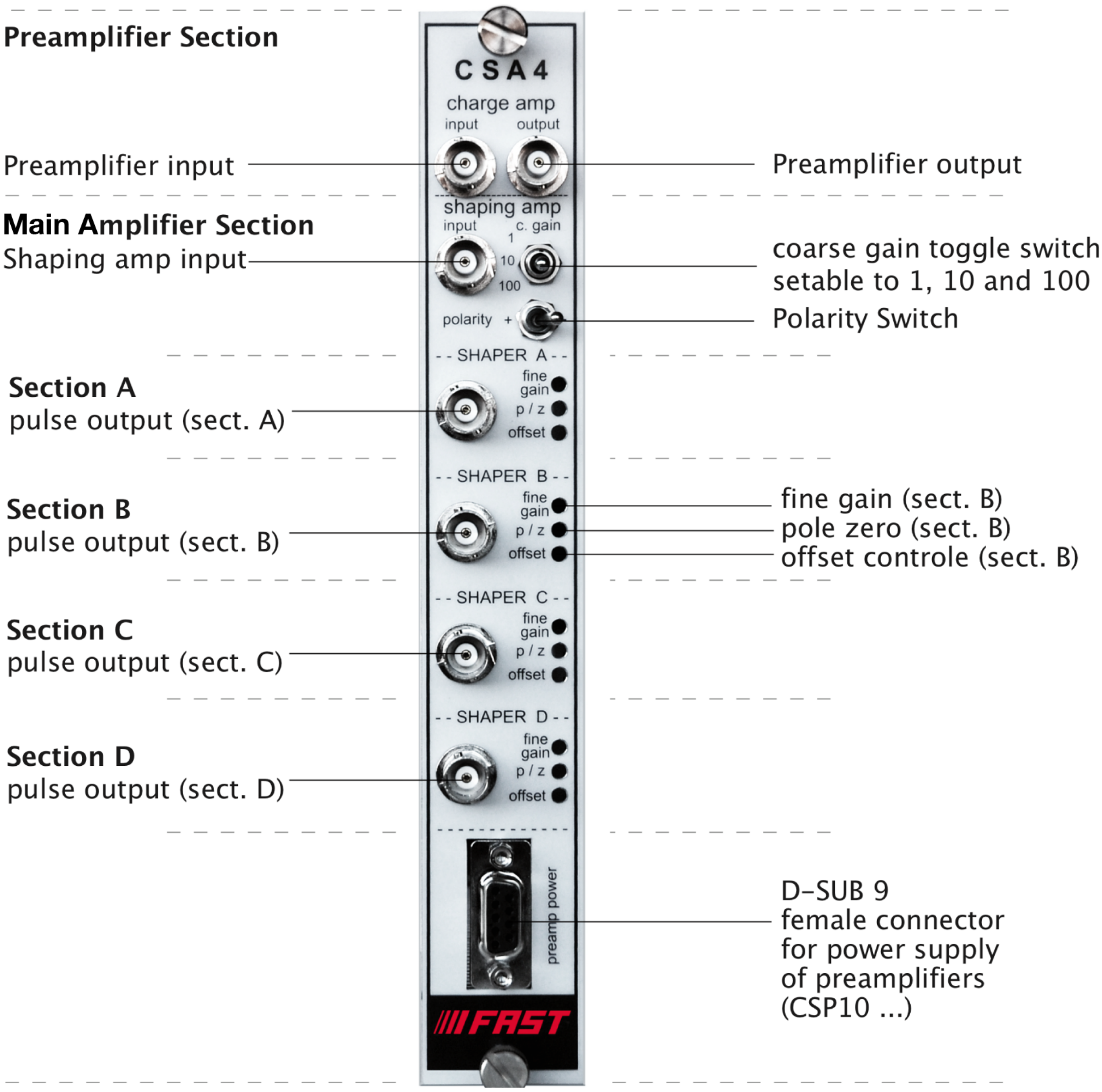
NET WEIGHT–1.0 kg (2.2 lbs)

