Carroll & Ramsey Associates *950 Gilman St., Berkeley, CA 94710*

Ph. (510) 559-8153 *E-mail: <cra@carroll-ramsey.com>* *Fax (510) 559-8158*

MODEL 105S-1 SINGLE-CHANNEL HIGH-SENSITIVITY RADIATION DETECTOR

Rev. K

Serial # _____

The model 105S-1 from Carroll & Ramsey Associates is a high-sensitivity radiation detector system used for HPLC, flow monitoring in radio-chemical synthesis, and similar applications.

GENERAL DESCRIPTION

The system comprises a compact detector probe (2 cm x 2 cm x 3 cm) in conjunction with a bench-top amplifier / console unit (7.75"W x 7.5"D x 2.5"H). The sensitive element of the detector probe is a 1 cm^3 CsI(Tl) scintillating crystal, optically coupled to a 1 cm^2 silicon PIN diode which, in turn, is connected to a charge-integrating preamplifier [1]. The noise floor for the detector probe is approximately 50 KeV.

[1]Covered by one or more of the following US Patents: 5,990,745; 6,054,705.

Stable, reliable operation at low photon fluxes is enhanced by operating the detector in AC-coupled pulse-mode. This essentially eliminates drift and instability due to changes in system parameters, such as diode leakage current, with time and temperature. In this mode of operation, individual gamma ray photon interactions in the scintillating crystal are converted to flashes of light which are then converted in the diode / preamplifier to discrete pulses of current. The pulses of current are amplified, thresholded, and integrated to produce a "DC" signal which is proportional to the count rate of photons which exceed threshold.

The CsI(Tl) crystal, PIN diode, and preamplifier are wrapped in metal foil which, in turn, is cast in a protective plastic capsule which forms the head of the probe. The probe is connected to the post amplifier / display console through a short length of small-diameter coaxial cable. The post-amplifier produces three separate signals:

1) Analog pulses whose amplitude is proportional to the energy absorbed in the CsI crystal; these signal pulses may be used for spectroscopy (in conjunction with a multi-channel analyzer). The analog pulse shaping time-constant (~6 μsec) is chosen as a compromise between reasonably good pulse-height resolution and reasonable dead-time (total pulse width at the baseline ~15μsec.)

2) Digital pulses for counting events which exceed threshold. Output pulses are low-power TTL compatible, counts asserted high, and

3) An integrated (filtered) “ratemeter” signal proportional to the detector count-rate, (counts over threshold) which may be used to drive a chart recorder, computer data acquisition system, or similar read-out system. The filter time constant is on the order of 1-2 seconds. Full-scale output is 10 volts; output impedance is 10K ohms. The output signal level may be adjusted to suit the users data acquisition by means of a multi-turn potentiometer on the printed wiring board (‘south-east corner’, viewed from the front) inside the chassis.

COUPLING TO SAMPLE

The detector count-rate is proportional to the amount of gamma-activity (decays per second) which passes close to the CsI(Tl) crystal. A loop of small diameter, flexible tubing wound tightly around the head of the probe provides the greatest sensitivity. More turns of tubing means more activity, but with a longer transit time.

A typical configuration might be an activity concentration of 10 μCi / ml in the peak at a flow rate of 1 ml / min in 1/32" ID tubing wound in a 3-turn, 2.5 cm diameter loop around the probe. The volume of the sample loop is ~0.11ml, so the amount of activity in the sample loop is ~1.1 μCi. which produces ~120,000 counts per minute. At 1 ml / min in 1/32" ID tubing, the fluid velocity is 202 cm per minute, or 7 seconds transit time in a 3-turn, 2.5 cm dia sample loop.

Fewer turns spaced farther from the probe may be used when the activity concentration in the sample loop is more than a few tens of microcuries per ml.

SENSITIVITY

Sensitivity of the detector probe for commonly-used gamma and β^+ emitters (assuming the threshold is set just above the noise floor) is of the order of 120 counts per minute per nanocurie for sources in close proximity; i.e., where the sampling loop is wound tightly around the probe.

