
CSPA10 ... 13

Charge Sensitive Preamplifier

User Manual

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Equipment manufactured by FAST ComTec GmbH is warranted 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 Customer except for defects discovered within 30 days after receipt of equipment where shipping expense will be paid by FAST ComTec.

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

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WARNINGS

The input of the CSPA1X is very sensitive. Never connect the detector when the high voltage is applied. Increase or decrease the high voltage only at a very slow rate. Observe the output of the CSPA1X during bias voltage change with an oscilloscope. Do not allow the output to saturate during change of high voltage.

1 Introduction

FAST ComTec's CSPA10...13 is a single channel charge sensitive preamplifier module intended for use with various types of radiation detectors including semiconductor detectors (e.g. Si, CdTe and CZT), P-I-N photodiodes, avalanche photodiodes (APDs), and various gas-based detectors. The CSPA10...13 is one of a series of four charge sensitive preamplifiers offered by **FAST ComTec**, which differ from each other most notably by their gain. A guide to selecting the best charge sensitive preamplifier for your application can be found on the next page or at our web site: <http://www.fastcomtec.com>. As with all FAST ComTec's preamplifier modules, the CSPA10...13 is housed in a small shielded metal case with a input for plug-in power supply.

CSPA1x is a successor model of CSP1x, which includes easier supply with classic plug-in power supply. Other improvements include integrated protection circuit and better variability.

The FAST ComTec Model CSPA10...13 Charge Sensitive Preamplifier is designed for optimum performance with Silicon Surface Barrier (SSB) detectors. Operating as a charge to voltage converter, the unit accepts charge carriers produced in the detector during each absorbed nuclear event. The output then provides a voltage in direct proportion to the collected charge at the rate of 1.4V per picocoulomb. This translates to a gain of 62mV per MeV (see table) for room temperature silicon detectors.

For typical use with positively biased SSB detectors, the extremely linear energy output provides a negative polarity pulse ideal for energy spectroscopy.

The high charge rate capability of the design is evidenced by an energy rate capacity of greater than 10^5 MeV per second when used with silicon detectors. In order to take full advantage of such a high count rate capability, a main amplifier with a correspondingly high count rate ability, such as the FAST ComTec Model CSA4, should be used.

The basic operation of the preamplifier is indicated in the functional schematic diagram below, see Fig. 1.1. The first stage acts as an operational integrator which produces an output potential proportional to the accumulated charge on the feedback capacitor C_f . The integrator drives the output buffer with a gain of +2.

The noise contribution of the preamplifier is only 1.7 KeV, FWHM, (Si) with an increase of less than 34 eV for each picofarad of additional source capacitance. To reduce noise injected through the HV input, a decoupling network is utilized for filtering the detector bias voltage.

To reduce the possibility of transmission line reflections when using long lengths of coaxial cable, the energy output is provided with a series resistor, eliminating the necessity of terminating the line at the receiving end.

For those applications utilizing lower voltage detectors with vacuum chamber feedthrough connectors or direct detector cabling inside a chamber, the Model CSPA10...13-1B provides a BNC for the detector and HV bias input. Necessary power is provided by any FAST ComTec main amplifier through the five foot compatible cable furnished with the preamp.

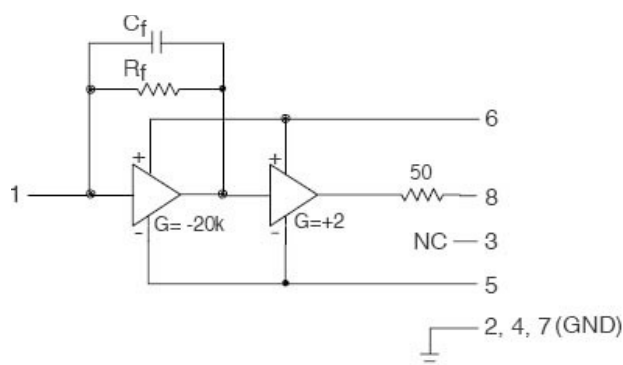


Fig. 1.1: Functional Schematic diagram

Tables to the CSP10...13

Table 1: Sensitivity Versions

Preamp model	Gain (mV /picoCoulomb)	Max. detect. Pulse (e^-)	equiv. noise in silicon keV (FWHM)
CSPA10	1400	10^7	1.7 keV
CSPA11	150	10^8	6.0 keV
CSPA12	15	10^9	65 keV
CSPA13	1.5	10^{10}	230 keV

