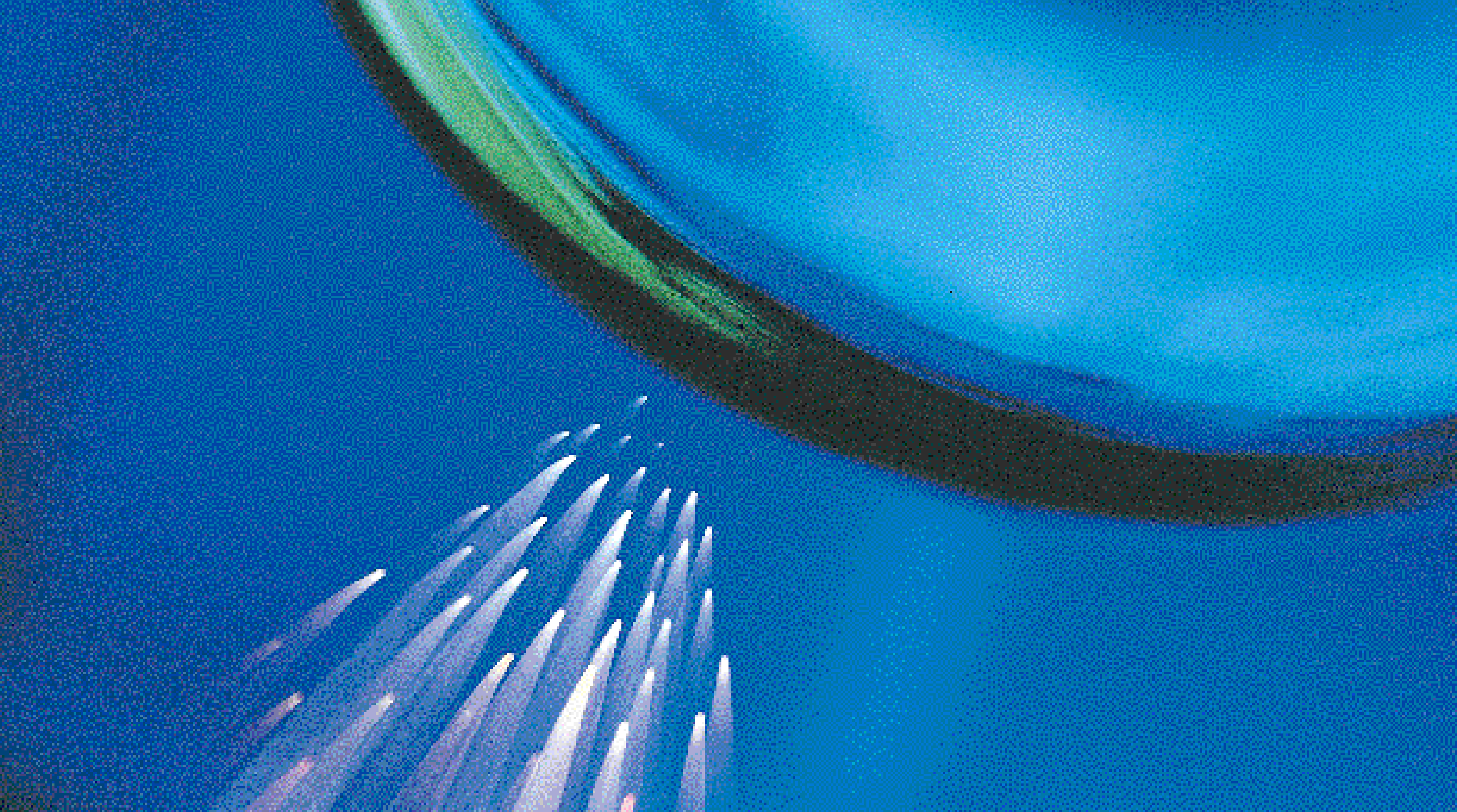
Photomultiplier Tubes

HAMAMATSU

Opening The Future with Photonics



Hamamatsu has been engaged in photonics technology for 45 years and has developed a variety of photonic devices such as photodetectors, imaging devices, and scientific light sources. Our state-of-the-art photonic devices have applications in a wide range of fields, including scientific research, industrial instrumentation, and physical photometry as well as general electronics. The continually expanding frontiers of science demand equally constant exploration of new technology. Hamamatsu's research and development of photonic devices not only keep pace with scientific needs, but stay one step ahead, pioneering new trails into the future of light and optics.

This catalog provides information on our photomultiplier tubes, their accessories, electron multipliers and microchannel plates. But this catalog is just the starting point of our line because we will modify our production specs or design completely new types to match your performance specs.

Variants of the listed types are usually available with:

1. Different photocathode materials
2. Different window materials
3. Different configurations and pin connections
4. Other special requirements for your applications

For further information, please contact your nearest Hamamatsu sales offices.

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Construction and Operating Characteristics

INTRODUCTION

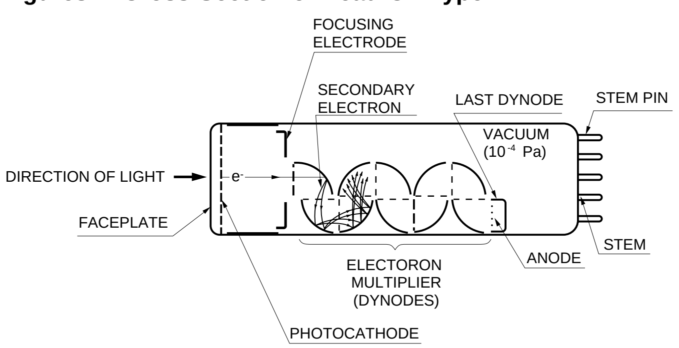
Among the photosensitive devices in use today, the photomultiplier tube (or PMT) is a versatile device that provides extremely high sensitivity and ultra-fast response. A typical photomultiplier tube consists of a photoemissive cathode (photocathode) followed by focusing electrodes, an electron multiplier and an electron collector (anode) in a vacuum tube, as shown in Figure 1.

When light enters the photocathode, the photocathode emits photoelectrons into the vacuum. These photoelectrons are then directed by the focusing electrode voltages towards the electron multiplier where electrons are multiplied by the process of secondary emission. The multiplied electrons are collected by the anode as an output signal.

Because of secondary-emission multiplication, photomultiplier tubes provide extremely high sensitivity and exceptionally low noise among the photosensitive devices currently used to detect radiant energy in the ultraviolet, visible, and near infrared regions. The photomultiplier tube also features fast time response, low noise and a choice of large photosensitive areas.

This section describes the prime features of photomultiplier tube construction and basic operating characteristics.

Figures 1: Cross-Section of Head-On Type PMT



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CONSTRUCTION

The photomultiplier tube generally has a photocathode in either a side-on or a head-on configuration. The side-on type receives incident light through the side of the glass bulb, while in the head-on type, it is received through the end of the glass bulb. In general, the side-on type photomultiplier tube is relatively low priced and widely used for spectrophotometers and general photometric systems. Most of the side-on types employ an opaque photocathode (reflection-mode photocathode) and a circular-cage structure electron multiplier which has good sensitivity and high gain at a relatively low supply voltage.

The head-on type (or the end-on type) has a semitransparent photocathode (transmission-mode photocathode) deposited upon the inner surface of the entrance window. The head-on type provides better spatial uniformity (see page 10) than the side-on type having a reflection-mode photocathode. Other features of head-on types include a choice of photosensitive areas from tens of square millimeters to hundreds of square centimeters.

Variants of the head-on type having a large-diameter hemispherical window have been developed for high energy physics experiments where good angular light acceptability is important.

Figure 2: External Appearance

a) Side-On Type **b) Head-On Type**

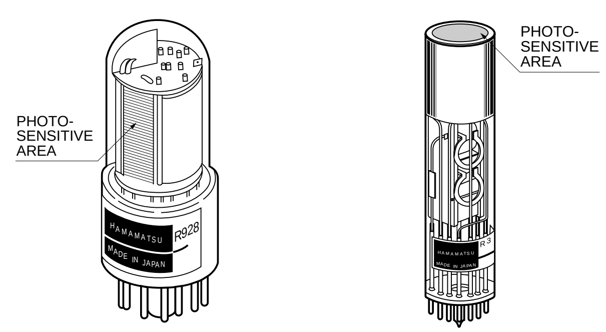

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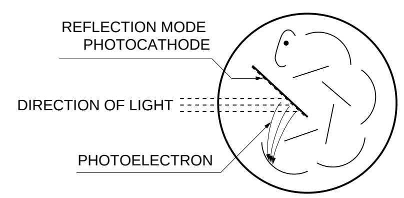
Figure 3: Types of Photocathode

a) Reflection Mode



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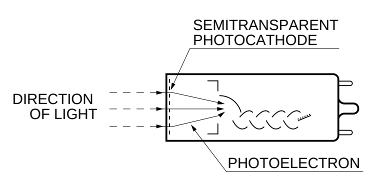
b) Transmission Mode



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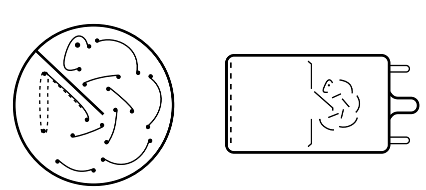
ELECTRON MULTIPLIER

The superior sensitivity (high gain and high S/N ratio) of photomultiplier tubes is due to the use of a low-noise electron multiplier which amplifies electrons by a cascade secondary electron emission process. The electron multiplier consists of from 8, up to 19 stages of electrodes called dynodes.

There are several principal types in use today.

1) Circular-cage type

The circular-cage is generally used for the side-on type of photomultiplier tube. The prime features of the circular-cage are compactness and fast time response.



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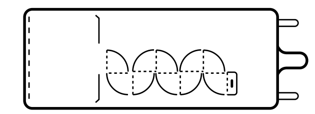
2) Box-and-grid type

This type consists of a train of quarter cylindrical dynodes and is widely used in head-on type photomultiplier tubes because of its relatively simple dynode design and improved uniformity, although time response may be too slow in some applications.



