

Photomultiplier tubes (PMT)

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Motivation

- Low response time
- It admits weak signals
- Scientific Research: PMTs are fundamental in scientific experiments involving the detection of subatomic particles, studies in particle physics, nuclear physics experiments, as well as research in astrophysics and materials science.
- Radiation Detectors: PMTs are also used in radiation detectors to convert the light generated by the interaction of radioactive particles with a medium into electrical signals.

SIMPLIFIED DIAGRAM OF A PMT

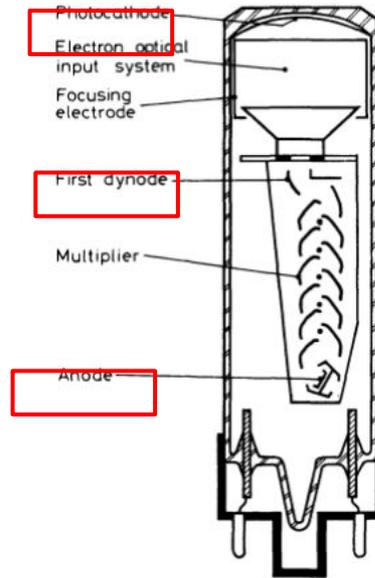
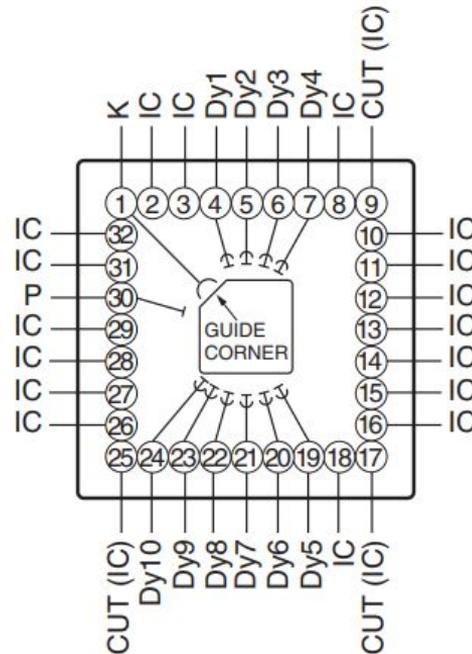


Fig. 8.1. Schematic diagram of a photomultiplier tube (from Schonkeren [9.1])



Model R7600U, electronics behind it

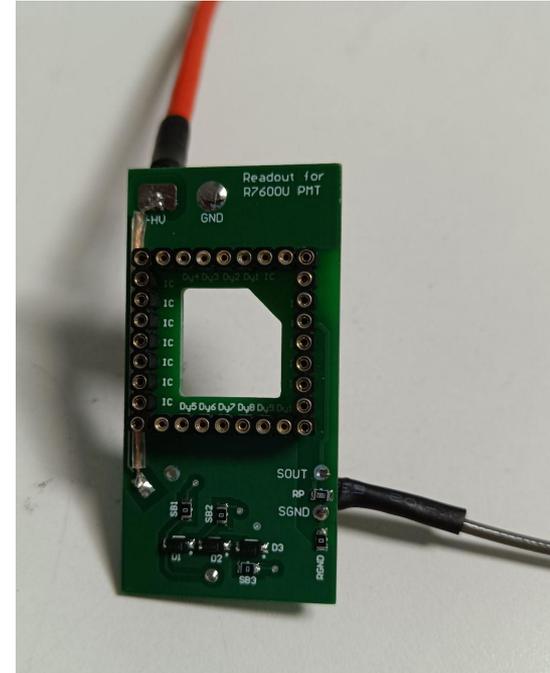
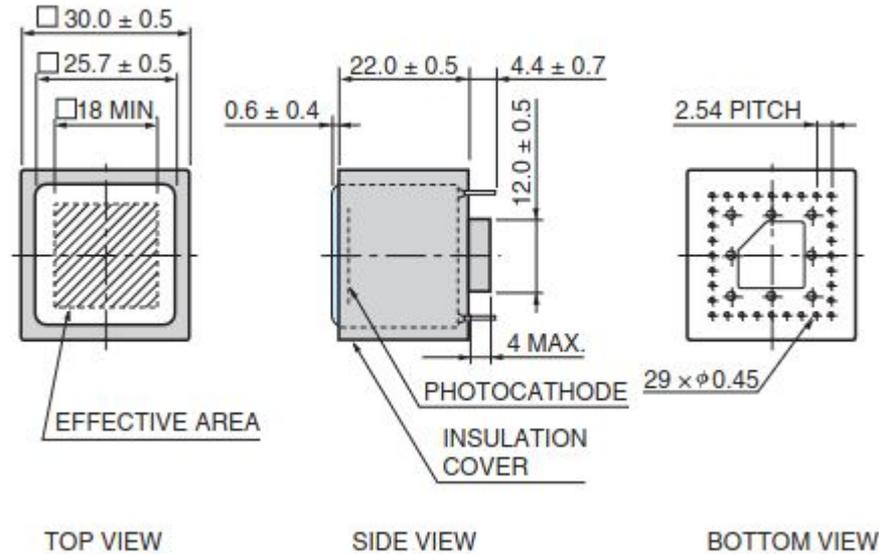
- **Photocathode**, part of the PMT that absorbs incident photons from light. When a photon strikes the photocathode, an electron is released through the photoelectric effect.
- **Dynode**, Dynodes are secondary electrodes arranged in series and at a higher potential than the photocathode, it serves as an electron multiplier.
- **Anode**, it collects all the electrons generated in the cascade and produces an electric current proportional to the number of electrons released
- **CUT**, acts as a capacitor, allowing the output signal to be transmitted
- **IC**, is a semiconductor. It may include amplifiers, filters, and other components



