Using Surplus Philips XP2422/SN PMTs in Scintillation Probes

David Prutchi, Ph.D.

www.diyPhysics.com Technical Note 2013-4, April 2013

Abstract

This short note discusses the construction of a dynode string voltage divider for a surplus XP2422/SN photomultiplier tube. These PMTs are suitable for building scintillation probes with high pulse-height resolution.

Introduction

In our book "Exploring Quantum Physics Through Hands-On Projects"[1] we introduced the use of a photomultiplier tube (PMT) as a single-photon detector to be used for demonstrating the particle-nature of light, both for directly detecting visible-light photons, as well as for detecting their capability of transferring momentum to mass particles as evidenced by the Compton Scattering effect [2].

We used the RCA 6655A PMT in the probe presented in the book (Figure 29 in Reference [1]). However, the surplus availability of specific PMT models is very variable, so for the benefit of our readers, we decided to provide an alternative designed based on the XP2422/SN – a 60 mm, hexagonal, 10-stage PMT (Figure 1) that is currently widely available in the surplus market, for example from Sphere Research[1]. The XP2422/SN PMT is especially suited for gamma-ray spectral analysis when coupled to a NaI(Tl) scintillation crystal because of its high pulse-height resolution (PHR).

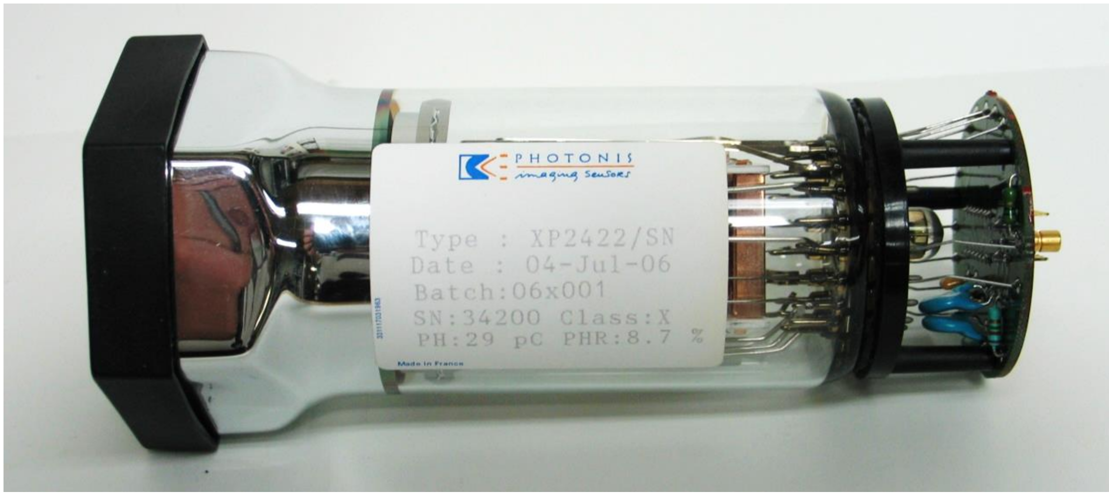

Figure 1 – New XP2422/SN photomultiplier tubes that were meant for medical gamma cameras are available at low cost from Sphere Research in Canada.

[1] Sphere Research Corporation, 3394 Sunnyside Road, West Kelowna, B.C., CANADA V1Z 2V4
URL: http://www.sphere.bc.ca, Phone: +1 (250) 769-1834, Fax: +1 (250) 769-4106

Using the XP2422/SN PMT

In a photomultiplier tube, a single electron released from a photocathode by a single photon is accelerated towards another electrode in order to produce secondary electrons. Two or more electrons are then released when the accelerated photoelectron slams into the electrode. As shown in Figure 2, the same process can be repeated over and over again with the secondary electrons used to successively multiply the number of electrons released in a cascade. A much larger number of electrons finally reach the anode as the result of a single photon hitting the photocathode. Commercially-available photomultiplier tubes based on this principle produce as many as 10^6 to 10^7 secondary electrons at the anode for each photon that releases a photoelectron from the photocathode.