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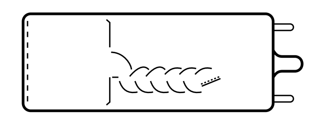
3) Linear-focused type

The linear-focused type features extremely fast response time and is widely used in head-on type photomultiplier tubes where time resolution and pulse linearity are important.



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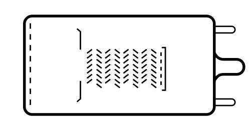
4) Venetian blind type

The venetian blind type has a large dynode area and is primarily used for tubes with large photocathode areas. It offers better uniformity and a larger pulse output current. This structure is usually used when time response is not a prime consideration.



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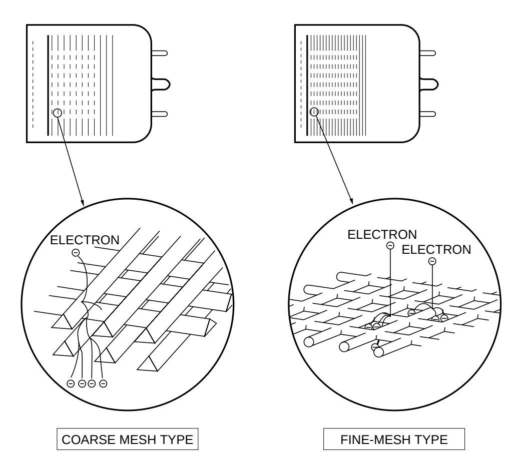
5) Mesh type

The mesh type has a structure of fine mesh electrodes stacked in close proximity. This type provides high immunity to magnetic fields, as well as good uniformity and high pulse linearity. In addition, it has position-sensitive capability when used with cross-wire anodes or multiple anodes. (See pages 58 and 59.)



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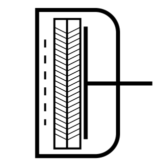
6) Microchannel plate (MCP)

The MCP is a thin disk consisting of millions of micro glass tubes (channels) fused in parallel with each other. Each channel acts as an independent electron multiplier. The MCP offers much faster time response than the other discrete dynodes. It also features good immunity from magnetic fields and two-dimensional detection ability when multiple anodes are used. (See pages 60 and 61 for MCP-PMTs.)



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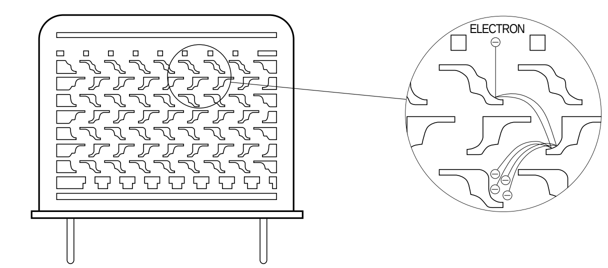
7) Metal channel type

The Metal channel dynode has a compact dynode costruction manufactured by our unique fine machining technique.

It achieves high speed response due to its narrower space between each stage of dynodes than the other type of conventional dynode construction.

It is also adequate for position sensitive measurement.



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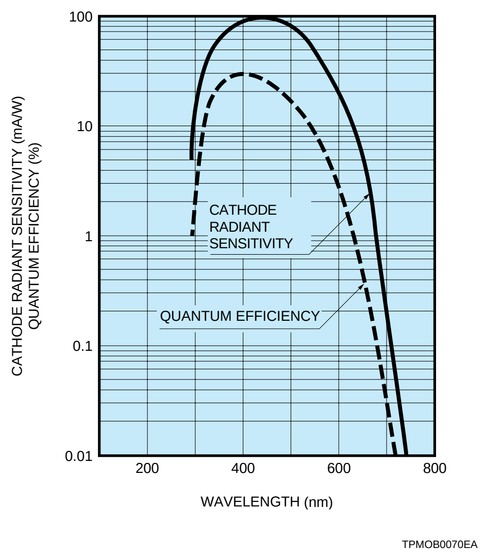
In addition, hybrid dynodes combining two of the above dynodes are available. These hybrid dynodes are designed to provide the merits of each dynode.

SPECTRAL RESPONSE

The photocathode of a photomultiplier tube converts energy of incident light into photoelectrons. The conversion efficiency (photocathode sensitivity) varies with the wavelength of the incident light. This relationship between photocathode sensitivity and wavelength is called the spectral response characteristic. Figure 4 shows the typical spectral response of a bialkali photomultiplier tube. The spectral response characteristics are determined on the long wavelength side by the photocathode material and on the short wavelength side by the window material. Typical spectral response characteristics for various types of photomultiplier tubes are shown on pages 88 and 89. In this catalog, the longwavelength cut-off of spectral response characteristics is defined as the wavelength at which the cathode radiant sensitivity becomes 1 % of the maximum sensitivity for bialkali and Ag-O-Cs photocathodes, and 0.1 % of the maximum sensitivity for multialkali photocathodes.

Spectral response characteristics shown at the end of this catalog are typical curves for representative tube types. Actual data may be different from type to type.

Figure 4: Typical Spectral Response of Head-On, Bialkali Photocathode



PHOTOCATHODE MATERIALS

The photocathode is a photoemissive surface usually consisting of alkali metals with very low work functions. The photocathode materials most commonly used in photomultiplier tubes are as follows:

1) Ag-O-Cs

The transmission-mode photocathode using this material is designated S-1 and sensitive from the visible to infrared range (300 nm to 1200 nm). Since Ag-O-Cs has comparatively high thermionic dark emission (refer to "ANODE DARK CURRENT" on page 8), tubes of this photocathode are mainly used for detection in the near infrared region with the photocathode cooled.

2) GaAs(Cs)

GaAs activated in cesium is also used as a photocathode. The spectral response of this photocathode usually covers a wider spectral response range than multialkali, from ultraviolet to 930 nm, which is comparatively flat over 300 nm to 850 nm.

3) InGaAs(Cs)

This photocathode has greater extended sensitivity in the infrared range than GaAs. Moreover, in the range between 900 nm and 1000 nm, InGaAs has much higher S/N ratio than Ag-O-Cs.

4) Sb-Cs

This is a widely used photocathode and has a spectral response in the ultraviolet to visible range. This is not suited for transmission-mode photocathodes and mainly used for reflection-mode photocathodes.

5) Bialkali (Sb-Rb-Cs, Sb-K-Cs)

These have a spectral response range similar to the Sb-Cs photocathode, but have higher sensitivity and lower noise than Sb-Cs. The transmission mode bialkali photocathodes also have a favorable blue sensitivity for scintillator flashes from NaI (Tl) scintillators, thus are frequently used for radiation measurement using scintillation counting.

6) High temperature bialkali or low noise bialkali (Na-K-Sb)

This is particularly useful at higher operating temperatures since it can withstand up to 175 °C. A major application is in the oil well logging industry. At room temperatures, this photocathode operates with very low dark current, making it ideal for use in photon counting applications.

7) Multialkali (Na-K-Sb-Cs)

The multialkali photocathode has a high, wide spectral response from the ultraviolet to near infrared region. It is widely used for broad-band spectrophotometers. The long wavelength response can be extended out to 930 nm by special photocathode processing.

8) Cs-Te, Cs-I

These materials are sensitive to vacuum UV and UV rays but not to visible light and are therefore called solar blind. Cs-Te is quite insensitive to wavelengths longer than 320 nm, and Cs-I to those longer than 200 nm.

WINDOW MATERIALS

The window materials commonly used in photomultiplier tubes are as follows:

1) Borosilicate glass

This is frequently used glass material. It transmits radiation from the near infrared to approximately 300 nm. It is not suitable for detection in the ultraviolet region. For some applications, the combination of a bialkali photocathode and a low-noise borosilicate glass (so called K-free glass) is used. The K-free glass contains very low potassium (K_2O) which can cause background counts by ^{40}K. In particular, tubes designed for scintillation counting often employ K-free glass not only for the faceplate but also for the side bulb to minimize noise pulses.

2) UV-transmitting glass (UV glass)

This glass transmits ultraviolet radiation well, as the name implies, and is widely used as a borosilicate glass. For spectroscopy applications, UV glass is commonly used. The UV cut-off is approximately 185 nm.

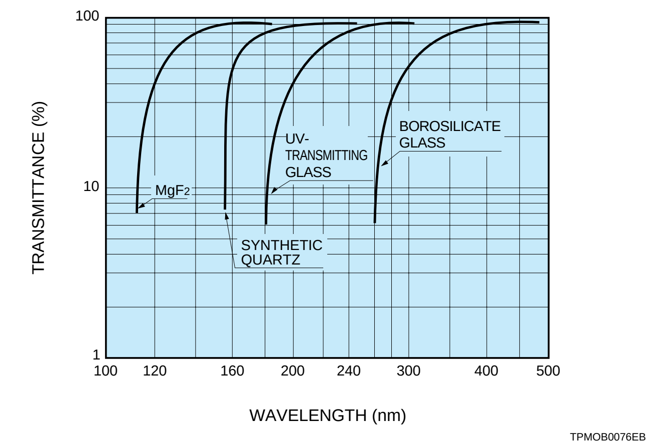
3) Synthetic silica

The synthetic silica transmits ultraviolet radiation down to 160 nm and offers lower absorption in the ultraviolet range compared to fused silica. Since thermal expansion coefficient of the synthetic silica is different from Kovar which is used for the tube leads, it is not suitable for the stem material of the tube (see Figure 1 on page 4). Borosilicate glass is used for the stem, then a graded seal using glasses with gradually different thermal expansion coefficients are connected to the synthetic silica window. Because of this structure, the graded seal is vulnerable to mechanical shock so that sufficient care should be taken in handling the tube.

4) MgF_2 (magnesium fluoride)

The crystals of alkali halide are superior in transmitting ultraviolet radiation, but have the disadvantage of deliquescence. Among these, MgF_2 is known as a practical window material because it offers low deliquescence and transmits ultraviolet radiation down to 115 nm.

