

AN INTERFACE FOR ROUTINE SPECTRAL DISPLAY FROM SEVERAL
LIQUID SCINTILLATION COUNTERS

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Abstract

An interfacing circuit for coupling several Tri-Carb liquid scintillation counters to a multichannel analyzer is described. The display of the analyzer is completely controlled from the liquid scintillation counters and information from any one of the three channels in each counter can be displayed.

The system is being used for both instructional and diagnostic purposes. For the former it will be part of a course on the theory and use of liquid scintillation counting. For the latter it assists in setting up optimum counting conditions for single and double labels in new cocktails as well as for new labels, and to help diagnose counting problems such as chemi- and/or photoluminescence.

Introduction. Work at our laboratory involves about 100 people, many of whom employ liquid scintillation counting. Because this is both an instructional and a research institution, there is a high annual turnover rate, so that newcomers employing radioisotopes must learn to use liquid scintillation counting properly before embarking on their projects. For this reason a short course is taught annually covering the theory and use of liquid scintillation counting as well as sample preparation and data handling methods. Visual display of spectra obtained under a variety of realistic counting conditions would be a valuable adjunct to the course; this was the primary motive for the work reported here.

In addition, we have long had a need for rapidly, and simply, generating beta spectra of samples from new compounds that contain any of a variety of isotopes (e.g., ¹⁴C, ³H, ³P, ³³P, ³⁶Cl, ⁵¹Cr, ¹²⁵I) and that require specific liquid scintillation cocktails. This would permit us to more intelligently set the optimum counting conditions than is now the case, and thus would be a significant improvement over the present method of blindly probing for the best arrangement of gain, window location, and width.

Fairman and Sedlet (1) briefly described a multichannel analyzer (MCA) coupled to a liquid scintillation counter (LSC)
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with a logarithmic energy scale (1). This was used to help develop a method for the analysis of a ^{210}Pb , ^{210}Bi , ^{210}Po mixture. No details of the interfacing circuit were supplied. Neary and Budd (2) employed a similar system capable of operating in the logarithmic or linear output mode. They studied the differences in beta spectra arising from chemical and color quenching. No details on interfacing of the MCA and LSC were given. Klein and Eisler (3) also coupled an MCA with an LSC to determine the effect of color vs. chemical quenching and used the cathode ray tube to visually project the altered spectra. They used the MCA amplifier to obtain a linear display of the energy scale and eliminated the upper discriminator in order to display the full spectra.

Experimental. The above reports employed Beckman counters. Our laboratory has three Packard Inst. Co. counters, two Model 3375 and one 3385. We understand that liquid scintillation counters from this company are in use in substantial numbers around the world. Thus it seemed worthwhile to develop an interfacing system for this make. We proceeded along the same line as described in reference (1), *i.e.*, the signal to be presented to the multichannel analyzer was picked off after the summation circuit and linear amplifier but immediately before the upper and lower discriminators. The gating pulse, *i.e.*, the one used to determine which signal pulse was to proceed to the multichannel analyzer, was obtained from the ratemeter output jack located on the rear of the counter. Thus, the requirement that the signal and gating pulses be in coincidence meant that the pulse analyzed (in the MCA) was the pulse counted (in the LSC). Furthermore, this arrangement meant that the effect of altering the gain or discriminator settings on the LSC would appear in the spectral display.

Unfortunately, presentation of the unaltered pulses to the coincidence circuit of several commercial multichannel analyzers tested (3 in all) produced no useful spectra. The problem was that the pulses put out by the liquid scintillation counters did not match the coincidence input pulse requirements of the MCA's. We chose, finally, the Northern Scientific Model NS-700 largely because this MCA is in use by other groups in the laboratory.

The differences in output signals by the LSC's and input requirements of the MCA are: the former puts out negative pulses (from the summing network) having rise, width, and fall times in the 30-100 nsec range while the MCA requires positive going pulses of 100 nsec rise and fall and 1000 nsec width.