3. Controls and Connectors

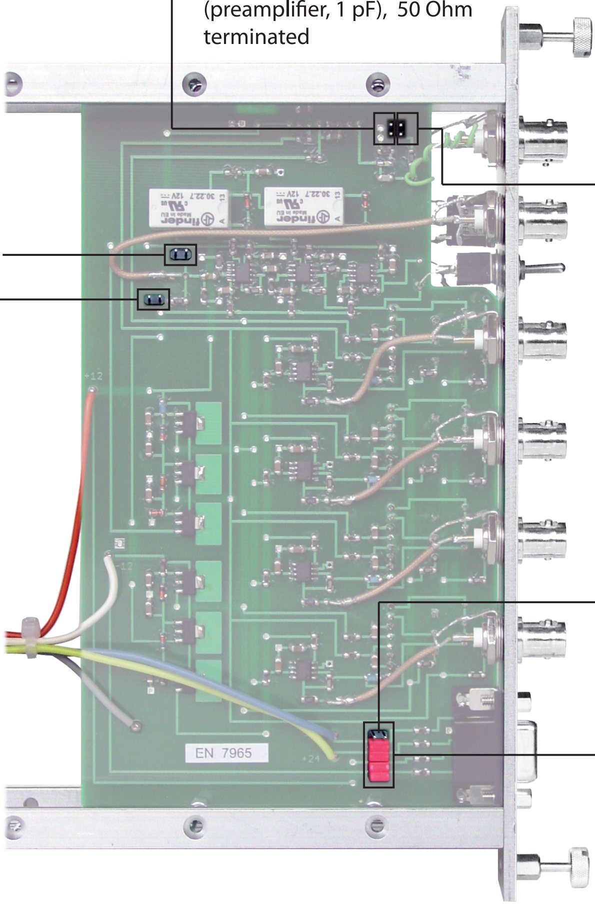
3.1. General

This section describes the functions of the controls and connectors located on the front panels of the Model CSA4. It is recommended that this section be read bevor proceeding with the operation of the amplifier.