Figure 5: Typical Transmittance of Various Window Materials



As stated above, spectral response range is determined by the photocathode and window materials. It is important to select an appropriate combination which will suit your applications.

RADIANT SENSITIVITY AND QUANTUM EFFICIENCY

As Figure 4 shows, spectral response is usually expressed in terms of radiant sensitivity or quantum efficiency as a function of wavelength. Radiant sensitivity (S) is the photoelectric current from the photocathode, divided by the incident radiant power at a given wavelength, expressed in A/W (amperes per watt). Quantum efficiency (QE) is the number of photoelectrons emitted from the photocathode divided by the number of incident photons. It is customary to present quantum efficiency in a percentage. Quantum efficiency and radiant sensitivity have the following relationship at a given wavelength.

$$QE = \frac{S \times 1240}{\lambda} \times 100\ \%$$

Where S is the radiant sensitivity in A/W at the given wavelength, and λ is the wavelength in nm (nanometers).

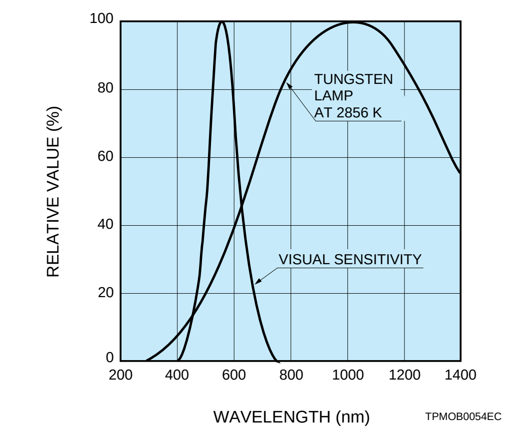
LUMINOUS SENSITIVITY

Since the measurement of the spectral response characteristic of a photomultiplier tube requires a sophisticated system and much time, it is not practical to provide customers with spectral response characteristics for each tube ordered. Instead cathode or anode luminous sensitivity is commonly used.

The cathode luminous sensitivity is the photoelectric current from the photocathode per incident light flux (10^{-5} lumens to 10^{-2} lumens) from a tungsten filament lamp operated at a distribution temperature of 2856 K. The anode luminous sensitivity is the anode output current (amplified by the secondary emission process) per incident light flux (10^{-10} lumens to 10^{-5} lumens) on the photocathode. Although the same tungsten lamp is used, the light flux and the applied voltage are adjusted to an appropriate level. These parameters are particularly useful when comparing tubes having the same or similar spectral response range. Hamamatsu final test sheets accompanying the tubes usually indicate these parameters except for tubes with Cs-I or Cs-Te photocathodes, which are not sensitive to tungsten lamp light. (Radiant sensitivity at a specific wavelength is listed for those tubes instead.)

Both the cathode and anode luminous sensitivities are expressed in units of A/lm (amperes per lumen). Note that the lumen is a unit used for luminous flux in the visible region and therefore these values may be meaningless for tubes which are sensitive beyond the visible region. (For those tubes, the blue sensitivity or red/white ratio is often used.)

Figure 6: Typical Human Eye Response and Spectral Energy Distribution of 2856 K Tungsten Lamp



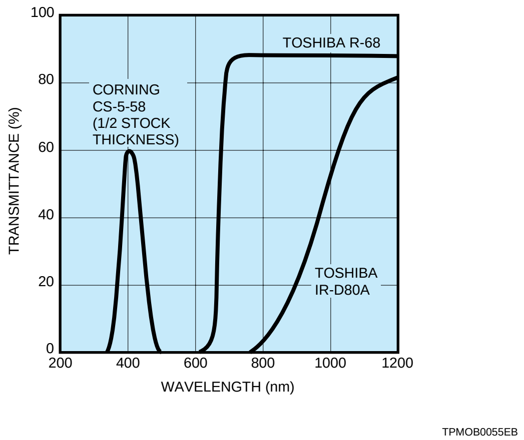
BLUE SENSITIVITY INDEX AND RED/WHITE RATIO

For simple comparison of spectral response of photomultiplier tubes, cathode blue sensitivity index and red/white ratio are often used.

The cathode blue sensitivity index is the photoelectric current from the photocathode produced by a light flux of a tungsten lamp at 2856 K passing through a blue filter (Corning CS-5-58 polished to half stock thickness). Since the light flux, once transmitted through the blue filter cannot be expressed in lumens. The blue sensitivity is an important parameter in scintillation counting using an NaI (Tl) scintillator since the NaI (Tl) scintillator produces emissions in the blue region of the spectrum, and may be the decisive factor in energy resolution.

The red/white ratio is used for photomultiplier tubes with a spectral response extending to the near infrared region. This parameter is defined as the quotient of the cathode sensitivity measured with a light flux of a tungsten lamp at 2856 K passing through a red filter (Toshiba IR-D80A for the S-1 photocathode or R-68 for others) divided by the cathode luminous sensitivity with the filter removed.

Figure 7: Transmittance of Various Filters



GAIN (CURRENT AMPLIFICATION)

Photoelectrons emitted from a photocathode are accelerated by an electric field so as to strike the first dynode and produce secondary electron emissions. These secondary electrons then impinge upon the next dynode to produce additional secondary electron emissions. Repeating this process over successive dynode stages, a high gain is achieved. A very small photoelectric current from the photocathode can be observed as a large output current from the anode of the photomultiplier tube.

Gain is simply the ratio of the anode output current to the photoelectric current from the photocathode. Ideally, the gain of a photomultiplier tube having n dynode stage and an average secondary emission ratio δ per stage is δ^n. While the secondary electron emission ratio δ is given by

$$\delta = A \cdot E^{\alpha}$$

where A is constant, E is an interstage voltage, and α is a coefficient determined by the dynode material and geometric structure. It usually has a value of 0.7 to 0.8.

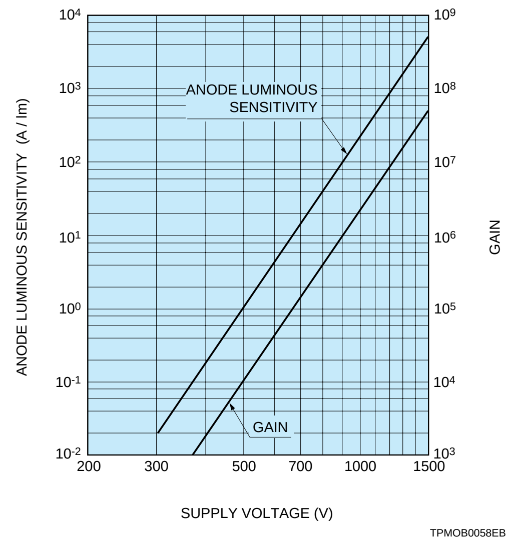
When a voltage V is applied between the cathode and the anode of a photomultiplier tube having n dynode stages, current amplification, μ, becomes

$$\mu = \delta^n = (A \cdot E^{\alpha})^n = \left\{ A \cdot \left(\frac{V}{n+1} \right)^{\alpha} \right\}^n$$

$$= \frac{A^n}{(n+1)^{\alpha n}} \cdot V^{\alpha n} = K \cdot V^{\alpha n}$$

Since photomultiplier tubes generally have 9 to 12 dynode stages, the anode output varies directly with the 6th to 10th power of the change in applied voltage. The output signal of the photomultiplier tube is extremely susceptible to fluctuations in the power supply voltage, thus the power supply must be very stable and provide minimum ripple, drift and temperature coefficient. Various types of regulated high-voltage power supplies designed with this consideration are available from Hamamatsu (see page 80).

Figure 8: Typical Gain vs. Supply Voltage

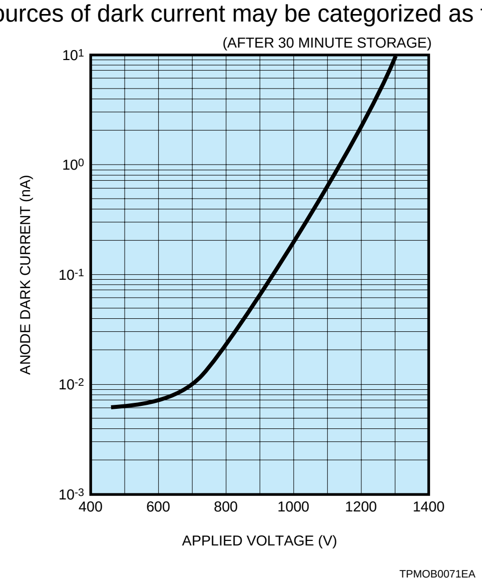


ANODE DARK CURRENT

A small amount of current flows in a photomultiplier tube even when the tube is operated in a completely dark state. This output current, called the anode dark current, and the resulting noise are critical factors in determining the detectivity of a photomultiplier tube. As Figure 9 shows, dark current is greatly dependent on the supply voltage.

Figure 9: Typical Dark Current vs. Supply Voltage

Major sources of dark current may be categorized as follows:

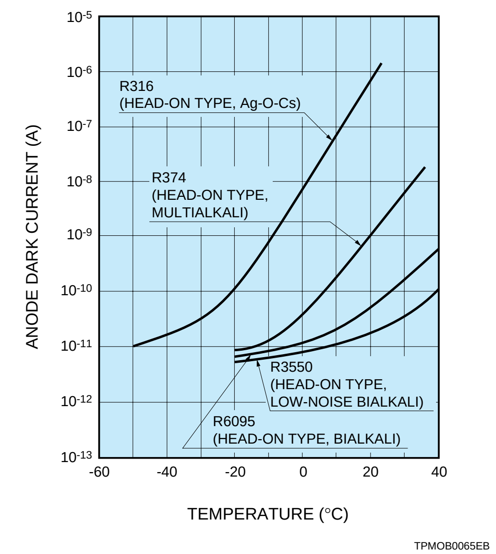


1) Thermionic emission of electrons

Since the materials of the photocathode and dynodes have very low work functions, they emit thermionic electrons even at room temperature. Most of dark currents originate from the thermionic emissions, especially those from the photocathode as they are multiplied by the dynodes. Cooling the photocathode is most effective in reducing thermionic emission and, this is particularly useful in applications where low dark counts are essential such as in photon counting.

