

**Radiation sensor for high-speed spectroscopy. Includes high voltage power supply and embedded multi-channel analyzer. Operated and powered through the USB port.**

### Highlights

- 3-inch Ø, 3-inch tall, NaI(Tl) crystal
- 6.5% fwhm (typ.) resolution at 662 keV
- Very linear photomultiplier
- Low-power embedded high voltage supply
- Low-power embedded MCA
- Digital temperature sensor
- Supports high count rates, up to 500,000 cps
- 0.5 mm mu-metal housing with mounting flange
- Built-in connectors for sensor-to-sensor communication
- eMorpho-HPR-50-8012 embedded MCA
- NP15-0530 embedded power base

### Features

- This radiation sensor uses an area-matched NaI(Tl) crystal and photomultiplier tube (PMT).
- The PMT type has been selected to provide excellent spectroscopy with good energy resolution and high linearity.
- The embedded high-voltage supply is powered and controlled through the embedded MCA.
- The high-voltage supply employs a transistorized voltage divider for best linearity at the lowest power consumption.
- The embedded MCA provides a 4K x 32-bit histogram and accurate count rate measurements. The achievable count rate is limited only by the NaI(Tl) scintillator characteristics
- The embedded MCA offers advanced data taking and diagnostic features such as waveform capturing, list mode operation, light pulse driver and phoswich support.
- Other sensors in this product line include 2-inch systems and CsI(Tl) systems for better energy resolution at high  $\gamma$ -ray energies.

## Specifications

<i>Parameter</i>	<i>Symbol</i>	<i>Min</i>	<i>Typ.</i>	<i>Max</i>	<i>Comment</i>
<b>Power</b>					
Supply voltage	V <sub>ss</sub>	4.35V	5.0V	5.5V	USB-powered
Supply current,	I <sub>ss</sub>		280mA		HV = 1500V MCA + HV
Supply current,	I <sub>ss</sub>		380mA		HV = 1500V MCA + HV, IHV = 100μA
<b>Photomultiplier</b>					
PMT gain			65,000		HV = 1500V
			100 pC/MeV		HV = 1500V
Energy resolution at 661.66 keV			6.5%	7.0%	@ 20kcps, Cs-137
PMT anode DC-current				50μA	Gain drift < 4%
PMT anode pulse current				10 mA	Gain drift < 1%
<b>HV-subsystem</b>					
HV range	HV_out	500V		1700V	
Max. HV output current	I <sub>HV</sub>		100μA		
<b>MCA</b>					
Histogram			4096 x 32-bit		
Waveform capture			1024 samples		
<b>Environmental</b>					
Operating temperature		5°C		60°C	
Magnetic field				10 mT	Gain drift < 1%
Entrance window		0.5 mm steel + 0.8mm Al + 2mm Teflon			

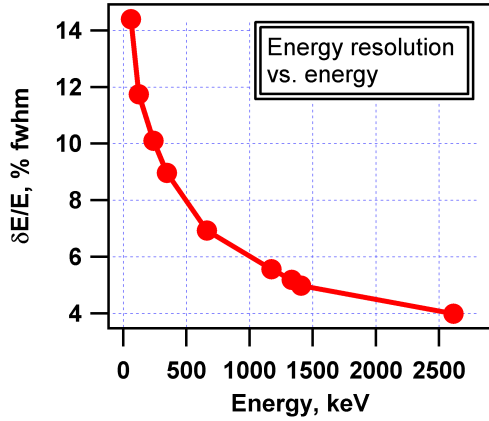


Figure 1: Energy resolution as a function of energy.

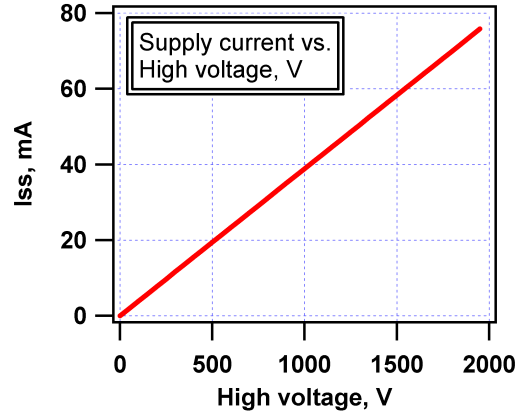


Figure 2: Supply current to the power base, measured at  $V_{ss} = 4.5$  V, at zero PMT anode current.