Table 2: model specifications (noise, risetime)

Preamp model	noise (ENC) e^- (RMS)*	noise (ENC) slope e^- /pF	rise time ($C_d=0pF$)
CSPA10	200 e^-	4 e^- /pF	7 ns
CSPA11	630 e^-	3.7 e^- /pF	3 ns
CSPA12	6,800 e^-	28 e^- /pF	6 ns
CSPA13	24,000 e^-	27 e^- /pF	20 ns

Table 3: input / High voltage connectors

model	Input	Connectors input / HV
CSPA1X-2S	2 kV / 4.7 nF	SHV / SHV
CSPA1X-4S	4 kV / 3.3 nF	SHV / SHV
CSPA1X-1B	1 kV / 4.7 nF	BNC / BNC
CSPA1X-1BS	1 kV / 4.7 nF	BNC / SHV

Table 4: ordering information

Model No.	Description	Order No.
SPA10-2S	Charge-sensitive preamp, SHV, 2kV/ 4.7nF, 1.4 V/pC	CPA02S
CSPA11-2S	Charge-sensitive preamp, SHV, 2 kV/ 4.7nF, 150 mV/pC	CPA12S
CSPA12-2S	Charge-sensitive preamp, SHV, 2kV/ 4.7nF, 15 mV/pC	CPA22S
CSPA13-2S	Charge-sensitive preamp, SHV, 2 kV/ 4.7nF, 1.5 mV/pC	CPA32S
CSPA10-4S	Charge-sensitive preamp, SHV, 4kV/ 3.3nF, 1.4 V/pC	CPA04S
CSPA11-4S	Charge-sensitive preamp, SHV, 4 kV/ 3.3nF, 150 mV/pC	CPA14S
CSPA12-4S	Charge-sensitive preamp, SHV, 4kV/ 3.3nF, 15 mV/pC	CPA24S
CSPA13-4S	Charge-sensitive preamp, SHV, 4 kV/ 3.3nF, 1.5 mV/pC	CPA34S
CSPA10-1B	Charge-sensitive preamp, BNC, 1 kV/ 4.7nF, 1.4 V/pC	CPA01B
CSPA11-1B	Charge-sensitive preamp, BNC, 1 kV/ 4.7nF, 150 mV/pC	CPA11B
CSPA12-1B	Charge-sensitive preamp, BNC, 1 kV/ 4.7nF, 15 mV/pC	CPA21B
CSPA13-1B	Charge-sensitive preamp, BNC, 1 kV/ 4.7nF, 1.5 mV/pC	CPA31B
CSPA10-1BS	Charge-sensitive preamp, BNC/SHV, 1kV/ 4.7nF, 1.4 V/pC	CPA01C
CSPA11-1BS	Charge-sensitive preamp, BNC/SHV, 1kV/ 4.7nF, 150 mV/pC	CPA11C
CSPA12-1BS	Charge-sensitive preamp, BNC/SHV, 1kV/ 4.7nF, 15 mV/pC	CPA21C
CSPA13-1BS	Charge-sensitive preamp, BNC/SHV, 1kV/ 4.7nF, 1.5 mV/pC	CPA31C

2 Specifications

2.1 Inputs

Preamplification channels: 1

up to ± 4000 volts (SHV connector)

± 4000 volts (SHV connector)

Test input 50 ohms terminated for tail pulser

2.2 Outputs

Decay time constant: 140 μ s (150 μ s, 50 μ s, 50 μ s resp.)

Unsaturated output swing: -3 to +3 volts

Output offset: +0.2 to -0.2 volts

Output impedance: 50 ohms

2.3 Performance

Equivalent noise charge (ENC)*: (see table 1, CSPA10)

ENC RMS: 200 electrons, 0.03 femtoCoul. (CSPA10)

Equivalent noise in silicon: 1.7 keV (FWHM)

Equivalent noise in CdZnTe: 2.4 keV (FWHM)

ENC slope: 4 electrons RMS /pF

Gain: see table 1

Rise time**: 7 ns (see table 2 page 2, CSPA10)

Maximum charge detectable per event: (see table 1)

Operating temperature: -40 to +85°C

• Measured with input unconnected, using Gaussian shaping amplifier with time constant =1 s. 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: $t_r = 0.4 C_d + 7 \text{ ns}$, where t_r is the pulse rise time in ns, and C_d is the added capacitance (e.g. detector capacitance) in pF.