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Alteration of the input amplifier of the MCA could have been performed, but this would have interfered with other applications of this analyzer. Therefore, an additional amplifier board was purchased from the Northern Scientific Co. and modified so as to both invert and stretch the LSC pulses to match the input requirement of the coincidence section of the MCA. Similarly, the gating (ratemeter) pulse was stretched so that its shape was very close to the shaped signal pulse. A simple block diagram of the system is shown in Fig. 1. The essential features of the interface are:

1) Signal routing. The signal is taken from each pulse height analyzer module at test point (see Packard schematic D7100003 linear amplifier emitter-follower output) and fed through coaxial cable to an attenuator of approximately 20:1. The attenuator output is matched to a 50 ohm coaxial line which is routed to the interface box where one of nine similar cables is selected by a rotary switch (channel selector). The signal is then fed to the input of the interface amplifier/shaper through a 100 ns risetime integrator terminated in 50 ohms. The integrator smooths any cable ringing or signal ringing originating in the LSC.

2) Interface amplifier/shaper. A standard Northern Scientific preamp/amplifier board (NS-700/S-129) was slightly modified for use as the interface amplifier/shaper. Voltage gain of the first stage was reduced from approximately 3300 with a 10 μ s time constant to approximately 7.5 with no capacitor in the feedback loop. Output from this stage is fed to a 2K ohm front panel mounted "gain control" potentiometer. The second stage is fed from the slider of the gain control and is unmodified with a non-inverting gain of 2. The third stage has been modified for two voltage gain settings, front panel selectable, of 0.9 or X9 inverting. Normally the X9 gain setting is used unless very high level input signals are encountered (e.g., ^{32}P). The last stage remains unmodified with a voltage gain of approximately 5 inverting and a 47 pf integrating capacitor across the feedback resistor. The shaped and amplified signal is then applied to the signal out connector through a 33 μ fd capacitor.

Gating pulse stretcher. Positive spikes from the ratemeter output jacks (9 in all) are fed through coaxial lines to the second wafer of the channel selector switch. A spike from the appropriate pulse height analyzer is then inverted and used to trigger a variable width multivibrator oneshot whose output is buffered and fed to the coincidence output jack. The oneshot width is screwdriver adjusted via a front panel mounted trimpot to match the width of the positive side of the signal from the signal-out jack. Pulses to the NS-700

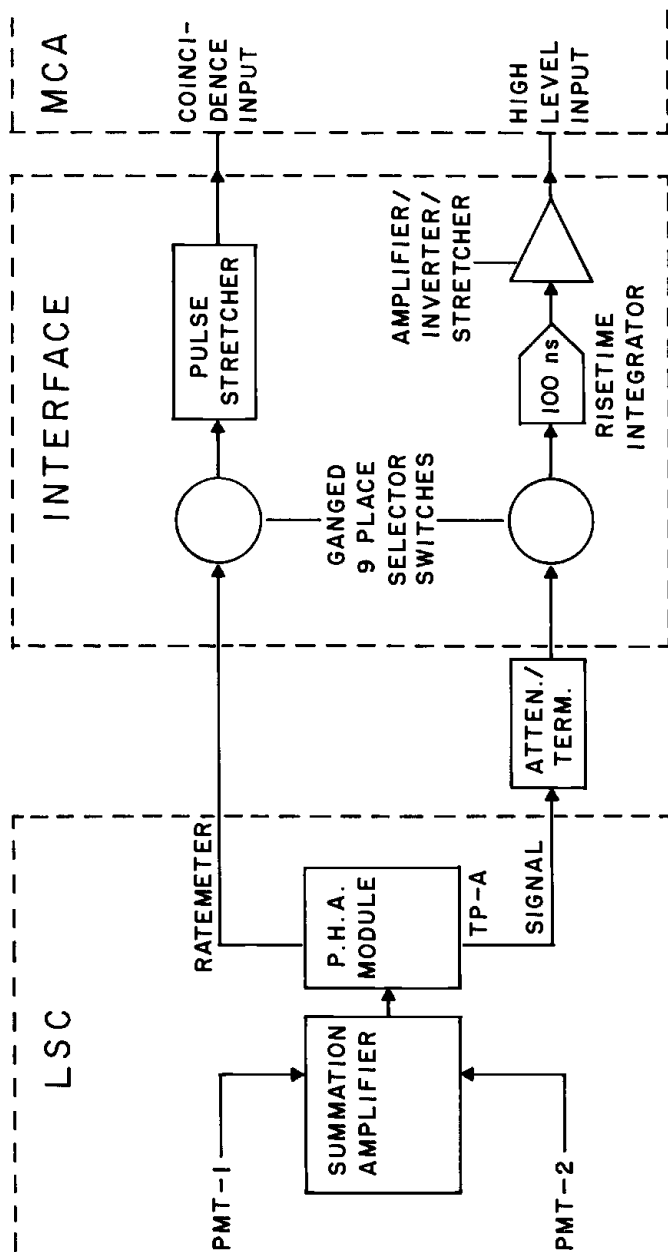


Figure 1. Block Diagram of LSC/MCA Interface.