3.2. Front Panel Controls

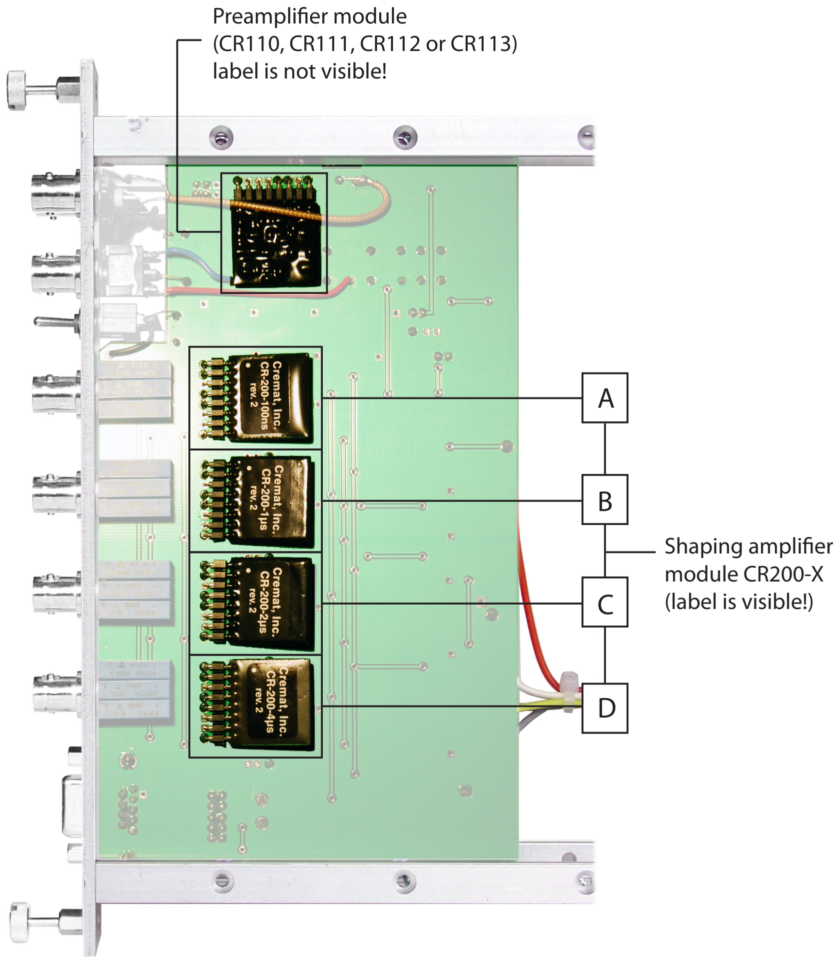


3.3. Internal Controls (Jumper)



J1	Selects input impedance of preamplifier input 50 Ω (installed)
J2	Test input terminates (signal, ground); terminated with 50 Ω, 1pF test capacitor
J3	Connects output of preamp section with the input of the shaping amplifier section
J4	selects input impedance of shaping amplifier in 50 Ω (installed) 1kΩ (open)
J5	not used
J6	If installed: - 24 V supply is available on preamp power connection
J7	If installed: + 24 V supply is available on preamp power connection
J8	If installed: +12 V supply is available on preamp power connection
J9	If installed: - 12 V supply is available on preamp power connection

3.4. Internal Module Positions



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

see 'equivalent circuit diagram' on previous page.

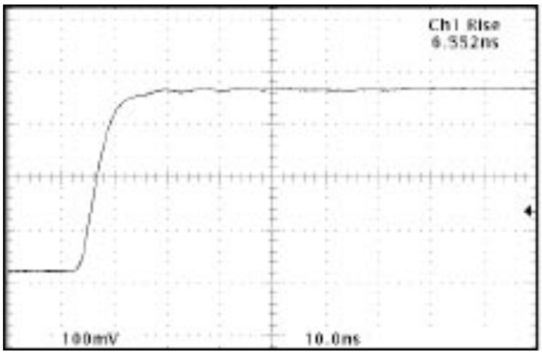
4. Theory of Operation

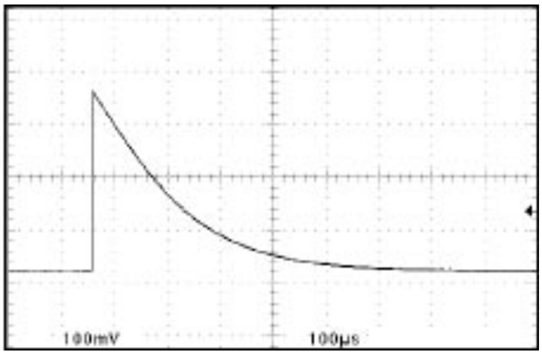
4.1. Functional Description (preamplifier)

Charge sensitive preamplifiers are used when radiation is detected as a series of pulses, resulting in brief bursts of current flowing into or out of the preamplifier input. Depending on the type of detector, this burst of current may be very brief (<1 ns) or as long as a few seconds. For an idealized detection current pulse taking the form of a delta function, the detected charge (time integral of the input current) will ideally take the form of a step function.

The output waveform of an actual charge sensitive preamplifier will of course have a non-zero rise time: for the preamplifier of the CSA4 this figure is approximately 7 ns. Furthermore, capacitance at the preamplifier input (i.e. detector capacitance) will further slow the rise time at a rate of 0.4 ns / pF. Keep in mind 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 s, so the expected rise time of the charge sensitive preamplifier output will be at least that long.

The output waveform of the preamplifier of the CSA4 using a capacitively-coupled fast square wave pulser at the input is shown below to the left. At long time domains, the output decays due to the discharge of the feedback capacitor through the feedback resistor, with an RC time constant of 140 µs. This decay of the output waveform is also shown below, to the right.