Figure 10 shows the relationship between dark current and temperature for various photocathodes. Photocathodes which have high sensitivity in the red to infrared region, especially S-1, show higher dark current at room temperature. Hamamatsu provides thermoelectric coolers (C659 and C4877) designed for various sizes of photomultiplier tubes (see page 81).

Figure 10: Temperature Characteristics of Dark Current



2) Ionization of residual gases (ion feedback)

Residual gases inside a photomultiplier tube can be ionized by collision with electrons. When these ions strike the photocathode or earlier stages of dynodes, secondary electrons may be emitted, thus resulting in relatively large output noise pulses. These noise pulses are usually observed as afterpulses following the primary signal pulses and may be a problem in detecting light pulses. Present photomultiplier tubes are designed to minimize afterpulses.

3) Glass scintillation

When electrons deviating from their normal trajectories strike the glass envelope, scintillations may occur and dark pulses may result. To minimize this type of dark pulse, photomultiplier tubes may be operated with the anode at high voltage and the cathode at ground potential. But this is inconvenient to handle the tube. To obtain the same effect without difficulty, Hamamatsu provides "HA coating" in which the glass bulb is coated with a conductive paint connected to the cathode. (See "GROUND POLARITY AND HA COATING" on page 13.)

4) Leakage current (ohmic leakage)

Leakage current resulting from the glass stem base and socket may be another source of dark current. This is predominant when the photomultiplier tube is operated at a low voltage or low temperature. The flatter slopes in Figures 9 and 10 are mainly due to leakage current.

Contamination from dirt and moisture on the surface of the tube may increase the leakage current, and therefore should be avoided.

5) Field emission

When a photomultiplier tube is operated at a voltage near the maximum rated value, electrons may be emitted from electrodes by the strong electric field and may cause noise pulses. It is therefore recommended that the tube be operated at a voltage 20 % to 30 % lower than the maximum rating.

The anode dark current decreases with time after the tube is placed in a dark state. In this catalog, anode dark currents are measured after 30 minute storage in a dark state.

ENI (EQUIVALENT NOISE INPUT)

ENI is an indication of the photon-limited signal-to-noise ratio. It refers to the amount of light usually in watts or lumens necessary to produce a signal-to-noise ratio of unity in the output of a photomultiplier tube. ENI is expressed in units of lumens or watts. For example the value of ENI (in watts) is given by

$$ENI = \frac{\sqrt{2q \cdot Idb \cdot \mu \cdot \Delta f}}{S} \quad \text{(watts or lumens)}$$

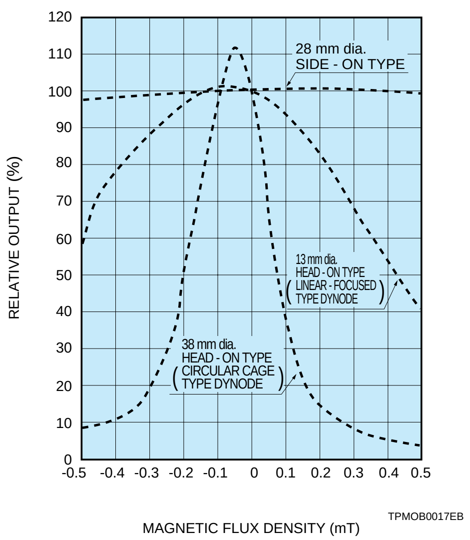
where
- q = electronic charge (1.60×10^{-19} coul.)
- Idb = anode dark current in amperes after 30 minute storage in darkness
- μ = current amplification
- Δf = bandwidth of the system in hertz (usually 1 hertz)
- S = anode radiant sensitivity in amperes per watt at the wavelength of interest or anode luminous sensitivity in amperes per lumen

For the tubes listed in this catalog, the value of ENI may be calculated by the above equation. Usually it has a value between 10^{-15} and 10^{-16} watts or lumens.

MAGNETIC FIELD EFFECTS

Most photomultiplier tubes are affected by the presence of magnetic fields. Magnetic fields may deflect electrons from their normal trajectories and cause a loss of gain. The extent of the loss of gain depends on the type of photomultiplier tube and its orientation in the magnetic field. Figure 11 shows typical effects of magnetic fields on some types of photomultiplier tubes. In general, tubes having a long path from the photocathode to the first dynode are very vulnerable to magnetic fields. Therefore head-on types, especially large diameter tubes, tend to be more adversely influenced by magnetic fields.

Figure 11: Typical Effects by Magnetic Fields Perpendicular to Tube Axis

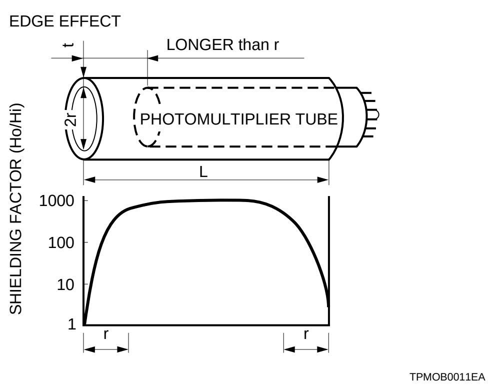


When a tube has to be operated in magnetic fields, it may be necessary to shield the tube with a magnetic shield case. Hamamatsu provides a variety of magnetic shield cases (see page 81). To express the effect of a magnetic shield case, the magnetic shielding factor is used. This is the ratio of the strength of the magnetic field outside the shield case, H_{out}, to that inside the shield case, Hin. It is determined by the permeability μ, the thickness t (mm) and inner diameter D (mm) of the shield case, as follows:

$$\frac{Hout}{Hin} = \frac{3\,\mu t}{4\,D}$$

It should be noted that the magnetic shielding effect decreases towards the edge of the shield case as shown in Figure 12. It is recommended that the tube be covered by a shield case longer than the tube length by at least half the tube diameter.

Figure 12: Edge Effect of Magnetic Shield Case



Hamamatsu provides photomultiplier tubes using fine mesh dynodes (see page 56). These tube types (see page 56) exhibit much higher immunity to external magnetic fields than the photomultiplier tubes using other dynodes. In addition, when the light level to be measured is rather high, triode or tetrode type photomultiplier tubes can be used in hishly magnetic fields.

SPATIAL UNIFORMITY

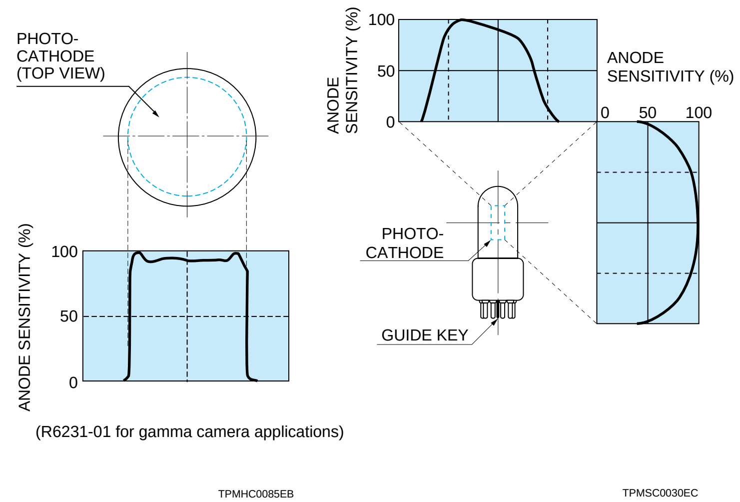
Spatial uniformity is the variation of sensitivity with position of incident light on a photocathode.

Although the focusing electrodes of a photomultiplier tube are designed so that electrons emitted from the photocathode or dynodes are collected efficiently by the first or following dynodes, some electrons may deviate from their desired trajectories in the focusing and multiplication processes, resulting in a loss of collection efficiency. This loss of collection efficiency varies with the position on the photocathode from which the photoelectrons are emitted and influences the spatial uniformity of a photomultiplier tube. The spatial uniformity is also determined by the photocathode surface uniformity itself.

In general, head-on type photomultiplier tubes provide better spatial uniformity than side-on types because of the photocathode to first dynode geometry. Tubes especially designed for gamma camera applications have excellent spatial uniformity, because uniformity is the decisive factor in the overall performance of a gamma camera.

Figure 13: Examples of Spatial Uniformity

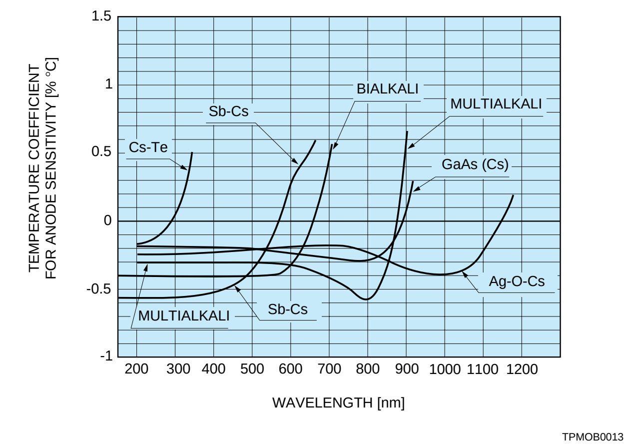
(a) Head-On Type (R6231-01 for gamma camera applications) **(b) Side-On Type** Reflection-mode photocathode



TEMPERATURE CHARACTERISTICS

By decreasing the temperature of a photomultiplier tube, dark current originating from thermionic emission can be reduced. Sensitivity of the photomultiplier tube also varies with the temperature. In the ultraviolet to visible region, the temperature coefficient of sensitivity usually has a negative value, while near the long wavelength cut-off it has a positive value. Figure 14 shows temperature coefficients vs. wavelength of typical photomultiplier tubes. Since the temperature coefficient change is large near the long wavelength cutoff, temperature control may be required in some applications.