A screwdriver-adjust, multi-turn potentiometer on the printed wiring board inside the chassis ('north-west' corner of circuit board, viewed from the front) controls the setting of the lower energy threshold. This potentiometer is normally set well-below the principle energy peak of the isotope being monitored. The upper threshold is set to track at a fixed voltage (~2.5 volts) above the lower threshold setting so as to bracket the peak of interest.

PULSE COUNTING

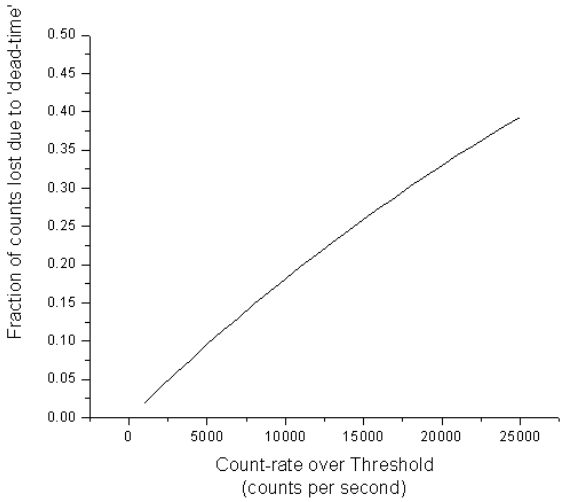
The output of the single-channel discriminator is available on the front panel BNC connector labeled **Digital Pulse** for use with a counter. Pulses are ~5 μsec. wide, low-power TTL compatible, counts asserted high.

COUNT-RATE LINEARITY

The Model 105S is a *counting* type of detector, wherein the minimum detectable count-rate is governed only by the ambient background radiation. Like any *counting* detector, both the 'digital' pulse output and the analog 'rate-meter' output will exhibit a ***dead-time loss*** given by:

Dead time loss = (1 - live fraction) =
1 - exp - ([count-rate above threshold] x [pulse-width])

The pulse-width is approximately 20 microseconds; this parameter is chosen as a reasonable compromise between good noise floor & pulse-height resolution versus good count-rate linearity. The effect of dead-time loss is shown in the graph below: For count-rates above ~10,000 counts per second (a very high count-rate!) dead-time begins to be a significant factor



RADIATION SHIELDING

Since the detector probe is so compact, a sample loop tightly wound around the probe can provide some spatial resolution by exploiting the inverse-square law -- being relatively blind to activity which is more than a few cm from the probe. However, for best results the detector probe and its sample loop should be shielded in a lead vessel or within a stack of lead blocks an inch or more thick, depending on the isotope being utilized and the ambient radiation background.

SPECTROSCOPY

An analog pulse signal output on the front panel allows gamma-ray spectroscopy in the range 100 KeV to 1500 KeV. System gain is fixed; one volt peak corresponds to ~0.5 MeV. A multi-channel analyzer or equivalent computer-based instrument, with an input impedance of 10K ohms or greater, is required to record a pulse-height spectrum. The standard probe's pulse-height resolution is ~10 % at 511 KeV -- which is sufficient to identify principal peaks of commonly-used isotopes.

INSTALLATION AND OPERATING ENVIRONMENT

Mains power for units sold in North America is 110 VAC, 60 Hz. Mains power for units sold in Europe is 230 VAC, 50 Hz. A country-specific, safety-approved AC line cord is included with the system. Internal operating voltages (+24 VDC, + 15 VDC, and +5VDC) are provided by a built-in, regulated power supply. There is no on-off switch; the unit may be left plugged into the mains and "on" at all times (power drain is less than ~4 watts). The fuse-holder is mounted inside the chassis, on the top of the printed wiring board, next to the modular power supply. Fuse type: 5 x 20 mm; 0.040A 'slow-blow'.

Warning!

Unplug unit from mains before opening for service, adjustment, or replacement of fuse. Such service should be carried out only by qualified personnel.