4.2. Detailed Circuit Description (preamplifier)

Figure 2 shows a simplified equivalent circuit diagram of the hybrid amplifier module used in the preamplifier of the CSA4, which is a two stage amplifier. The first stage is high gain, and the second stage is low gain with an emphasis on supplying sufficient output current to drive a terminated coaxial cable. Rf (100 MΩ) and Cf (1.4 pF) are the feedback resistor and capacitor respectively (tdecay= 140µs). The feedback values for the other models are:

Rf =10 MΩ and Cf =15 pF, tdecay= 150 µs (CSA4 with CR-111),

Rf =680 kΩ and Cf =15 pF, tdecay= 50 µs (CSA4 with CR-112),

Rf =68 kΩ and Cf =150 pF, tdecay= 50 µs (CSA4 with CR-113).

The CSA4 preamplifier module consists of:

- hybrid charge sensitive preamplifier
- input DC block capacitor
- test input with 50 ohm termination
- 1 pF test capacitor, high voltage path with filter circuit and power supply circuitry

4.3. General Description (shaping amplifier)

The CSA4 is a four 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 CSA4 is available with any set of four out of 7 different shaping times: 100 ns, 250 ns, 500 ns, 1 µs, 2 µs, 4 µs, and 8 µs. Each has a fixed gain of 10.

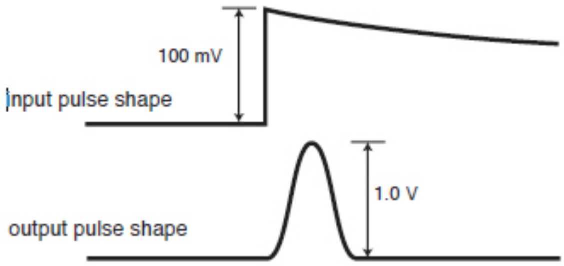


Figure 1. Comparison of sample input and output pulse shapes

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 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 **µ**s would have a FWHM of 2.4 **µ**s.

4.4. Equivalent circuit diagram (shaping amplifier module)

Figure 2 shows an equivalent circuit of the shaping amplifier modules. 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.

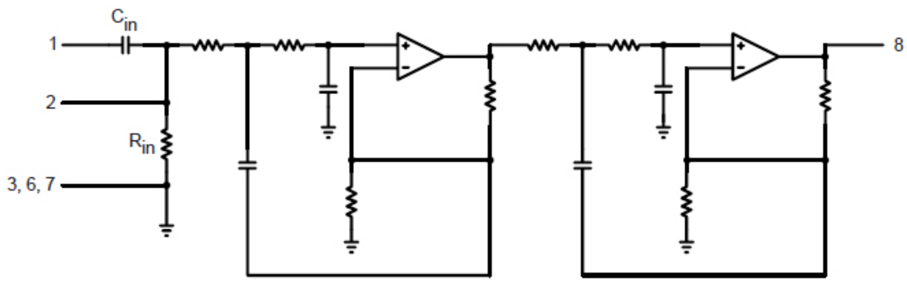
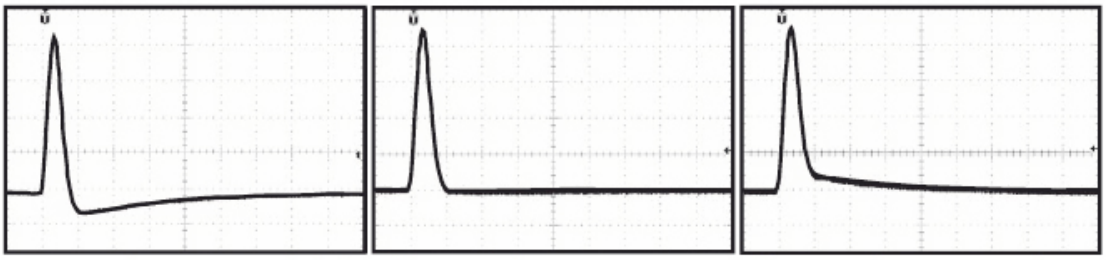


Figure 2

4.5. 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 adjusting $R_{P/Z}$. This resistor is in parallel with the input capacitor (internal to the CSA4 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*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 CSA4.