Figure 14: Typical Temperature Coefficients of Anode Sensitivity

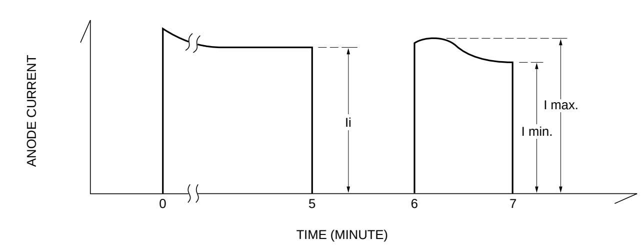


HYSTERESIS

A photomultiplier tube may exhibit an unstable output for several seconds to several tens of seconds after voltage and light are applied, i.e., output may slightly overshoot or undershoot before reaching a stable level (Figure 15). This instability is called hysteresis and may be a problem in spectrophotometry and other applications.

Hysteresis is mainly caused by electrons being deviated from their planned trajectories and electrostatically charging the dynode support ceramics and glass bulb. When the applied voltage is changed as the light input changes, marked hysteresis can occur. As a countermeasure, many Hamamatsu side-on photomultiplier tubes employ "anti-hysteresis design" which virtually eliminate hysteresis.

Figure 15: Hysteresis Measurement

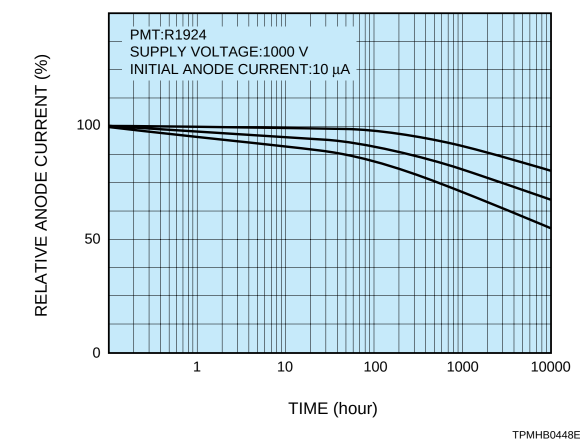


DRIFT AND LIFE CHARACTERISTIC

While operating a photomultiplier tube continuously over a long period, anode output current of the photomultiplier tube may vary slightly with time, although operating conditions have not changed. This change is reffered to as drift or in the case where the operating time is 10^3 hours to 10^4 hours it is called life characteristics. Figure 16 shows typical life characteristics.

Drift is primarily caused by damage to the last dynode by heavy electron bombardment. Therefore the use of lower anode current is desirable. When stability is of prime importance, the use of average anode current of 1 μA or less is recommended.

Figure 16: Examples of Life



TIME RESPONSE

In the measurement of pulsed light, the anode output signal should reproduce a waveform faithful to the incident pulse waveform. This reproducibility is greatly affected by the electron transit time, anode pulse rise time, and electron transit time spread (TTS).

As illustrated in Figure 17, the electron transit time is the time interval between the arrival of a delta function light pulse (pulse width less than 50 ns) at the photocathode and the instant when the anode output pulse reaches its peak amplitude. The anode pulse rise time is defined as the time required to rise from 10 % to 90 % of the peak amplitude when the whole photocathode is illuminated by a delta function light pulse (pulse width less than 50 ps). The electron transit time has a fluctuation between individual light pulses. This fluctuation is called transit time spread (TTS) and defined as the FWHM of the frequency distribution of electron transit times (Figure 18) at single photoelectron event. The TTS is an important factor in time-resolved measurement.

The time response characteristics depend on the dynode structure and applied voltage. In general, tubes of the linear-focused or circular-cage structure exhibit better time response than tubes of the box-and-grid or venetian blind structure. MCP-PMTs, which employ an MCP in place of conventional dynodes, offer better time response than tubes using other dynodes. For example, the TTS can be significantly improved compared to normal photomultiplier tubes because a nearly parallel electric field is applied between the photocathode, MCP and the anode. Figure 19 shows typical time response characteristics vs. applied voltage for types R2059 (51 mm dia. head-on, 12-stage, linear-focused type) .

Figure 17: Anode Pulse Rise Time and Electron Transit Time

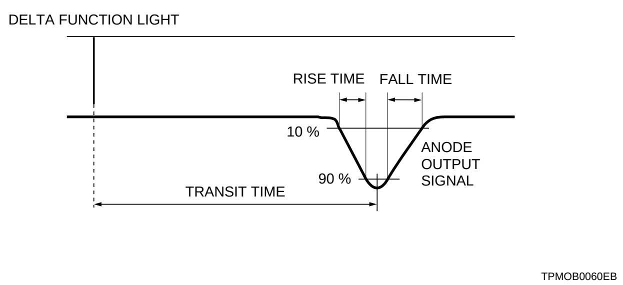


Figure 18: Electron Transit Time Spread (TTS)

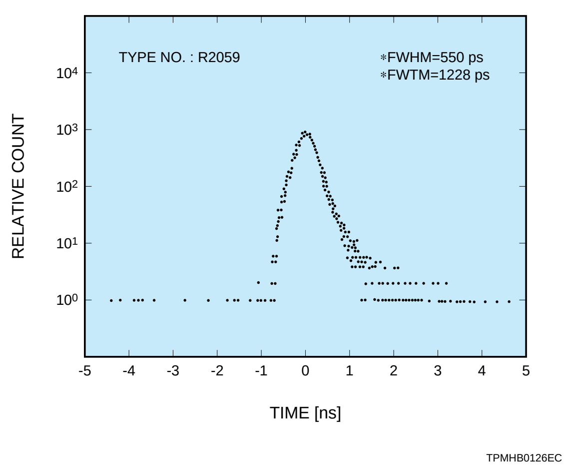
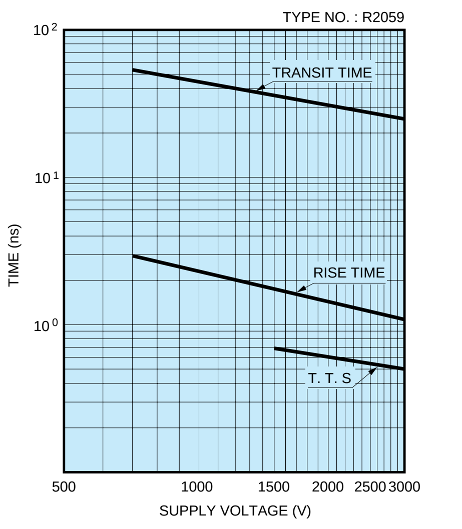


Figure 19: Time Response Characteristics vs. Supply Voltage

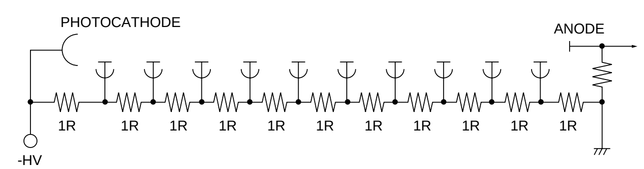


VOLTAGE-DIVIDER CONSIDERATION

Interstage voltages for the dynodes of a photomultiplier tube are usually supplied by a voltage-divider circuits consisting of series-connected resistors. Schematic diagrams of typical voltage-divider circuits are illustrated in Figure 20. Circuit (a) is a basic arrangement (DC output) and (b) is for pulse operations. Figure 21 shows the relationship between the incident light level and the average anode output current of a photomultiplier tube using the voltage-divider circuit (a). Deviation from the ideal linearity occurs at a certain incident level (region B). This is caused by an increase in dynode voltage due to the redistribution of the voltage loss between the last few stages, resulting in an apparent increase in sensitivity. As the input light level is increased, the anode output current begins to saturate near the value of the current flowing through the voltage divider (region C). Therefore, it is recommended that the voltage-divider current be maintained at least at 20 times the average anode output current required from the photomultiplier tube.

Figure 20: Schematic Diagrams of Voltage-Divider Circuits

(a) Basic arrangement for DC operation



(b) For pulse operation

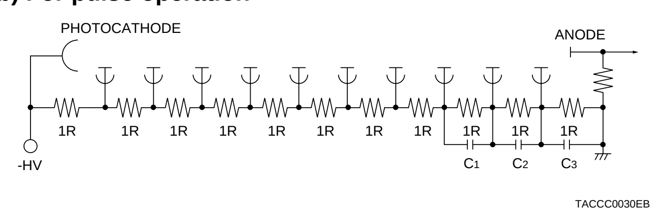
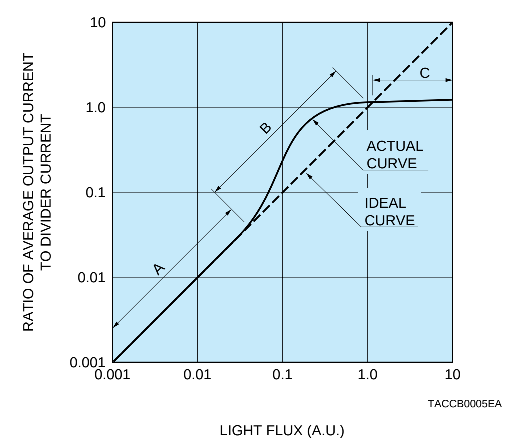


Figure 21: Output Characteristics of a PMT Using Voltage-Divider Circuit (a)



Generally high output current is required in pulsed light applications. In order to maintain dynode potentials at a constant value during pulse durations and obtain high peak currents, large capacitors are used as shown in Figure 20 (b). The capacitor values depend on the output charge. If linearity of better than 1 % is needed, the capacitor value should be at least 100 times the output charge per pulse, as follows:

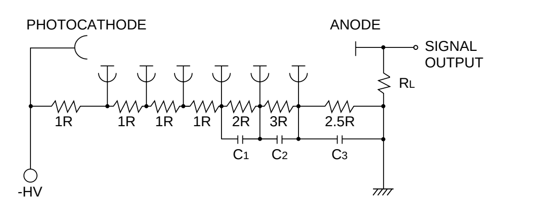
$$C > 100 \frac{I \cdot t}{V} \text{ (farads)}$$

where I is the peak output current in amperes, it is the pulse width in seconds, and V is the voltage across the capacitor in volts.