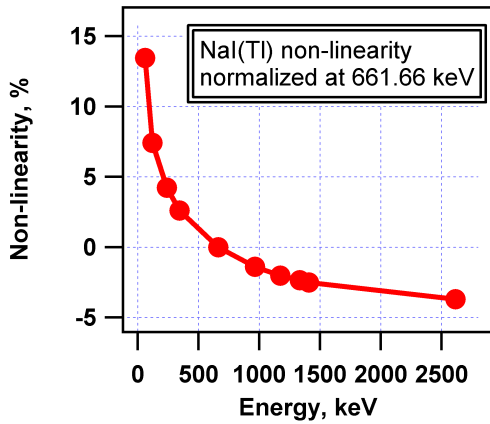


Figure 3: Deviation from linearity as a function of energy.

**Change of brightness as a function of energy**

<i>E / keV</i>	<i>Dev. %</i>	<i>E / keV</i>	<i>Dev. %</i>
59.54	13.5	964.08	-1.39
121.78	7.41	1173.24	-2.03
238.63	4.23	1332.50	-2.35
344.28	2.61	1408.01	-2.51
661.66	0.00	2614.53	-3.71

Figure 4: Measured non-linearity values.

### Theory of operation – Signal chain

Every R2D nuclear radiation sensor is delivered with calibration data and operational parameters stored in non-volatile memory. For the majority of applications no further adjustments will be necessary. However, if the sensors have to operate under unusual conditions, understanding the function and perhaps limitations of its components becomes important.

The photomultiplier that is coupled to the scintillator is powered by a TwinBase, which is a combination of a well-matched high-voltage generator and divider pair.

The high voltage is controlled through the eMorpho, which is the embedded MCA of the R2D sensor. The eMorpho receives the photomultiplier anode signal and measures the electric charge of the anode pulses. This quantity is proportional to the energy deposited in the scintillator crystal, and is used to construct energy histograms.

The instrument gain is determined by the high voltage applied to the photomultiplier. The suggested operating point is that high voltage, which generates an anode sensitivity of 100 pC/MeV as determined by using radioactive sources. The recommended high voltage is stored in the sensor's non-volatile memory.

### Theory of operation – Linearity

A number of factors have to be evaluated when discussing linearity. First of all, NaI(Tl) like other inorganic scintillators is a non-linear material. The amount of scintillation light it produces is not strictly proportional to the energy deposited by a gamma-ray, but there is a deviation from linearity, cf figures 3 and 4.

Beyond the intrinsic non-linearity of the scintillator, the linearity of the photomultiplier can be affected if the anode peak pulse current or the average anode current become too large.

**The anode peak pulse current** can be determined from the pulse charge corresponding

to a particular region in the energy histogram. Divide the pulse charge by the 230 ns decay time of NaI(Tl) to determine the anode peak pulse current:

$$I_p = \frac{Q}{\tau}$$

For instance, at 100 pC the peak pulse current is  $100 \text{ pC} / 230 \text{ ns} = 0.434 \text{ mA}$

**The average anode current** can be determined from the gain, expressed in pC/MeV, the average energy deposit and the true pulse count rate.

The instrument provides a calibration to relate the pulse height histogram to the charge of the pulses.

Computing the average charge deposit from the histogram and multiplying with the estimated true pulse count rate yields the average anode current. It should be limited to 50  $\mu\text{A}$  for best performance, but can be as high as 100  $\mu\text{A}$ .

Here are two examples to illuminate this.