Keep in mind that the CSA4 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 to use the DC offset adjustment at the frontpanel to correct for this.



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

Figure 3

4.6. Choosing the Optimal Shaping Time for your Application

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**Ω**) 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.

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

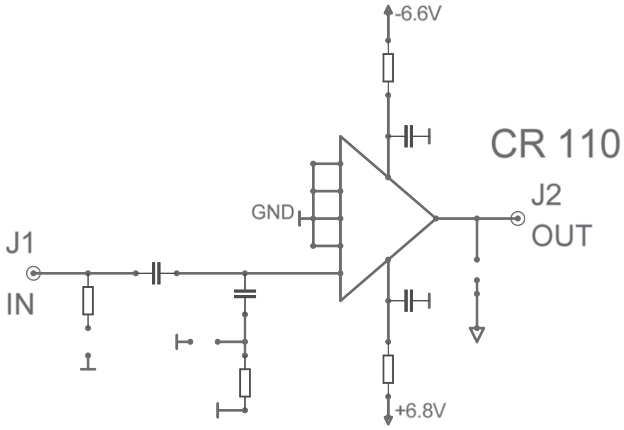
see 'equivalent circuit diagram' on previous page.

4.7. Output Driver

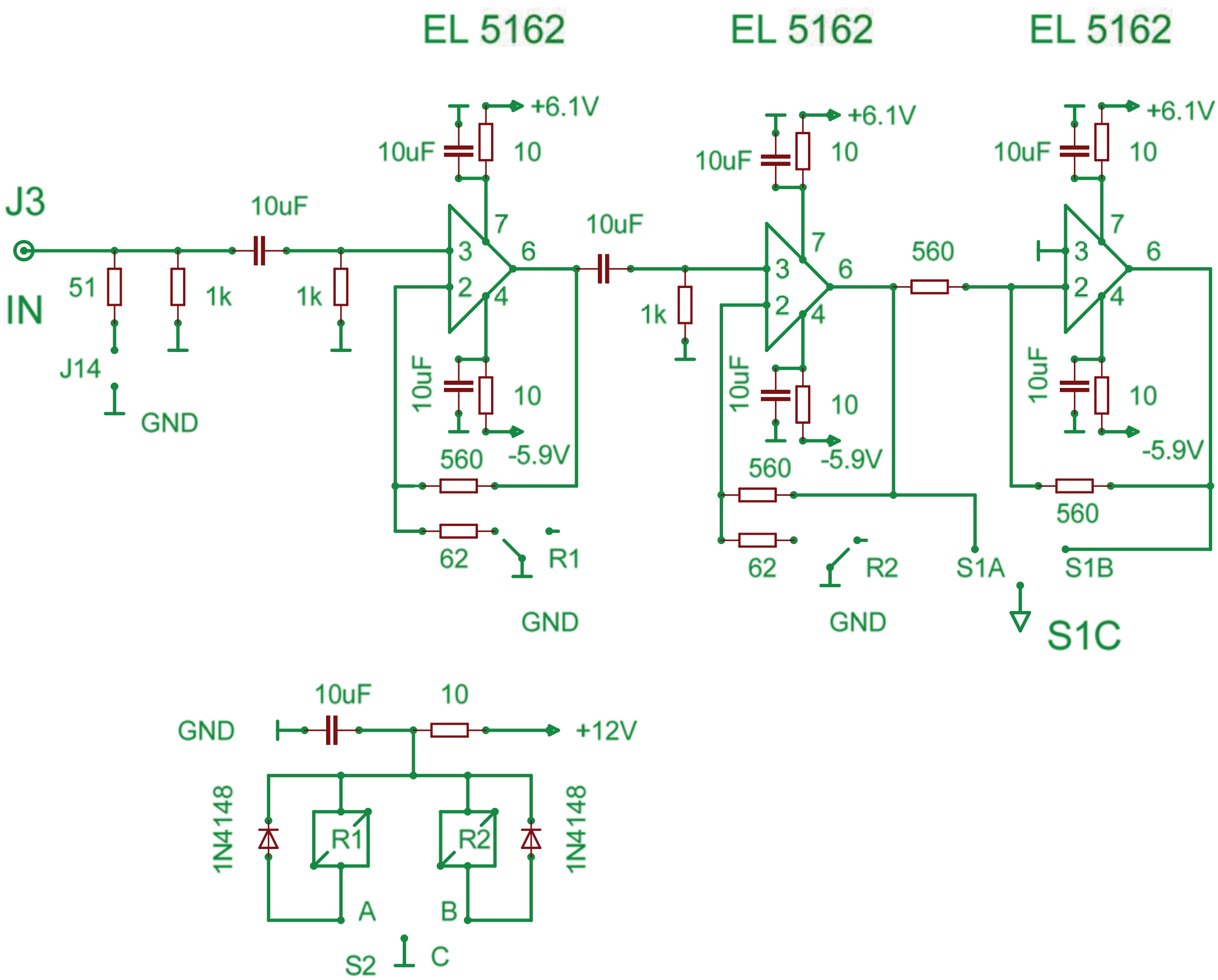
The CR200 shaping amplifier module is followed by a fast driver amplifier with a fixed gain of 2.5 and an output impedance of 50 Ω. It is capable of producing a 0 ... 8 V signal into high impedance loads and 0 ... 4 V amplitude into 50 Ω.
The front panel offset controls affect the DC level of the output signal and should be adjusted for a 0 V output voltage of the base line.