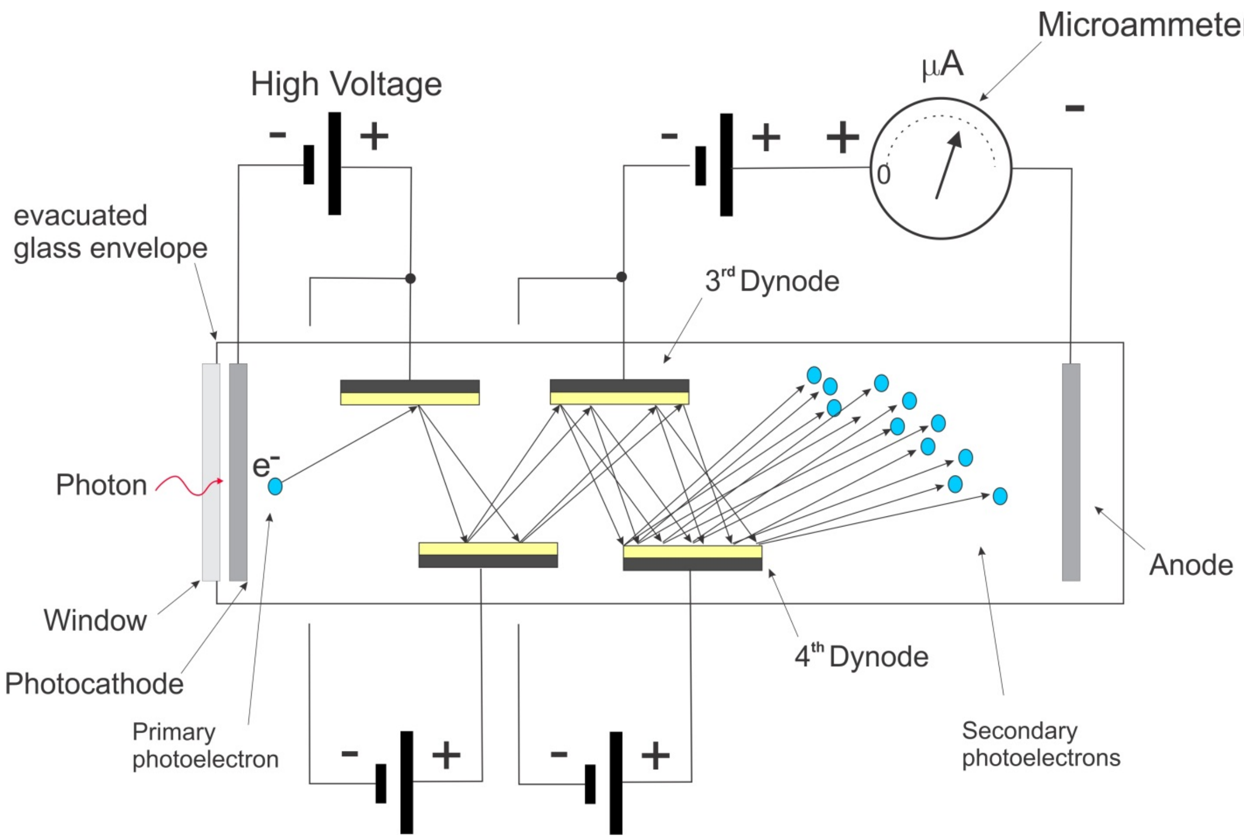

Figure 2 – The photomultiplier tube (PMT) is the workhorse detector of experimental Particle Physics. The photoelectrons released at the photocathode of a photomultiplier tube are accelerated toward an electrode (first dynode), and cause the release of two or more secondary electrons. Each of these causes the release of two or more electrons from the second dynode. The cascade continues until a very large number of electrons are available for detection at the anode. [Adapted from d. Prutchi and S.R. Prutchi, "Exploring Quantum Physics Through Hands-On Projects", J. Wiley & Sons, 2012].