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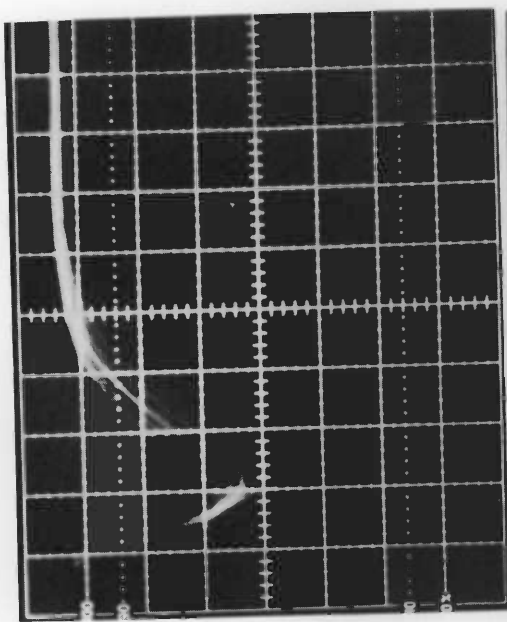
coincidence input are now of sufficient width and level to operate internal gating circuitry.

Recalling that the system had to be able to interrogate nine channels from three LSC's, it is evident that considerable cabling was employed. Problems associated with the cables (ringing, attenuation, distortion) were solved by 50 ohm termination. Nevertheless, the original signal from the LSC's was rather distorted (Fig. 2a) and resulted in a sharply distorted tritium spectrum (Fig. 2b). The introduction of a 100 nsec rise time integrator on the input circuit smoothed the pulses very well (Fig. 2c) and this in turn resulted in an acceptable tritium spectrum (Fig. 2d).

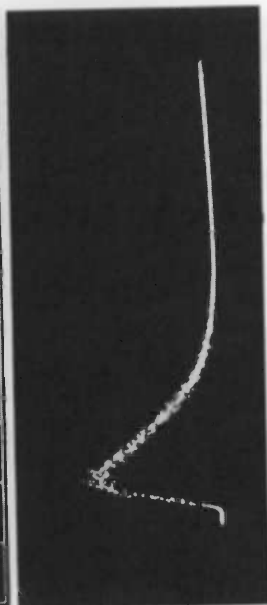
To be sure that the MCA was viewing exactly the same portion of the spectrum as the LSC, the added requirement was made that the count rates in both instruments agree. It was our experience that normal-appearing spectra were sometimes obtained where the count rate in the MCA differed significantly from that in the LSC--generally, but not invariably, lower. The gain control on the interface circuit served to achieve this end by increasing gain to avoid weak signal loss down the cable or decreasing gain to avoid overload of the interface amplifier with resultant clipping. The interface box is shown in Fig. 3, with the fast rise time integrator on the right and the pulse shaper in the center. Fig. 4 shows the assembled system with spectra from a ^3H channel and ^{14}C channel.

Results and Discussion. With this system in hand, some studies were made of the spectral shapes of samples counted under various conditions. Figure 5 shows the spectrum of $^3\text{H} + ^{14}\text{C}$ in the tritium and carbon-14 channels. Note the tritium "spike" on the low energy part of the carbon-14 spectrum in Fig. 5a. In each channel, one of the LSC discriminators can be visually adjusted to give a satisfactory setting for one isotope in the presence of the other. For the best separation one may still have to adjust each discriminator (the upper level in the ^3H channel and the lower level in the ^{14}C channel) stepwise, getting the efficiency and "spillover" each time. The visual setting permits one to narrow the range of interest, a feature of great benefit to the inexperienced user.