K : Photocathode
Dy : Dynode
P : Anode
CUT : Short pin
IC : Internal connection
(Don't use)

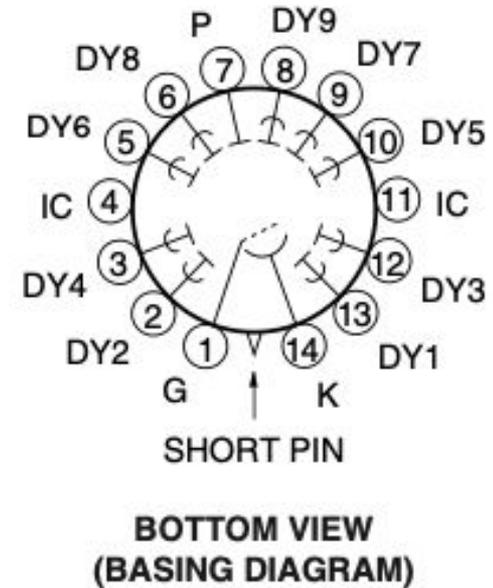
BASING DIAGRAM

Dimensional outline for R7600U (in mm)

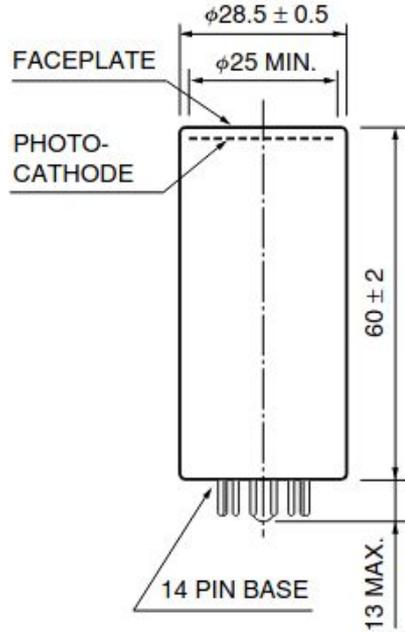


Model R3998-02, electronics behind it

- **Grid**, guide electrode, which has the function of accelerating and focusing the electrons released by the photocathode towards the dynodes for amplification.