Keep in mind that other factors within the detection system may further limit this value.

2.4 Connector types and cables

Power: power connector 2.1 x 5.5 mm, DC connector, center positive;

HV Input: SHV (BNC for CSPA1X-1B)

Detector Input: SHV for the models CSPA1x-2S, CSPA1x-4S

BNC for the models CSPA1x-1B

Output: BNC

Test input: BNC

2.5 Power

Power supply voltage (Vs): + 12 volts nominal (ext. 12V plug-in power supply with 1,8m cable)

Power supply current: < 30 mA

Power dissipation: < 400 mW

2.6 Physicals

Net weight case : 195 gr (Net weight: approx. 320 gr with plug-in power supply)

Size without connectors: 113 mm x 70 mm x 24 mm

Size with connectors: 153 mm x 70 mm x 24 mm

3 Controls and Connectors

3.1 General

This section describes the functions of the controls and connectors located on the front and rear panels of the Model CSPA10...13. It is recommended that this section be read before proceeding with the operation of the preamplifier.

3.2 Front Panel / Rear Panel

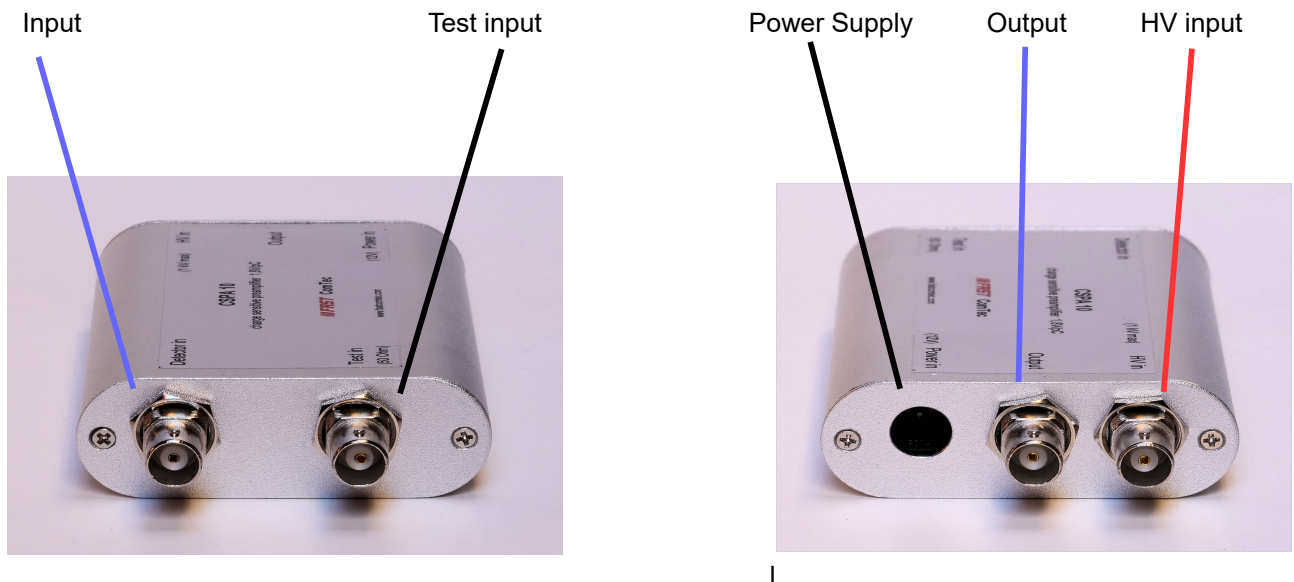


Fig. 3.1: Front- and Rear panel

4 Installation

4.1 Noise Consideration

The preamplifier components associated with the detector bias (HV) have been scientifically cleaned. This process removes all residues and fingerprints which could cause excessive noise and possible failure of the preamplifier when high voltage is applied. It is strongly recommended that caution be exercised never to touch these components nor have them exposed to the atmosphere without the preamplifier case, for any long duration.