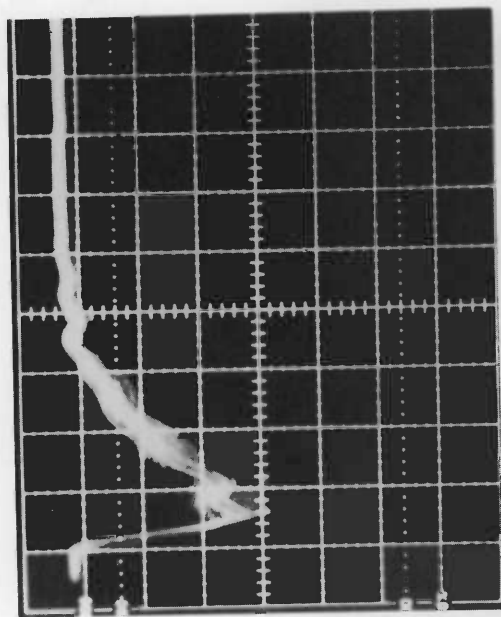
One of the most annoying problems faced in biological research with radiotracers is that of chemiluminescence. It is normally detected by making repeated counts to see if the rate decreases with time. Because of its low energy, one should observe this readily in the tritium channel as a low energy spike. Chemiluminescence was generated by adding a few



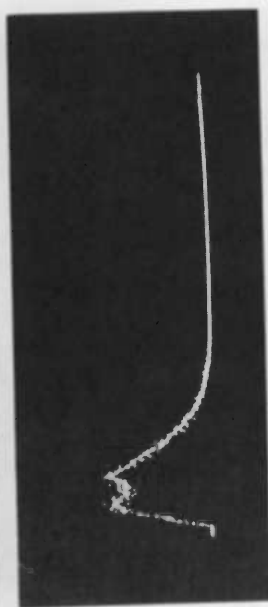
c)



d)



a)



b)

Figure 2. Effect of Rise Time Integrator.
 a) tritium pulses before 100 nsec integrator
 b) tritium spectrum before " " "
 c) tritium pulses after " " "
 d) tritium spectrum after " " "

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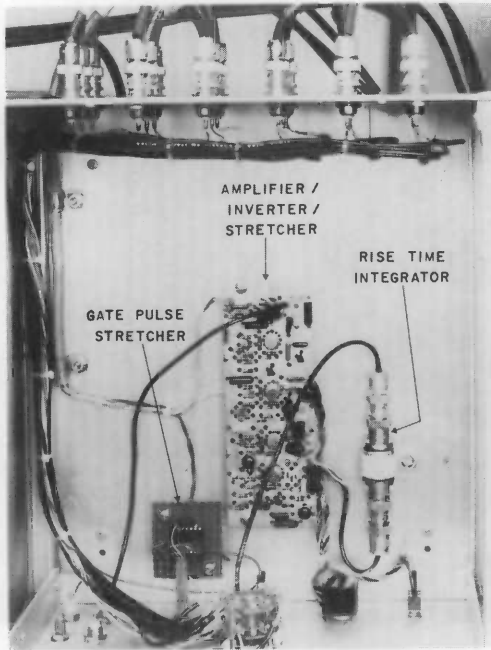


Figure 3. Interface with Top Removed.