Dimensional outline R3998-02 (in mm)



Features

(PMT R7600U)

- Effective area: 18mm X 18mm
- Spectral response: 300 - 650 (nm)
- Peak in 420 (nm)
- time response < 10 (ns)



(PMT R3998-02)

- Effective area: 25mm diameter
- Spectral response: 300 - 650 (nm)
- Peak in 420 (nm)



Quantum efficiency $\eta(\lambda)$

$$\eta(\lambda) = \frac{\text{number of photoelectrons released}}{\text{number of incident photons on cathode } (\lambda)}$$

- PMT RT7600U (RT7600U-01 / RT7600U-20 TYPE)
- PMT R3998-02

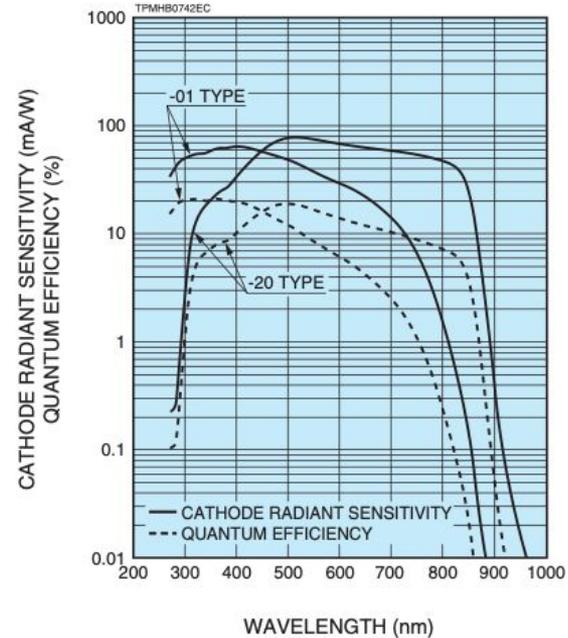
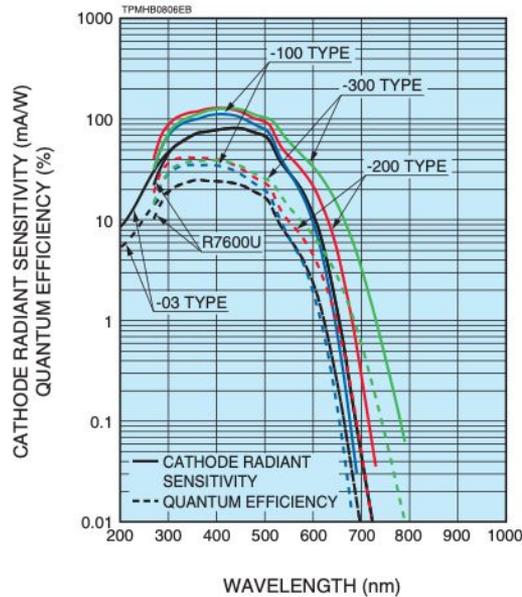


Maximum Quantum efficiency PMT R7600U

PMT R7600U -> $S_{max} = 25\%$ in 400 [nm]

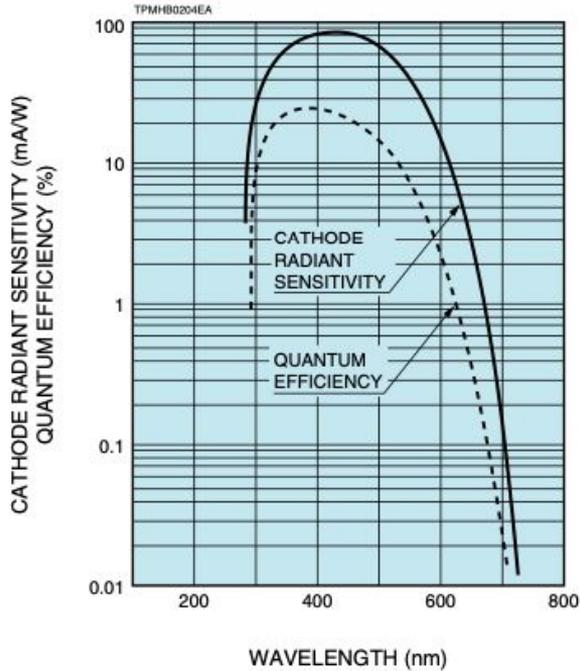
$S_{max} = 20\%$ in 350 [nm] {R7600U-01}
 $S_{max} = 20\%$ in 500 [nm] {R7600U-20}