The XP2422/SN PMT, like the one shown in Figure 1, was used by Philips Medical Systems in some of its gamma cameras. It is a 10-stage round tube with a 60 mm hexagonal window. The PMT achieves a gain of around 1.2×10^5 at a bias voltage of 1,250 V. It is sensitive to photons within the 290 nm to 650 nm wavelength range, and its sensitivity peaks at 420 nm.

The surplus XP2422/SN tubes have a printed circuit board that was wired by Photonis directly to the base of the tube. This board has a SMB connector to output the PMT's anode AC-coupled signal. The PCB also holds capacitors to stabilize the voltage divider for the last dynodes, and a 14-pin connector that is wired in Philips' gamma cameras to a separate assembly containing the voltage divider string and a high-voltage power supply. As shown in Figure 3, we traced back the wiring and were able to recreate the pinout for the 14-pin terminal based on the flying-lead pinout of Figure 4.

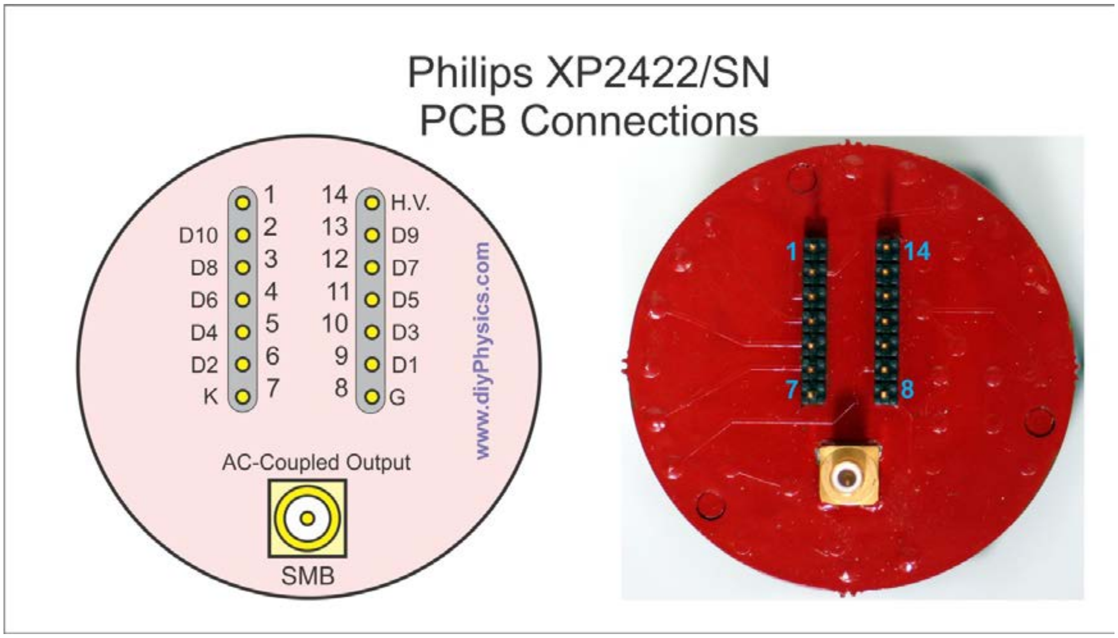

Figure 3 – Identification of connectors in the PCB of the Photonis XP2422/SN PMT assembly.