In high energy physics applications where a high pulse output is required, as the incident light is increased while the interstage voltage is kept fixed, output saturation will occur at a certain level. This is caused by an increase in the electron density between the electrodes, causing space charge effects which disturb the electron current. As a corrective action to overcome space charge effects, the voltage applied to the last few stages, where the electron density becomes high, should be set at a higher value than the standard voltage distribution so that the voltage gradient between those electrodes is enhanced. For this purpose, a so-called tapered divider circuit (Figure 22) is often employed. Use of this tapered divider circuit improves pulse linearity 5 to 10 times better than that obtained with normal divider circuits (equally divided circuits).

Hamamatsu provides a variety of socket assemblies incorporating voltage-divider circuits. They are compact, rugged, lightweight and ensure the maximum performance for a photomultiplier tube by simple wiring.

Figure 22: Tapered Divider Circuit



GROUND POLARITY AND HA COATING

The general technique used for voltage-divider circuits is to ground the anode with a high negative voltage applied to the cathode, as shown in Figure 20. This scheme facilitates the connection of such circuits as ammeters or current-to-voltage conversion operational amplifiers to the photomultiplier tube. However, when a grounded anode configuration is used, bringing a grounded metallic holder or magnetic shield case near the bulb of the tube can cause electrons to strike the inner bulb wall, resulting in the generation of noise. Also, for head-on type photomultiplier tubes, if the faceplate or bulb near the photocathode is grounded, the slight conductivity of the glass material causes a current to flow between the photocathode (which has a high negative potential) and ground. This may cause significant deterioration of the photocathode. For this reason, when designing the housing for a photomultiplier tube and when using an electrostatic or magnetic shield case, extreme care is required.

In addition, when using foam rubber or similar material to mount the tube in its housing, it is essential that material having sufficiently good insulation properties be used. This problem can be solved by applying a black conductive layer around the bulb and connecting to the cathode potential (called HA Coating), as shown in Figure 23.

As mentioned above, the HA coating can be effectively used to eliminate the effects of external potential on the side of the bulb. However, if a grounded object is located on the photocathode faceplate, there are no effective countermeasures. Glass scintillation, if it occurrs in the faceplate, has a larger influence on the noise. It also causes deterioration of the photocathode sensitivity and, once deteriorated, the sensitivity will never recover to the original level. To solve these problems, it is recommended that the photomultiplier tube be operated in the cathode ground scheme, as shown in Figure 24, with the anode at a positive high voltage. For example, in scintillation counting, since the grounded scintillator is directly coupled to the photomultiplier tube, it is recommended that the cathode be grounded, with a high positive voltage applied to the anode. Using this scheme, a coupling capacitor Cc is used to separate the high positive voltage applied to the anode from the signal, making it impossible to obtain a DC signal output.

Figure 23: HA Coating

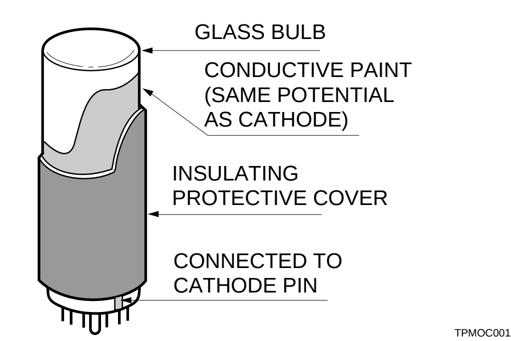
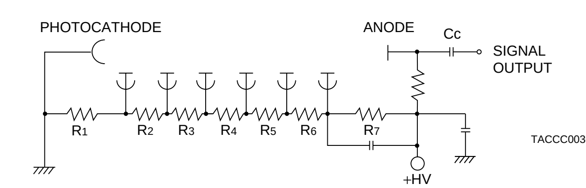


Figure 24: Cathode Ground Scheme



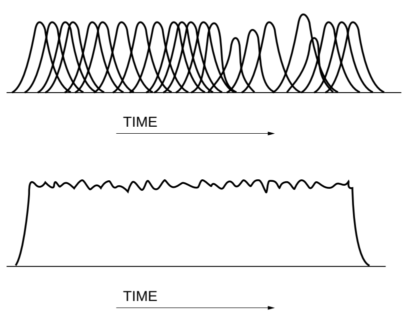
SINGLE PHOTON COUNTING

Photon counting is one effective way to use a photomultiplier tube for measuring very low light levels. It is widely used in astronomical photometry and chemiluminescence or bioluminescence measurement. In the usual application, a number of photons enter the photomultiplier tube and create an output pulse train like (a) in Figure 25. The actual output obtained by the measurement circuit is a DC current with a fluctuation as shown at (b).

Figure 25: Overlapping Output Pulses

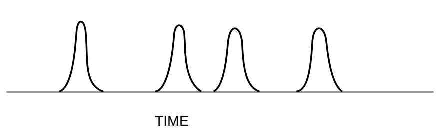
(a)

(b)



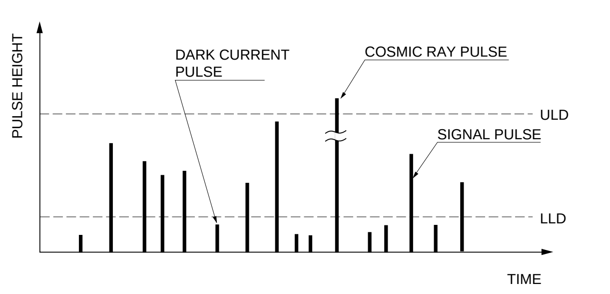
When the light intensity becomes so low that the incident photons are separated as shown in Figure 26. This condition is called a single photon (or photoelectron) event. The number of output pulses is in direct proportion to the amount of incident light and this pulse counting method has advantages in S/N ratio and stability over the DC method averaging all the pulses. This pulse counting technique is known as the photon counting method.

Figure 26: Discrete Output Pulses (Single Photon Event)



Since the photomultiplier tube output contains a variety of noise pulses in addition to the signal pulses representing photoelectrons as shown in Figure 27, simply counting the pulses without some form of noise elimination will not result in an accurate measurement. The most effective approach to noise elimination is to investigate the height of the output pulses.

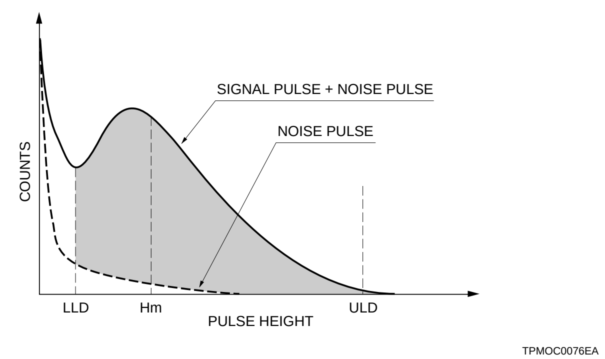
Figure 27: Output Pulse and Discrimination Level



A typical pulse height distribution (PHD) for the output of photomultiplier tubes is shown in Figure 28. In this PHD, the lower level discrimination (LLD) is set at the valley trough and the upper level discrimination (ULD) at the foot where the output pulses are very few. Most pulses smaller than the LLD are noise and pulses larger than the ULD result from cosmic rays, etc. Therefore, by counting pulses between the LLD and ULD, accurate light measurements becomes possible. In the PHD, Hm is the mean height of the pulses. It is recommended that the LLD be set at 1/3 of Hm and the ULD at triple Hm. In most cases, however, the ULD setting can be omitted.

Considering the above, a clear definition of the peak and valley in the PHD is a very significant characteristic for photomultiplier tubes for use in photon counting.

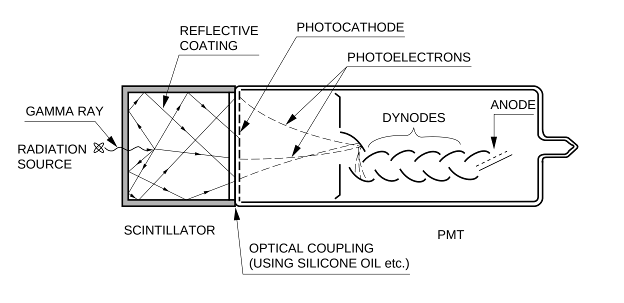
Figure 28: Typical Pulse Height Distribution



SCINTILLATION COUNTING

Scintillation counting is one of the most sensitive and effective methods for detecting radiation. It uses a photomultiplier tube coupled to a transparent crystal called scintillator which produces light by incidence of radiation.

Figure 29: Diagram of Scintillation Detector



In radiation measurements, there are two parameters that should be measured. One is the energy of individual particles and the other is the amount of particles. Radiation measurements should determine these two parameters.

When radiation enters the scintillator, it produce light flashes in response to each particle. The amount of flash is proportional to the energy of the incident racliation. The photomultiplier tube detects individual light flashes and provides the output pulses which contain information on both the energy and amount of pulses, as shown in Figure 30. By analyzing these output pulses using a multichannel analyzer (MCA), a pulse height distribution (PHD) or energy spectrum is obtained, and the amount of incident particles at various energy levels can be measured accurately. Figure 31 shows typical PHDs or energy spectra when gamma rays (^{55}Fe, ^{137}Cs, ^{60}Co) are detected by the combination of an NaI(Tl) scintillator and a photomultiplier tube. For the PHD, it is very important to have distinct peaks at each energy level. This is evaluated as pulse height resolution (energy resolution) and is the most significant characteristic in radiation particle measurements. Figure 32 shows the definition of energy resolution taken with a ^{137}Cs source.