Figure 1: Typical spectral response



Maximum Quantum efficiency PMT R3998-02

Figure 1: Typical Spectral Response



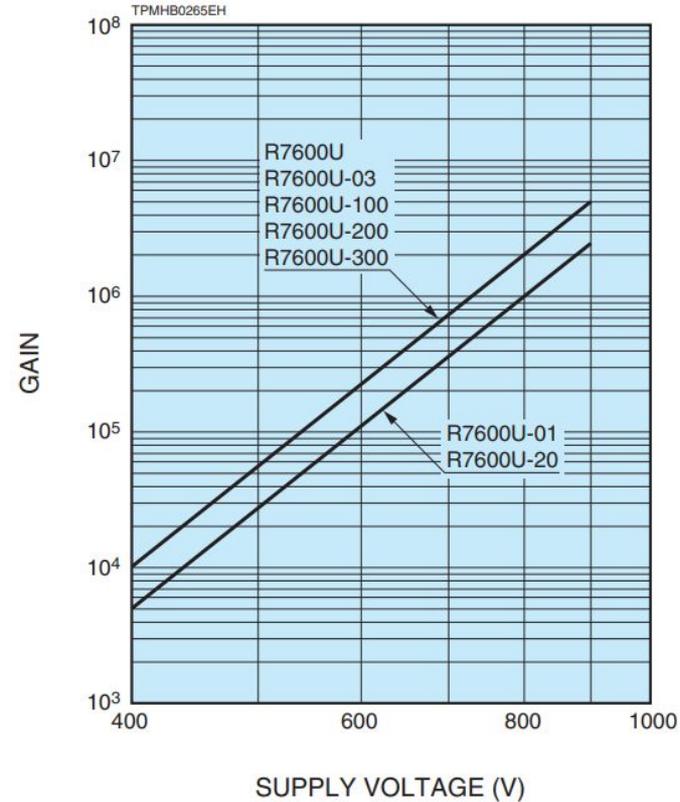
$S_{\text{max}} = 25 \% \text{ in } 370 \text{ [nm]}$

Gain in a PMT

The gain in a PMT refers to the factor by which the signal is amplified as a result of the electron multiplication process within the tube. It is presented as a function of the applied operating voltage:

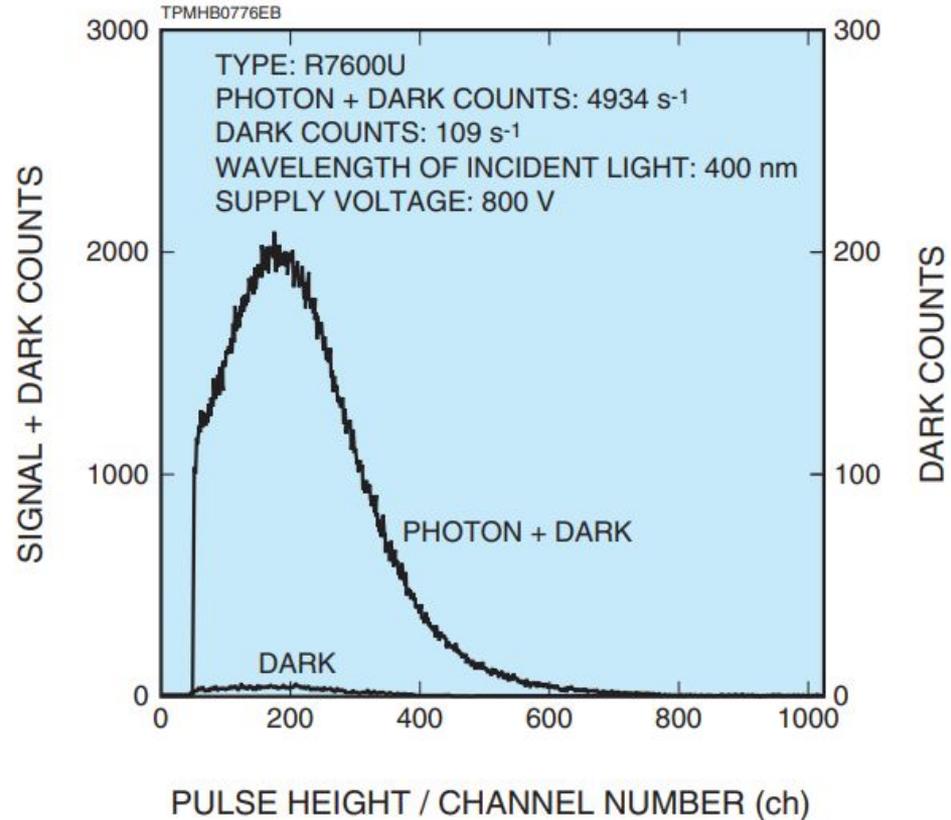
$$\text{Ganancia} = 10 * \log (I_{\text{out}} / I_{\text{in}})$$

In the figure we can see the gain for the model R7600U, and for this particular model we can find that the gain is 2×10^6 . And, for the model R3998 is 1.3×10^6 .