Any capacitance added to the input of the preamplifier will increase the noise contribution and degrade the rise time performance of the Model CSPA10...13. The capacitance should be minimized by using the shortest possible interconnecting cable between the detector and the preamplifier.

The detector load resistance R is normally 100 megaohms. If silicon surface barrier detectors are used whose leakage current is greater than 1 microamp, the voltage drop across the resistor must be allowed for, or alternatively, the value of R reduced to provide a voltage drop. The latter will cause the 0 pF noise of the preamplifier to increase, but this will usually be insignificant compared to the noise generated in the detector by the increased leakage current. Do not reduce R below 10 megaohms without contacting the factory.

4.2 Detector Bias

The Model CSPA1X-4S Preamplifier HV Input accepts up to ± 4000 VDC from the detector bias supply.

Never connect or disconnect the preamplifier from a detector while the high voltage is on.

Always wait at least one minute after the detector bias has been reduced to zero before disconnecting the preamplifier from the detector. Maximum stability of the preamplifier is maintained 60-90 seconds after preamplifier power and high voltage is applied.

The Model CSPA1X-2S has a larger input coupling capacitor (4.7 nF) for detectors with high capacity. If the maximum detector bias is below 1000V, the Model CSP1AX-1B is the right choice.

The input connector and the HV bias connector is BNC. It is usually more convenient to use BNC, because these connectors are much more common.

For Vacuum applications, the feed through connector is in many cases only available as BNC.

5 Operating Instructions

5.1 General

The purpose of this section is to familiarize the user with the Model CSPA10...13 Preamplifier and to check that the unit is operating correctly. Since it is difficult to determine the exact system configuration in which the unit will be used, explicit operating instructions cannot be given. However, if the following procedure is carried out the user will gain sufficient familiarity with the instrument to permit its proper use in the system at hand.

The instructions which follow may be best carried out with the preamplifier on latest bench, separated from the detector.

Because the input is charge sensitive, and ultra high impedances are involved, the Preamplifier is inherently somewhat microphonic. For best results, testing should be done with the Preamplifier chassis cushioned on a block of foam rubber, and the cover securely fastened to the frame.

5.2 Test Input

The Model CSPA10...13 accommodate a TEST input via a BNC connector on the front panel introduces the externally applied signal (preferably a negative tail pulse of -1 to -5 volt peak amplitude) to a charge injection capacitor to the summing junction of the integrator. The test signal voltage is usually adjusted in amplitude by the user so as to give a reference peak signal in his data spectrum at a convenient location so as to normalize multiple detectors. This input does provide a resistive terminating impedance.

In the endless mode data acquisition is started only once, e.g. by a software start i.e. asynchronously to the rest of the experiment. Then all arriving events are recorded and stored with an absolute time relative only to the initial start. Since the dynamic range is up to 53 bit or 8.3 days the available absolute time range will be sufficient for every imaginable experiment.

5.3 Initial Setup

1. Connect the Preamplifier to a source of low voltage power such as a FAST ComTec Spectroscopy Amplifier using the five foot cable provided.
2. Using the RG-58C/U coax, connect the Preamplifier output to channel 1 of a dual trace Oscilloscope.
3. Connect the negative, attenuated output of a tail pulse generator (such as the Berkeley Nucleonics Corp.: BH-1, PB-5 Tail Pulser) to channel 2 using RG-58C/U and a „tee“ at the Scope input.
4. The other side of the „tee“ should be connected to the Test input BNC connector through a length of RG-58C/U coax.
5. Select Scope vertical sensitivities of 50 mV/div. And set the time base to 10 μ s/div. Turn Preamplifier power on.

5.4 Initial Checkout

Using the Test input BNC provided on the Model CSPA10...13, a detector input of approximately 100 MeV per input volt is simulated. Adjust the pulse generator for -100 mV peak input signal and observe a Preamplifier energy output of +150 mV peak (nominal). This is equivalent to a detector input of 2.4 MeV (nominal).