Figure 30: Incident Particles and PMT Output

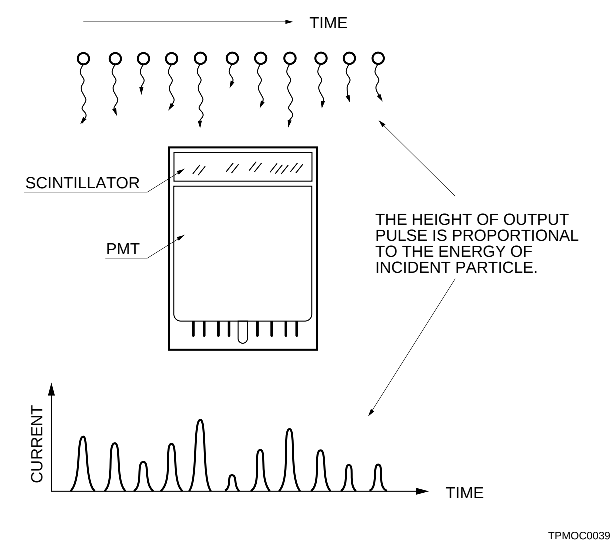
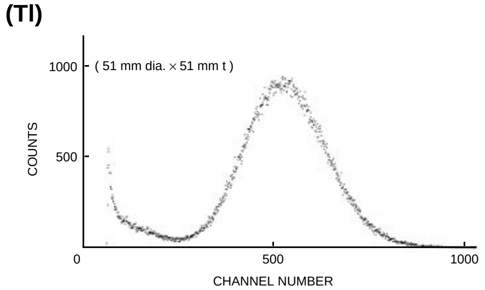
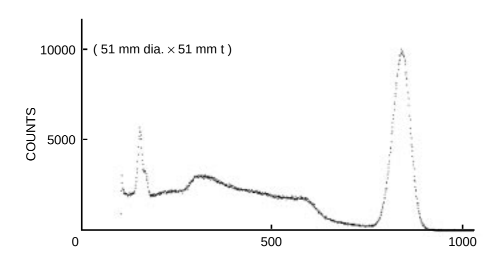


Figure 31: Typical Pulse Height Distributions (Energy Spectra)

a) ^{55}Fe+NaI (Tl)



b) ^{137}Cs+NaI (Tl)



c) ^{60}Co+NaI (Tl)

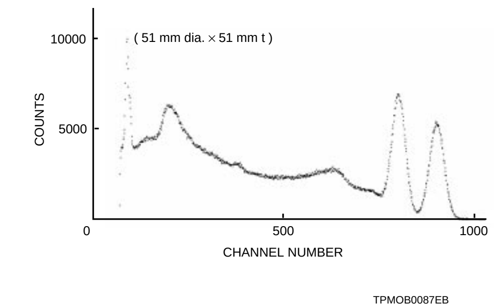


Figure 32: Definition of Energy Resolution

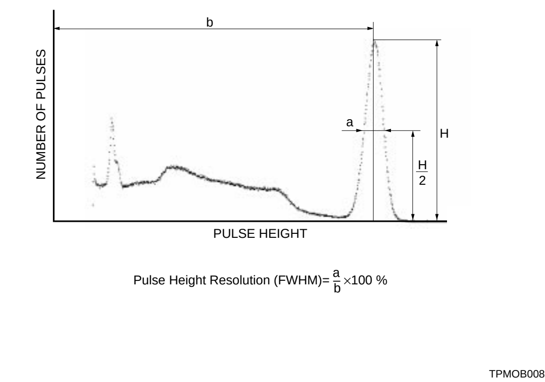
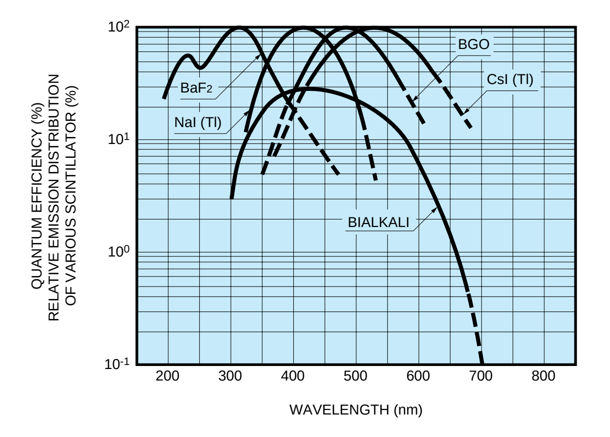


Figure 33: Spectral Response of PMT and Spectral Emission of Scintillators



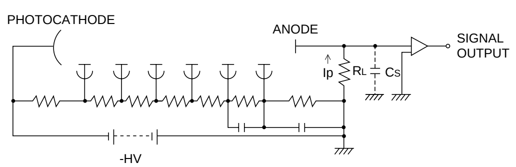
Pulse height resolution is mainly determined by the quantum efficiency of the photomultiplier tube in response to the scintillator emission. It is necessary to choose a tube whose spectral response matches with the scintillator emission. In the case of thallium-activated sodium iodide, or NaI(Tl), which is the most popular scintillator, head-on type photomultiplier tube with a bialkali photocathode is widely used.

Connections to External Circuits

LOAD RESISTANCE

Since the output of a photomultiplier tube is a current signal and the type of external circuit to which photomultiplier tubes are usually connected has voltage inputs, a load resistance is used to perform a current-voltage transformation. This section describes considerations to be made when selecting this load resistance. Since for low output current levels, the photomultiplier tube may be assumed to act as virtually an ideal constant-current source, the load resistance can be made arbitrarily large, thus converting a low-level current output to a high-level voltage output. In practice, however, using very large values of load resistance creates the problems of deterioration of frequency response and output linearity described below.

Figure 34: PMT Output Circuit

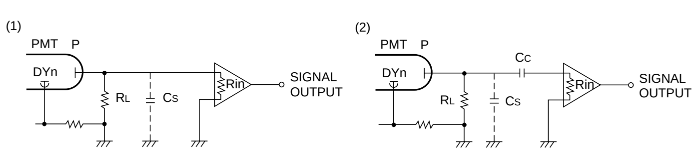


If, in the circuit of Figure 34, we let the load resistance be R_L and the total of the capacitance of the photomultiplier tube anode to all other electrodes, including such stray capacitance as wiring capacitances be C_s, the cutoff frequency f_c is expressed by the following relationship.

$$f_c = \frac{1}{2\pi C_s \cdot R_L}$$

From this relationship, it can be seen that, even if the photomultiplier tube and amplifier have very fast response, response will be limited to the cutoff frequency f_c of the output circuit. If the load resistance is made large, at high current levels the voltage drop across R_L becomes large, affecting a potential difference between the last dynode stage and the anode. As a result, a loss of output linearity (output current linearity with respect to incident light level) may occur.

Figure 35: Amplifier Internal Resistance



In Figure 35, let us consider the effect of the internal resistance of the amplifier. If the load resistance is R_L and the input impedance of the amplifier is R_{in}, the combined parallel output resistance of the photomultiplier tube, R_o, is given by the following equation.

$$R_o = \frac{R_L \cdot R_{in}}{R_L + R_{in}}$$

This value of R_o, which is less than the value of R_L, is then the effective load resistance of the photomultiplier tube. If, for example, $R_L = R_{in}$, the effective load resistance is 1/2 that of R_L alone. From this we see that the upper limit of the load resistance is actually the input resistance of the amplifier and that making the load resistance much greater than this value does not have significant effect. While the above description assumed the load and input impedances to be purely resistive, in practice, stray capacitances, input capacitance and stray inductances influence phase relationships. Therefore, as frequency is increased, these circuit elements must be considered as compound impedances rather than pure resistances.

From the above, three guides can be derived for use in selection of the load resistance:

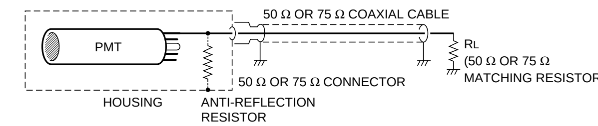
1) In cases in which frequency response is important, the load resistance should be made as small as possible.
2) In cases in which output linearity is important, the load resistance should be chosen such that the output voltage is below several volts.
3) The load resistance should be less than the approximate input impedance of the external amplifier.

HIGH-SPEED OUTPUT CIRCUIT

For the detection of high-speed and pulsed light signals, a coaxial cable is used to make the connection between the photomultiplier tube and the electronic circuit, as shown in Figure 36. Since commonly used cables have characteristic impedances of 50 Ω or 75 Ω, this cable must be terminated in a pure resistance equivalent to the characteristic impedance to provide impedance matching and ensure distortion-free transmission for the signal waveform. If a matched transmission line is used, the impedance of the cable as seen by the photomultiplier tube output will be the characteristic impedance of the cable, regardless of the cable length, and no distortion will occur in signal waveforms.
If proper matching at the signal receiving end is not achieved, the impedance seen at the photomultiplier tube output will be a function of both frequency and cable length, resulting in significant waveform distortion. Such mismatched conditions can be caused by the connectors used as well, so that the connector to be used should be chosen with regard given to the frequency range to be used, to provide a match to the coaxial cable.