The probe is attached to its signal cable (type RG-174 coaxial cable) by means of a type '*smb*' subminiature coaxial connector. To assemble, align the small plug on the end of the cable against the receptacle on the body of the probe. Press together firmly – but carefully -- until the connectors are seated correctly. To remove the cable from the probe, reverse the above procedure, taking care to pull only on the body of the connector – ***not on the cable!*** The probe assembly is reasonably rugged, but is not designed to endure rough treatment such as environmental extremes, high humidity, excessive mechanical shock, continuous vibration, etc. ***Handle with care!*** The detector will also produce spurious electronic signals (microphonics) if the probe or its connecting cable is subject to shock, stress, or vibration during operation. The probe should be held fixed in place and padded, if necessary, to minimize any vibration coupled from other mechanical apparatus such as motors, fans, pumps, etc.

Caution: ***Plug in the probe prior to applying AC power.***

A coaxial signal cable with spade-lugs is provided for connecting the analog "ratemeter" signal to the user's data acquisition system. The analog (+) signal appears on the center conductor of the coaxial cable; the shield should be connected to data-acquisition signal 'common' or 'ground'. Some systems, such as 'PeakSimple" employ a 'balanced' (+) and (-) signal input. In this case, an additional jumper wire must be connected between data acquisition input (-) and ground.

The system is intended for indoor use. Components have not been characterized for operation outside the range 10ºC - 45ºC. The system components and system wiring must not be in close proximity to any flame, heating element, or exposed electrical terminals. The system components have not been characterized for operation in extreme radiation fields such as encountered in close proximity to accelerator targets during irradiation. The system should be protected from mechanical shock or vibration, or contact with volatile or corrosive reagents or solvents.

EMI and RF SUSCEPTIBILITY

Nuclear particle accelerators are used for the production of short-lived radio-isotopes. Such accelerators usually employ high-powered radio-frequency (RF) systems which have the potential to 'leak' RF energy into the environment.

The Model 105-S radiation detector system is widely -- <u>and successfully</u> -- installed and used in PET / Radio-chemistry laboratories, which are almost always situated close to a cyclotron or similar type of 'RF continuous wave' nuclear particle accelerator.

However, the Model 105-S detects and amplifies very low-level input signals. Thus, there is a possibility that RF interference from other equipment – either radiated through free space or conducted through power or signal wiring – may occasionally cause spurious or false detector signal outputs. This may occur as a result of fast electrical transients or modulated RF signals -- for example -- from nearby digital cellular telephones or from electrically 'noisy' devices such as on / off (make-and-break) relay contacts, or from small 'universal' (AC/DC) motors often used in small electrical appliances.

For best results, signal cables should be high-quality shielded coaxial type (examples: RG-174 , RG-58, or equivalent). Signal cables which are longer than a few meters in length should be run in separate conduits or wire-ways -- away from facility power and control wiring. RF devices such as cellular telephones and electrically 'noisy' equipment should not be operated in the near vicinity of sensitive radiation detection equipment (or -- for that matter – near any sensitive electronic instrumentation).

WARRANTY

Systems are warranted against defects in materials and workmanship for a period of 90 days from date of shipment. Carroll & Ramsey Associates' (CRA) sole obligation for products that prove to be defective will be repair or replacement. In no event shall CRA's obligation exceed the buyer's purchase price. CRA specifically disclaims any implied warranties for merchantibility or fitness for a specific purpose, nor will CRA be liable for any indirect, incidental, or consequential damages.

This warranty does not apply to products which have been subject to mis-use such as accident, severe mechanical shock and distress, over-voltage, immersion, exposure to volatile or corrosive agents, etc. The warranty does not apply to defects due to unauthorized modification, or which have been altered in such a way as to not be capable of undergoing functional test.

Products sold by Carroll & Ramsey Associates are not intended for use as critical components in medical devices or life-support devices or systems. Performance specifications, physical configuration, and packaging are subject to revision, change, or improvement at any time -- without prior notice.