For the CSPA11, you should get about +16 mV from a -100 mV test signal and for the CSPA12, you should get about +16 mV from a -1000 mV test signal.

5.5 Protection Circuit

CSPA1x is designed among others to realize better usability and trouble-free power supply. The detector input is protected by implemented diodes network circuit. It minimally increases the internal capacitance and thus also the values of internal noise. You can disable this function as needed (Fig. 7.1 Jumper J2: to pos. 2-3)

Further protection of measure is built-in input ser. resistor = 100 Ohm. This resistor is deactivated in order to keep the noise at a low level (Fig. 7.1. JP3 pos. 1-2).

The output resistor is set to 1 Ohm by default via jumper JP9. Alternatively you can increase this value to 50 Ohm (better output protection). The disadvantage is the halved value of the effective output signal.

5.6 Common Operating Problems

The modern spectrometer is an extremely sensitive, state-of-the-art system. Inexact performance of other than the grossest type is generally due to subtle factors. It is the ability to determine and correct these factors that constitutes the art in the science of spectroscopy instrumentation.

All of the many possible contributors to less than optimum performance cannot be listed here. The purpose of this section is to note the usual causes of loss of resolution, and to suggest curative steps.

Do not expect to diagnose all problems with the detector, a preamplifier, a main amplifier, and a multichannel analyzer. The spectroscopy system records results, it does not necessarily lead to the identification of causes. A good, modern oscilloscope will be needed. Also a high quality tail pulse generator will be extremely useful.

The simplest test is, of course, to connect your detector, apply bias, present a source, and accumulate a spectrum. Be sure a pulser is not feeding the preamplifier while the spectrum is accumulating, or resolution loss may result. If the results obtained are far different from what is expected, it then becomes necessary to troubleshoot the system.

First observe the amplifier output on an oscilloscope at various time base and amplitude settings. Is the amplifier properly pole/zero cancelled (do the output pulses cause undershoot that persist for longer than two or more main pulse widths)? Set the main amplifier pole/zero cancellation (without DC resolution) to obtain the most rapid, complete baseline recovery.

The next step is to remove all sources and, with the detector still connected and bias applied, present a test pulse to the detector input of the preamplifier using the test input described in Section 5-2. Make sure the pulser polarity is correct. Set the amplitude of the pulser so that its peak occurs near the region of the peak of the source previously used.

Observe the output of the amplifier without DC restoration. Note that the amplifier is not properly pole/zero canceled for the pulser feeding the preamp (due to the extra time constant of the pulser). This is of no consequence for a pure pulser input. Are the baseline fluctuations of 50/60 or 100/120 Hz frequency? A ground loop is indicated. Insert all system line plugs into the same output. Or are the baseline fluctuations of random frequency between 10 Hz and 15,000 Hz? The area may be too noisy, causing microphonic problems.

If high frequency noise is observed, is it random or periodic? Periodic noise is a sign of electronics failure; isolate the cause by observing the preamplifier output. Is the same pattern observed, or is the problem in the main amplifier? Random high frequency noise may be detector load resistor or input capacitor breakdown.

Next, accumulate a pulser peak on the analyzer. Calculate its resolution. Repeat with the detector removed and the input connector of the preamplifier shielded. (Wait five minutes to remove the preamplifier from the detector after removing the detector bias.) You now have three resolution figures available for essentially equal energy peaks:

R_s: source

R_D : pulser and biased detector connected

R_E : pulser without detector connected

If R_E is not less than 2.0 keV for two microseconds unipolar Gaussian shaping time constant, the problem is in the electronics and probably in the preamplifier.

If R_E is acceptable, but R_D is greater than 2.0 keV plus 10 eV/pF detector and connection capacitance, then the problem is either in the detector (microphonics, excess leakage current noise, breakdown due to moisture or grime on the detector output connectors), or in the preamplifier (leaky input capacitor, dirty or moist detector load resistor, dirty or moist detector input connector).