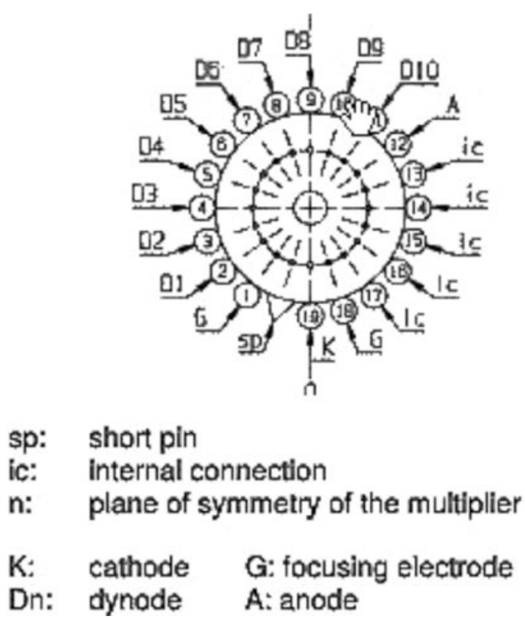

Figure 4 – Flying-lead pinout of the Photonis XP2422 PMT. The reference for numbering is one short pin that barely protrudes from the plastic retainer.

As shown in Figure 5, we constructed a voltage divider assembly on a piece of Vectorboard. Two 7-pin female headers (0.1" inter-pin spacing) interface the board to the XP2422/SN 14-pin connector. The components shown in Table 1 are soldered to the board. The completed assembly is shown mounted on the XP2422/SN in Figure 6.

Component	Connection to 14-Pin Header
1.1 MΩ resistor (two 2.2 MΩ resistors in parallel)	Between Pin 7 and Pin 8
3.3 MΩ resistor (a 2.2 MΩ resistor in series with two 2.2 MΩ resistors in parallel)	Between Pin 8 and Pin 9
2.2 MΩ resistor	Between Pin 6 and Pin 9
2.2 MΩ resistor	Between Pin 6 and Pin 10
2.2 MΩ resistor	Between Pin 5 and Pin 10
2.2 MΩ resistor	Between Pin 5 and Pin 11
2.2 MΩ resistor	Between Pin 4 and Pin 11
2.2 MΩ resistor	Between Pin 4 and Pin 12
2.2 MΩ resistor	Between Pin 3 and Pin 12
2.2 MΩ resistor	Between Pin 3 and Pin 13
2.2 MΩ resistor	Between Pin 2 and Pin 13
.01 µF 3 kV ceramic capacitor	Between Pin 2 and Pin 13
2.2 MΩ resistor	Between Pin 2 and Pin 14
No connection	Pin 1
HV reference wire	Pin 7
+1,250 VDC input wire	Pin 14