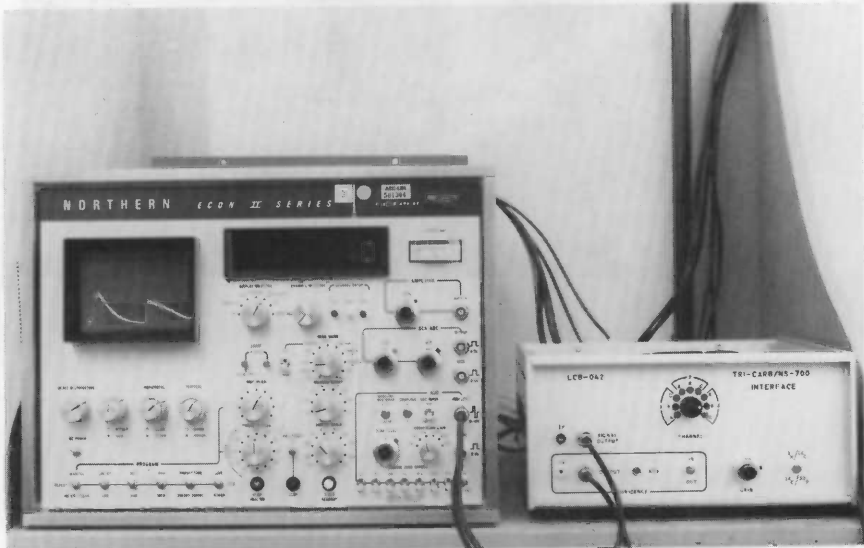
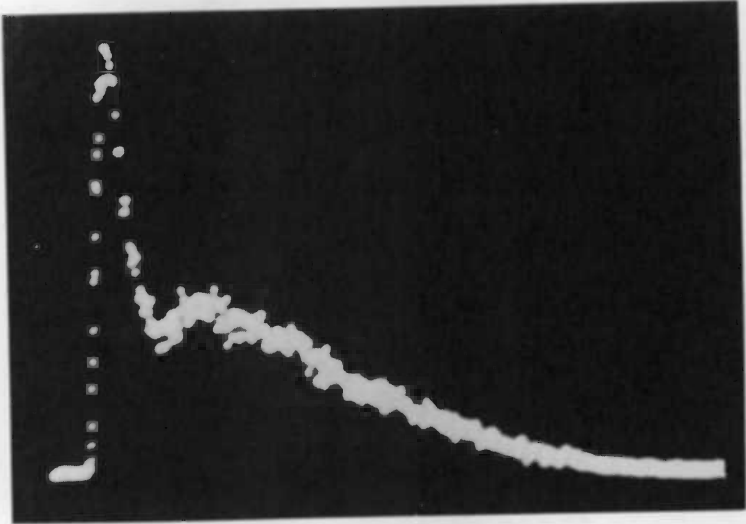


Figure 4. Multichannel Analyzer Plus Interface. Tritium (left) and carbon-14 (right) spectra displayed.

a)



b)

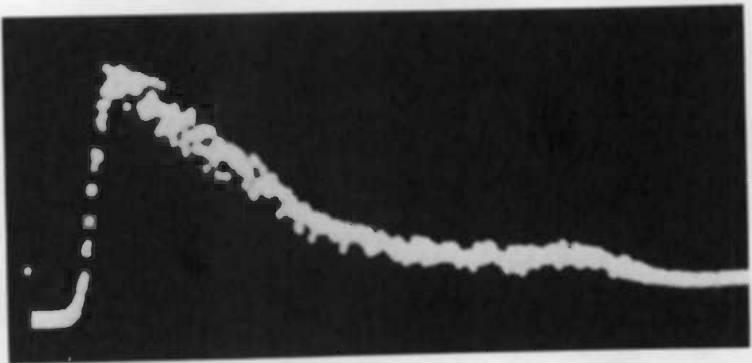


Figure 5. Doubly Labeled Sample.
a) $^3\text{H} + ^{14}\text{C}$ in ^{14}C channel
b) $^3\text{H} + ^{14}\text{C}$ in ^3H channel

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drops of a strong base to a commercial detergent cocktail and the spectrum shown in Fig. 6a was produced. This is compared with a lightly quenched ^3H sample (40% efficiency). The difference is readily apparent. Because chemical quenching shifts the beta spectrum to a lower energy, one would expect that for highly quenched samples, the presence of chemiluminescence would be difficult to distinguish from tritium. This is indeed the case, as shown in Fig. 6b. There is no obvious difference in the shape of the ^3H spectrum at 10% counting efficiency from the chemiluminescent spectrum.

The MCA can also operate in a multi-scaling mode, *i.e.*, where a count is made for a preset time, stored in channel 1, repeated, stored in 2, etc. Thus, count rate vs. time can be visually demonstrated, if one wishes, to show either chemi- or photoluminescence, as is demonstrated in Fig. 7. It is readily apparent that the half lives of the two processes are entirely different and that one can return to background in a few minutes with photoluminescence, but not for several hours with chemiluminescence.

The decay of chemi- or photoluminescence to true background is much more important for low count rate (*i.e.*, ~ 100 cpm) samples because both of these processes have complex kinetics and there may be a very long-lived tail (particularly for photoluminescence) in the decay curve, which will affect the results. Such low count rates are not readily studied by the above system because they require an inordinately long counting period to collect enough counts in each channel to generate a useful spectrum or decay plot. This, of course, is a basic limitation of the MCA-LSC system, so it is normally not used for low count rate samples.