If R_E and R_D are acceptable, but the live spectrum (R_S) is not as good as expected, the problem is probably in the detector (bad detector, poor charge collection, insufficient bias) or in the electronics following the preamplifier (count rate too high, improper amplifier pole/zero cancellation, wrong main amplifier time constant, wrong amplifier shaping-bipolar vs. Unipolar, improper amplifier shaping for the ADC being used, ADC cannot take the count rate, amplifier or ADC drift). These many alternatives are not easy to check. Substituting, one-by-one other detectors, preamplifiers, amplifiers, and multichannel analyzers may help pinpoint the problem. Checking the above common problems will aid in spotting the source of trouble.

6 Theory of Operation

6.1 Functional Description

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 CSP10...13 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 Cs(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 CSP10...13 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 μ s. This decay of the output waveform is also shown below, to the right.

6.2 Detailed Circuit Description

Fig. 6.1 shows a simplified equivalent circuit diagram of the hybrid amplifier module used in the CSPA10...13, 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. R_f (100 M Ω) and C_f (1.4 pF) are the feedback resistor and capacitor respectively

($t_{decay} = 140\mu s$). The feedback values for the other models are:

$R_f = 10$ M Ω and $C_f = 15$ pF, $t_{decay} = 150$ μ s (CSPA11),

$R_f = 680$ k Ω and $C_f = 15$ pF, $t_{decay} = 50$ μ s (CSPA12),

$R_f = 68$ k Ω and $C_f = 150$ pF, $t_{decay} = 50$ μ s (CSPA13).