Table 1 – Voltage divider network connections

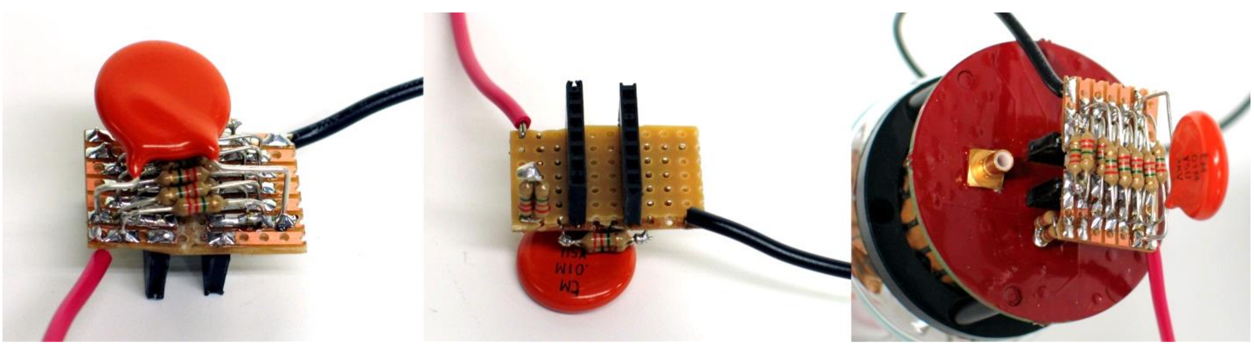

Figure 5 – Voltage divider network for the XP2422/SN PMT

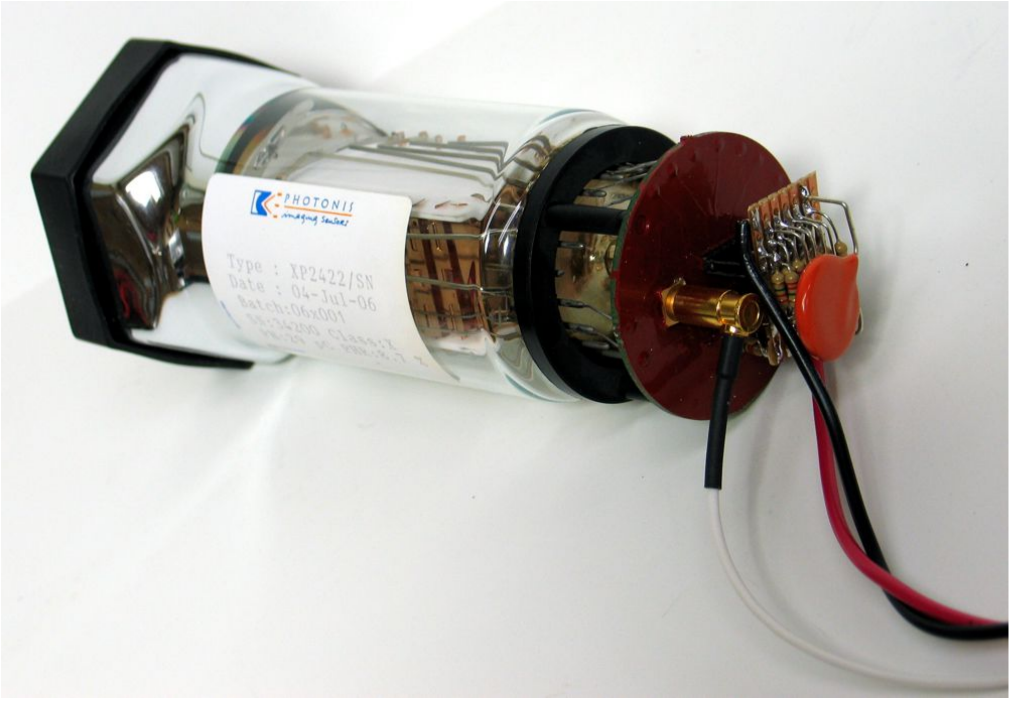

Figure 6 – Three cables connect the PMT assembly to an external +1,250V power supply and a scintillation processor: a HV reference wire, a high-voltage wire and a coax cable terminated by an SMB connector.

Photomultiplier tubes are extremely sensitive to magnetic fields and exhibit output variations even from sources such as terrestrial magnetism. To take advantage of the XP2422/SN PMT's high PHR, wrap the PMT with magnetic shielding foil (with a permeability of at least 105). We used a layer of NETIC and a layer of CONETIC from Magnetic Shielding (www.magnetic-shield.com) and held them in place using Gorilla tape. The magnetic field intensity within the shield will be attenuated to approximately 1/1000 that outside the shield case, ensuring a stable output when operating in proximity to magnetic fields.

Acknowledgements

We thank Walter Shawlee - president of Sphere Research Corporation - for supplying the XP2422/SN PMT used in this project.

References

1. D Prutchi, S.R. Prutchi, *Exploring Quantum Physics Through Hands-On Projects*, J. Wiley & Sons, 2012.
2. Prutchi S.R., D. Prutchi, *Experiment Note: Exploring Compton Scattering Using the Spectrum Techniques Universal Computer Spectrometer*, Commissioned by Spectrum Techniques, LLC, January 2012.

Please visit www.diyPhysics.com for other interesting, cutting-edge projects.