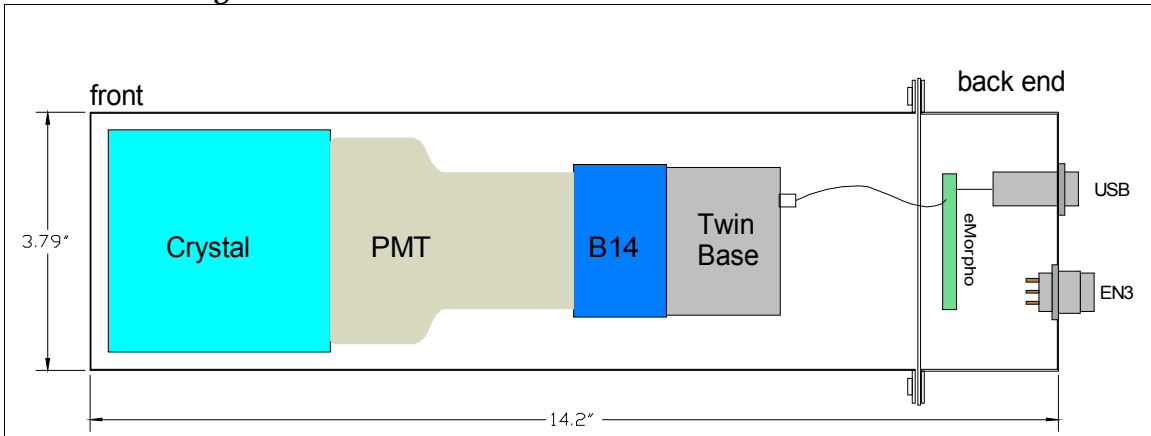
When measuring the intensity of a Cs-137 source ( $E = 661.66 \text{ keV}$ ) at nominal gain, the average energy deposited in the crystal will be 400 keV, corresponding to 40 pC. An average anode current of 50  $\mu\text{A}$  is reached only at a count rate of 1.25 Mcps, which is very high.

When measuring in the vicinity of a powerful neutron generator (neutron activation analysis), the average energy deposit in the 3-inch detector is much higher: 1.8 MeV. And it takes only 280 kcps to cause an average anode current of 50  $\mu\text{A}$ .

### Theory of operation – Temperature sensor

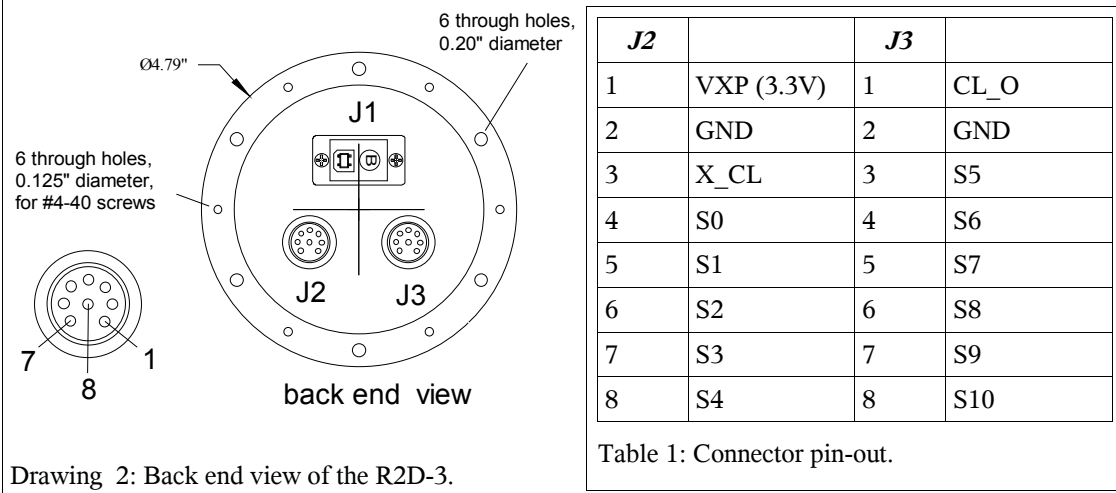
The R2D sensor includes a digital temperature sensor, which measure the internal temperature once per second with a resolution of 0.0625°K and an accuracy of 1K. This information can be used for temperature-related gain corrections or data-quality alerts, as well as to determine and enforce safe operating conditions for the unit.

**Outline drawing**



Drawing 1: Outline drawing of the R2D sensor using a 3-inch diameter scintillator crystal. The outer can is made of 0.5 mm thick mu-metal, which is a type of stainless steel that strongly attenuates magnetic fields. The main can houses the crystal, PMT (with Jedec B14 socket) and a TwinBase. The embedded eMorpho MCA, together with the connectors, is mounted in the back end lid.

There are 3 connectors in the back. J1 is a USB type B jack. J2 and J3 are Switchcraft EN3 mini weather tight connectors (plugs) with 8 pins each. Pinout and pin numbering are indicated below.



Drawing 2: Back end view of the R2D-3.

**Revision history:**

P0	Mar. 2006	Preproduction release; initial document
R1	Jan. 2009	Minor performance edits; Address update