The CSPA10...13 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

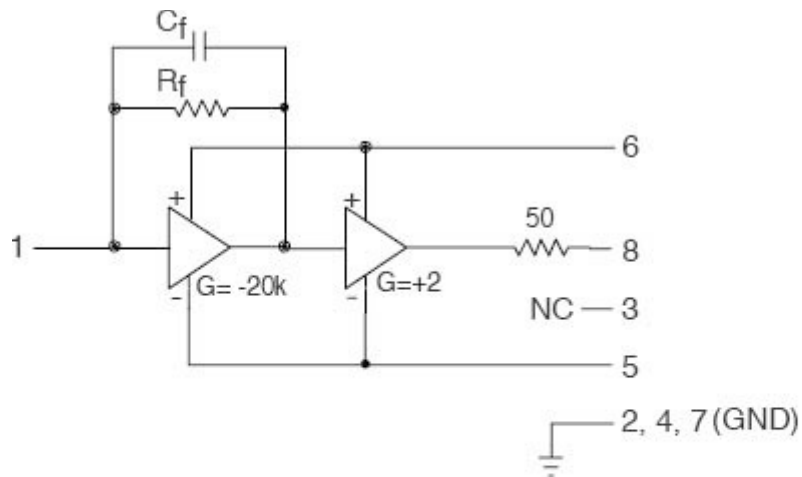


Fig. 6.1: Simplified circuit diagram

7 Jumper setting & opening of the case

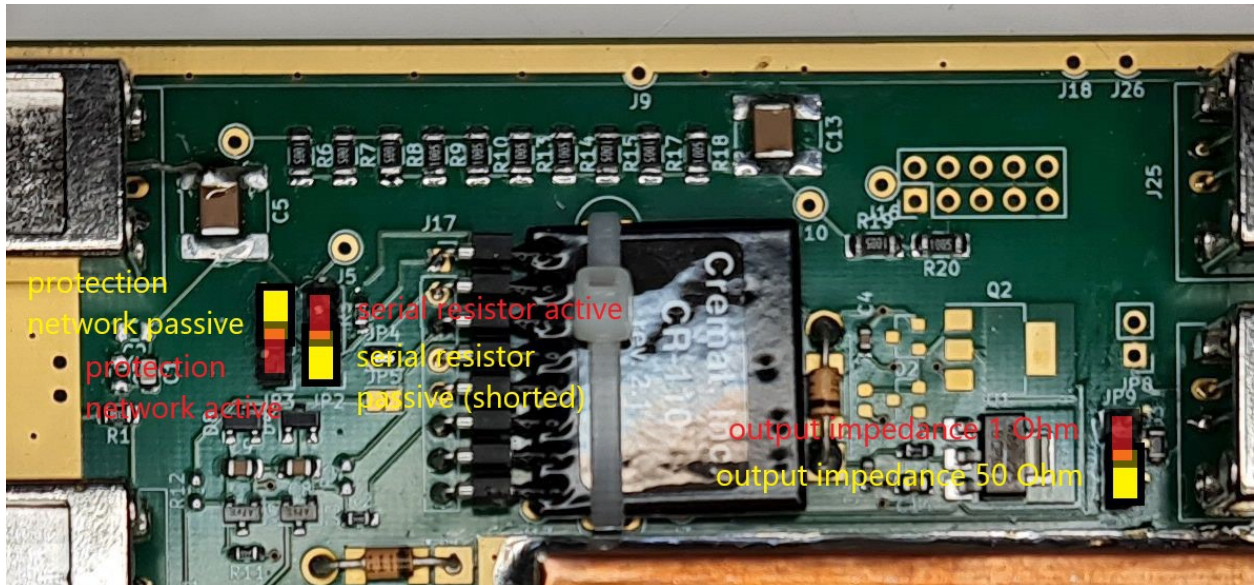


Fig. 7.1: CSPA1X board with jumpers

- JP3 * 1-2 shorted - protection network active (red) 2-3 protection passive
- JP2 * 1-2 shorted – inp. ser. resistor = 0 Ohm (yellow) 2-3 inp. ser. resistor = 1000 Ohm
- JP9 * 1-2 shorted – output resistor = 1 Ohm 2-3 output resistor = 50 Ohm
- * marked default setting