When setting up the system to study a spectrum, we have found that the greater the isotope energy, the lower the interface gain should be. The proper adjustment depends on each isotope, but the interface gain must be set so that the count rate of the LSC and MCA agree. A rule of thumb has evolved from use of this system: the interface gain adjusts the beta spectrum so that the high energy end is between 25 and 50% of full scale. Less than this results in a lower count rate in the MCA due to low energy pulse loss; much greater than this yields a distorted spectrum due to high energy pulse clipping. This may not be an inviolate rule for all isotopes, but was found to be so for tritium and carbon-14.

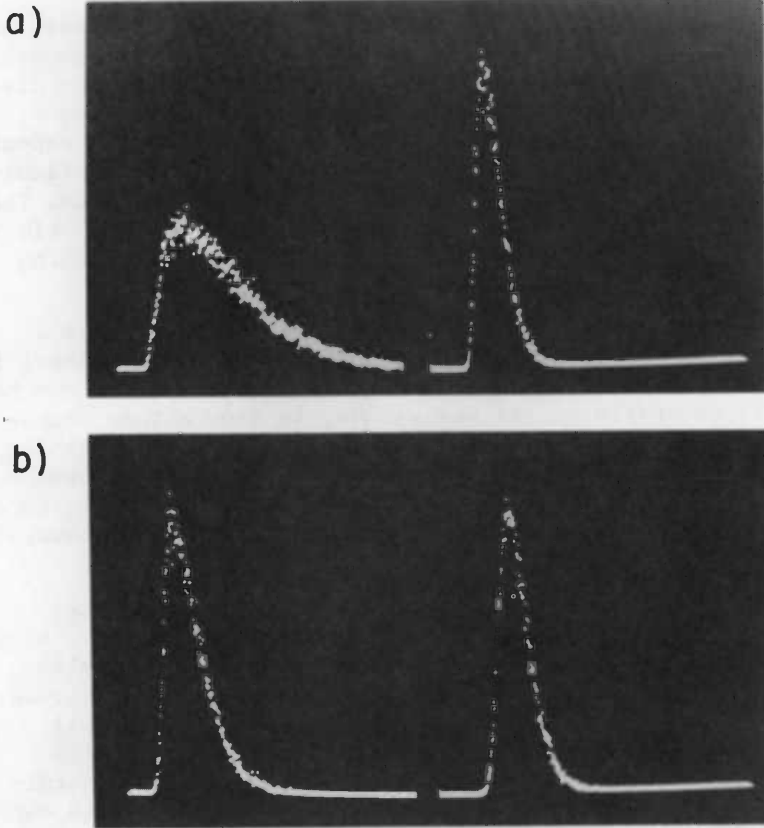


Figure 6. Tritium Spectra vs. Chemiluminescence
a) ^3H (left), chemiluminescence (right) - 40% ^3H efficiency
b) ^3H (left), chemiluminescence (right) - 10% ^3H efficiency

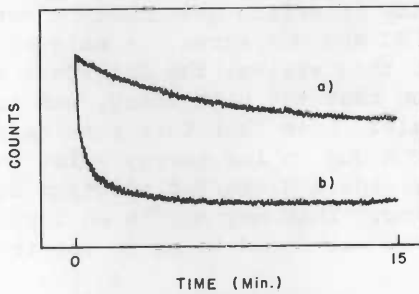


Figure 7. Decay Rates of Chemiluminescence (a) vs. Photoluminescence (b).

Conclusion. An interfacing circuit has been developed for a routine multi-channel analysis of radioisotope spectra from a number of liquid scintillation counters. A selector switch permits the selection of any one of nine channels from three liquid scintillation counters. The consequences of changing gain and/or discriminator settings are immediately reflected in the displayed spectrum.

The system permits one to observe the presence of chemi- or photoluminescence on new samples. It also is helpful in finding the appropriate liquid scintillation counter settings for doubly labeled samples. It is particularly useful for helping to set up counting conditions for radioisotopes not previously used. It promises to be a valuable instructional aid to those encountering liquid scintillation counting for the first time.

Schematics of the interface and associated cabling are available on request.

Acknowledgements. The prototype interface circuit was constructed by R. Healey of Healey Associates, Dublin, Calif. and much of the construction of the final system was done by John Griffin of this laboratory. The work reported in this paper was supported by the U.S. Energy Research and Development Administration.

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