5. Appendix

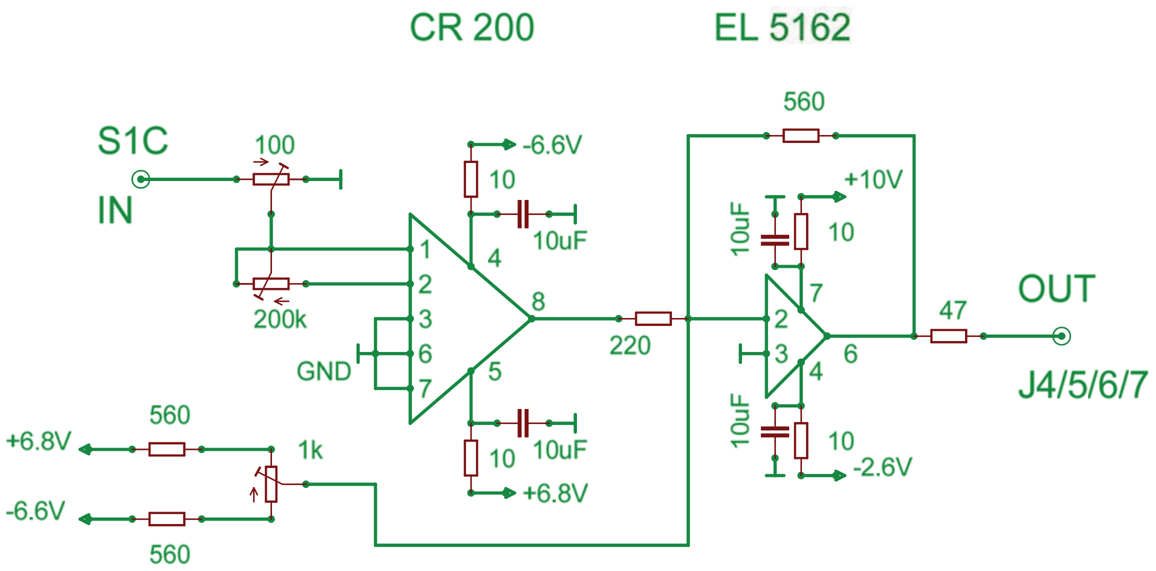
5.1. Schematic of the Preamplifier Stage



5.2. Detailed Schematic of the Shaping Amplifier Input Stage



5.3. Schematic of the Shaping Amplifier Outputs (four x)



5.4. Power