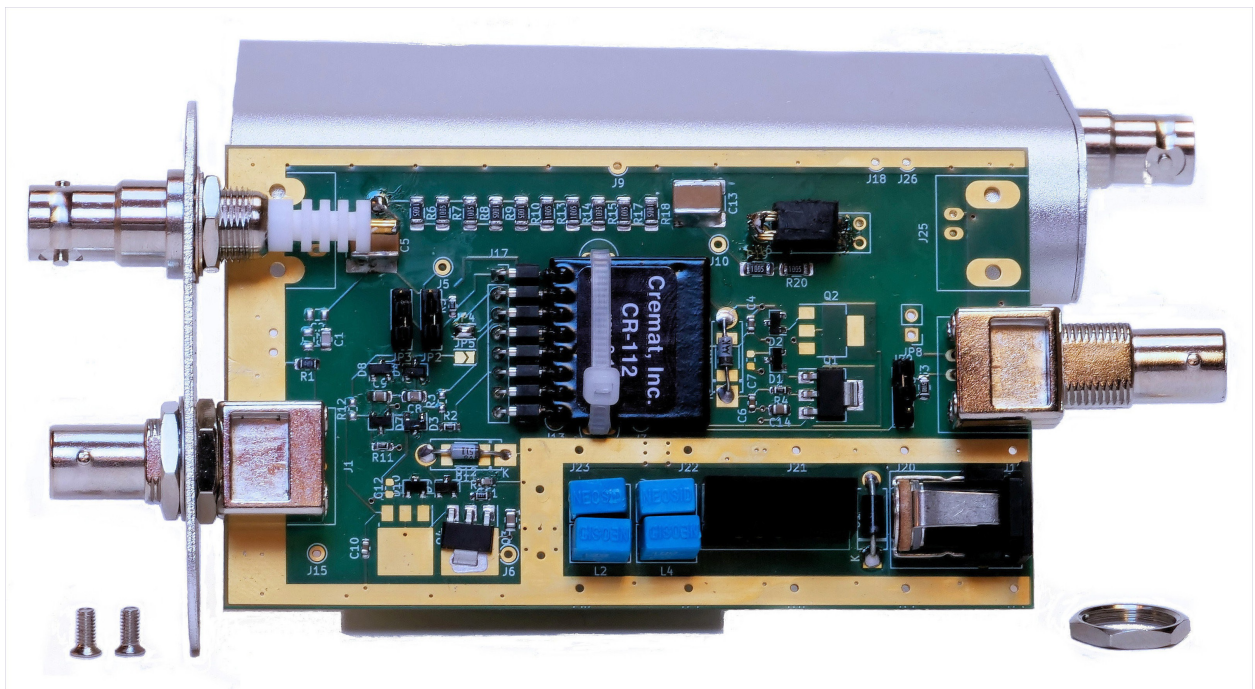


Fig. 7.2: CSPA1X board with connectors

8 Appendix

8.1 Detailed Schematic of the CSPA10...13

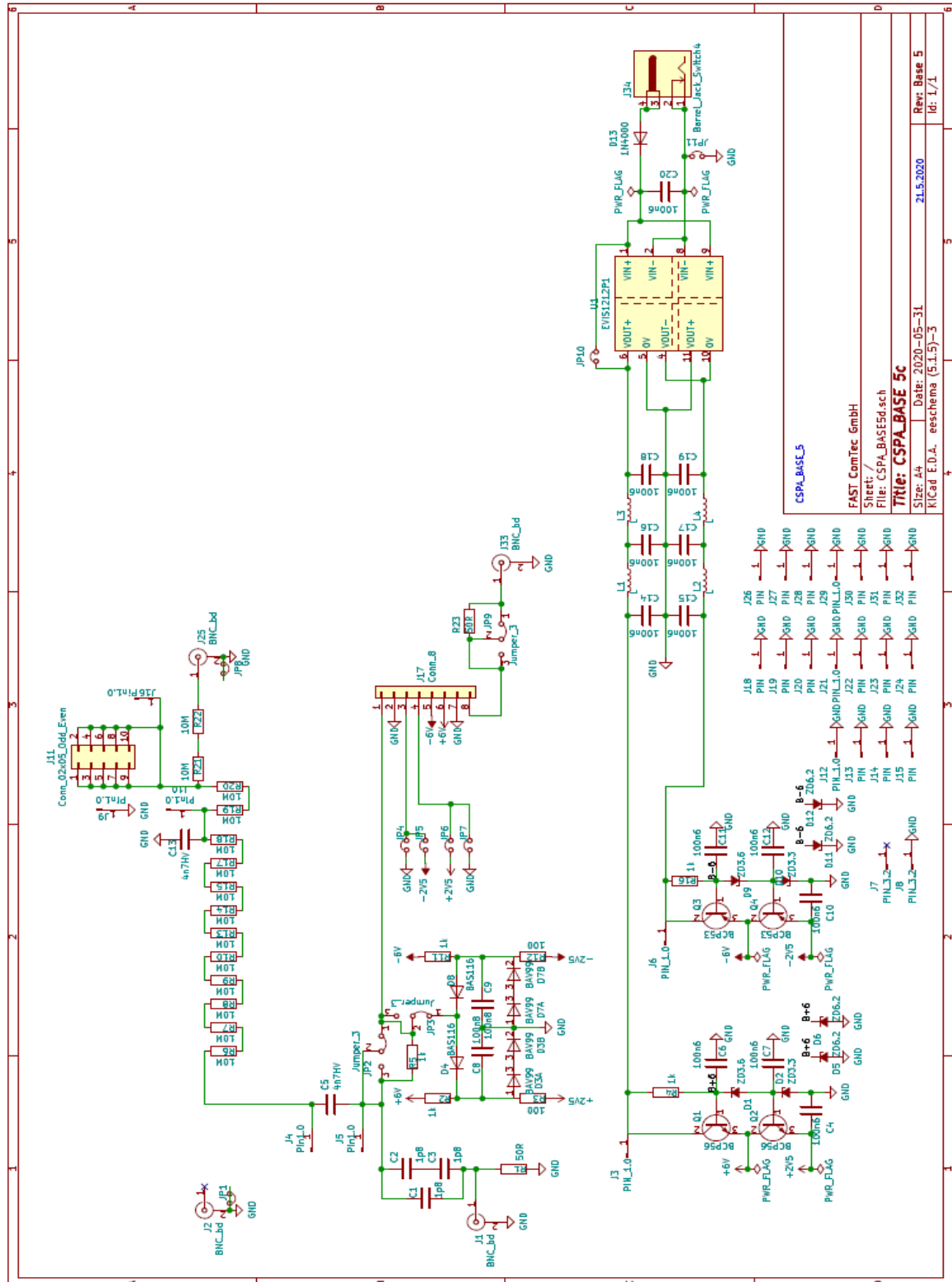


Fig. 8.1: Detailed circuit diagram of CSPA1X

Supplement: sieve capacitors $C_x=100\text{nF}$ (0804) on J17 Pin 6-7 and 4-5

8.2 Personal Notes