Single photoelectron

In the figure we can see an example of what is called single photon counting using the model R7600U. It refers to the detection of a single electron produced by the impact of a single photon on the photocathode of a photomultiplier tube. This initial electron undergoes a process of multiplication as it traverses the dynode chain within the PMT. This let us measure things like, sensitivity, resolution, quantum efficiency and calibration.



Average Anode Current (Absolute maximum values)

PMT R3998-02

Supply Voltage

- Between Anode and Cathode : 1500 [V] (DC)
- Between Anode and Last Dynode : 250 [V] (DC)

Average Anode Current : 0.1 [mA]

PMT R7600-U

Supply Voltage

- Between Anode and Cathode : Max. 900 [V] (DC)
- **Average Anode Current** : 0.1 [mA]

Estimates

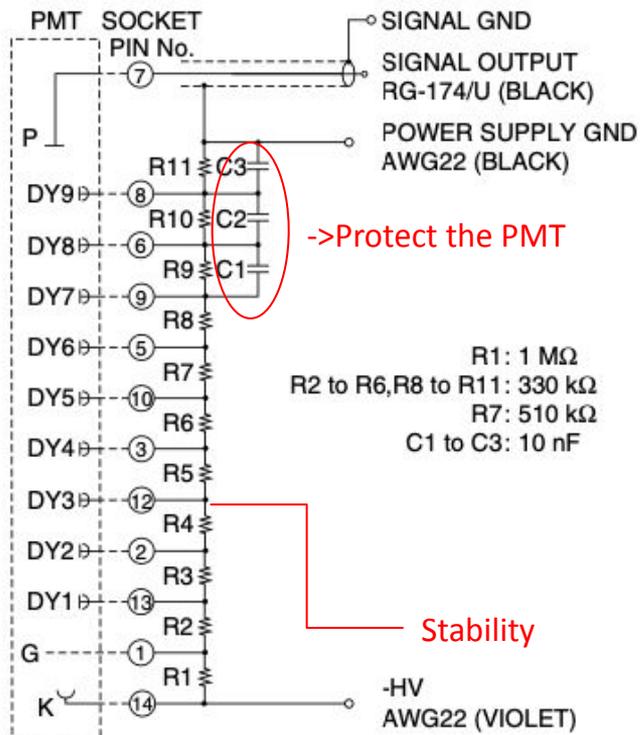
PMT R7600U
LAMBDA 300 [nm]
QUANTUM EFFICIENCY 20.0 %
100 PHOTONS CAPTURED
20 PHOTOELECTRONS OUT
Voltage 800 [V]
gain 2.00e+06
NUMBERS OF PHOTOELECTRONS IN ANODE 4.00e+07

PMT R7600U-01
LAMBDA 300 [nm]
QUANTUM EFFICIENCY 20.0 %
100 PHOTONS CAPTURED
20 PHOTOELECTRONS OUT
Voltage 800 [V]
gain 1.00e+06
NUMBERS OF PHOTOELECTRONS IN ANODE 2.00e+07

PMT R7600U-20
LAMBDA 500 [nm]
QUANTUM EFFICIENCY 20.0 %
100 PHOTONS CAPTURED
20 PHOTOELECTRONS OUT
Voltage 800 [V]
gain 1.00e+06
NUMBERS OF PHOTOELECTRONS IN ANODE 2.00e+07

PMT R3998-02
LAMBDA 420 [nm]
QUANTUM EFFICIENCY 25.0 %
100 PHOTONS CAPTURED
25 PHOTOELECTRONS OUT
Voltage 1500 [V]
gain 1.30e+06
NUMBERS OF PHOTOELECTRONS IN ANODE 3.25e+07

R3998-02



dissipated buffered signals (noise)
dark count

R7600U