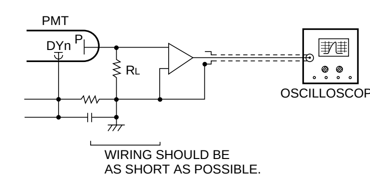
When a mismatch at the signal receiving end occurs, all of the pulse energy from the photomultiplier tube is not dissipated at the receiving end, but is partially reflected back to the photomultiplier tube via the cable. While this reflected energy will be fully dissipated at the photomultiplier tube when an impedance match has been achieved at the tube, if this is not the case, because the photomultiplier tube itself acts as an open circuit, the energy will be reflected and, thus returned to the signal-receiving end. Since part of the pulse makes a round trip in the coaxial cable and is again input to the receiving end, this reflected signal is delayed with respect to the main pulse and results in waveform distortion (so called ringing phenomenon). To prevent this phenomenon, in addition to providing impedance matching at the receiving end, it is necessary to provide a resistance matched to the cable impedance at the photomultiplier tube end as well. If this is done, it is possible to virtually eliminate the ringing caused by an impedance mismatch, although the output pulse height of the photomultiplier tube is reduced to one-half of the normal level by use of this impedance matching resistor.

Figure 36: Typical Connections Used to Prevent Ringing



Next, let us consider waveform observation of high-speed pulses using an oscilloscope (Figure 37). This type of operation requires a low load resistance. Since, however, there is a limit to the oscilloscope sensitivity, an amplifier may be required.
For cables to which a matching resistor has been connected, there is an advantage that the cable length does not affect the characteristics of the cable. However, since the matching resistance is very low compared to the usual load resistance, the output voltage becomes too small. While this situation can be remedied with an amplifier of high gain, the inherent noise of such an amplifier can itself be detrimental to measurement performance. In such cases, the photomultiplier tube can be brought as close as possible to the amplifier and a load resistance as large as possible should be used (consistent with preservation of frequency response), to achieve the desired input voltage.

Figure 37: With Ringing Suppression Measures



It is relatively simple to implement a high-speed amplifier using a wide-band video amplifier or operational amplifier. However, in exchange of design convenience, use of these ICs tends to create problems related to performance (such as noise). It is therefore necessary to know their performance limit and take corrective action.

As the pulse repetition frequency increases, baseline shift creates one reason for concern. This occurs because the DC signal component has been eliminated from the signal circuit by coupling with a capacitor which does not pass DC components. If this occurs, the reference zero level observed at the last dynode stage is not the actual zero level. Instead, the apparent zero level is the time-average of the positive and negative fluctuations of the signal waveform. This will vary as a function of the pulse density, and is known as baseline shift. Since the height of the pulses above this baseline level is influenced by the repetition frequency, this phenomenon is of concern when observing waveforms or discriminating pulse levels.

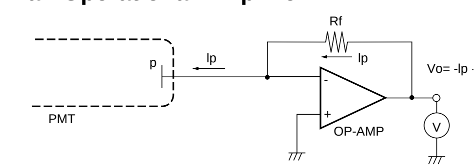
OPERATIONAL AMPLIFIERS

In cases in which a high-sensitivity ammeter is not available, the use of an operational amplifier will enable measurements to be made using an inexpensive voltmeter. This technique relies on converting the output current of the photomultiplier tube to a voltage signal. The basic circuit is as shown in Figure 38, for which the output voltage, V_o, is given by the following relationship.

$$V_o = -R_f \cdot I_p$$

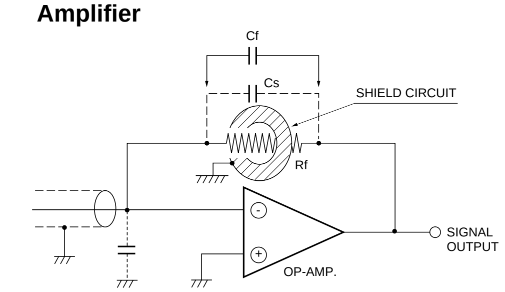
This relationship is derived for the following reason. If the input impedance of the operational amplifier is extremely large, and the output current of the photomultiplier tube is allowed to flow into the input terminal of the amplifier, most of the current will flow through R_f and subsequently to the operational amplifier output circuit. Therefore, the output voltage V_o is given by the expression $-R_f \times I_p$. When using such an operational amplifier, it is of course, not possible to increase the output voltage without limit, the actual maximum output being approximately equal to the operational amplifier power supply voltage. At the other end of the scale, for extremely small currents, limitations are placed by the operational amplifier offset current (I_{os}), the quality of R_f, and other factors such as the insulation materials used.

Figure 38: Current-Voltage Transformation Using an Operational Amplifier



If the operational amplifier has an offset current (I_{os}), the above-described output voltage becomes $V_o = -R_f (I_p + I_{os})$, the offset current component being superimposed on the output. Furthermore, the magnitude of temperature drift may create a problem. In general, a metallic film resistor which has a low temperature coefficient is used for the resistance R_f, and for high resistance values, a vacuum-sealed type is used. Carbon resistors, with their highly temperature-dependent resistance characteristics, are not suitable for this application. When measuring such extremely low level currents as 100 pA and below, in addition to the considerations described above, the materials used in the circuit implementation require care as well. For example, materials such as bakelite are not suitable, and more suitable materials are Teflon, polystyrol or steatite. In addition, low-noise cables should be used, since general-purpose coaxial cables exhibit noise due to mechanical changes. In the measurement of these low level currents, use of an FET input operational amplifier is recommended.

Figure 39: Frequency Compensation of an Operational Amplifier



In Figure 39, if a capacitance C_f (including any stray capacitance) exists in parallel to the resistance R_f, the circuit exhibits a time constant of ($R_f \times C_f$), so that response speed is limited to this time constant. This is a particular problem if R_f is large. Stray capacitance can be reduced by passing R_f through a hole in a shield plate. When using coaxial signal input cables, since the cable capacitance C_c and R_f are in the feedback loop, oscillations may occur and noise may be amplified. While the method of avoiding this is to connect C_f in parallel to R_f, to reduce gain at high frequencies, as described above, this creates a time constant of $R_f \times C_f$ which limits the response speed.

Selection Guide by Application

Applications	Required Major Characteristics	Applicable PMT
Spectroscopy		
Equipment Utilizing Absorption		
UV/Visible/IR Spectrophotometer When light passes through a substance, the light energy causes changes in the electron energy of the substance, resulting in partial energy loss. This is called absorption and gives analytical data. In order to determine the amount of the sample substance, it is irradiated while the light wavelength is scanned continuously. The spectral intensities of the light before and after passing through the sample are detected by a photomultiplier tube to measure the amount of absorption.	1) Wide spectral response 2) High stability 3) Low dark current 4) High quantum efficiency 5) Low hysteresis 6) Good polarization characteristic	R6356, R6357 R928, R955, R1477, R3896 R1463 R374, R376
Atomic Absorption Spectrophotometer This is widely used in the analysis of minute quantities of metallic elements. For each element to be analyzed, a special elementary hollow cathode lamp is used to irradiate a sample which is burned for atomization. A photomultiplier tube detects the light passing through the sample to measure the amount of absorption, which is compared with a reference sample measured in advance.		R928 R955
Equipment Utilizing Emission		
Photoelectric Emission Spectrophotometer When an external energy is applied to a sample, light emission occurs from the sample. By dispersing this emission using a monochromator, into characteristic spectral lines of elements and measuring their presence and intensity simultaneously with photomultiplier tubes, this equipment enables rapid qualitative and quantitative analysis of the elements contained in the sample.	1) High sensitivity 2) Low dark current 3) High stability	R6350, R6351, R6352 R6354, R6355, R6356, R7311 1P28, R106, R212, R4220 R759,
Fluorescence Spectrophotometer The fluorescence spectrophotometer is used in biological science, particularly in molecular biology. When an excitation light is applied, some substances emit light with a wavelength longer than that of the excitation light. This light is known as fluorescence. The intensity and spectral characteristics of the fluorescence are measured by a photomultiplier tube, and the substance is analyzed qualitatively and quantitatively.		R6353, R6358 R3788, R4220, R1527 R928
Raman Spectrophotometer When monochromatic light strikes a substance and scatters, Raman scattering also occurs at a different wavelength from the excitation light. Since the wavelength difference is a characteristic of the molecules, the spectral measurement of Raman scattering provides qualitative and quantitative data of the molecules. Raman scattering is extremely weak and a sophisticated optical system is used for measurement, thus the photomultiplier tube is operated in the photon counting mode.	1) High quantum efficiency 2) Low dark current 3) Single photon discrimination ability	R2949 R1463P, R649 R943-02
Others • Liquid or Gas Chromatography • X-Ray Diffractometer, X-Ray Fluorescence Analyzer • Electron Microscope		R3788 R647-01, R1166, R6095, R580 R647

Applications	Required Major Characteristics	Applicable PMT
Mass Spectroscopy and Solid Surface Analysis		
Solid Surface Analysis The composition and structure of a solid surface can be studied by irradiating a narrow beam of electrons, ions, light or X-rays onto the surface and measuring the secondary electrons, ions or X-rays that are produced. With the progress of the semiconductor industry, this kind of technology becomes essential in evaluating semiconductors, including defects, surface analysis, adhesion, and density profile. Electrons, ions, and X-rays are measured with electron multipliers and MCPs.	1) High environmental resistance 2) High stability 3) High current amplification 4) Low dark current	R474, R515, R596, R595 R2362, R5150-10
Environment Monitoring		
Dust Counter A dust counter measures the density of dust or particles floating in the atmosphere or inside rooms. It makes use of light scattering or absorption of beta-rays by particles.	1) Low dark noise 2) Low spike noise 3) High quantum efficiency	R6350 R105, R3788 R647-01
Turbidimeter When floating particles are contained in a liquid, light incident on the liquid is absorbed, scattered or refracted by these particles. It looks cloudy or hazy to the human eye. A turbidimeter is a device that numerically measures the turbidity by using light transmission and scattering.	1) Low dark current 2) Low spike noise 3) High quantum efficiency	R6350 R105 R1924
Others • NOx meters, SOx meters	1) High quantum efficiency at wavelength of interest 2) Low dark current 3) Good temperature characteristic 4) High stability	NOx= R928 R374, R2228, R5959 R5070 SOx= R6095, R3788, R1527 R2693
Biotechnology		
Cell Sorter The cell sorter is an instrument that selects and collects only specific cells using a fluorescent substance for labeling. The labeled cells are irradiated by laser beam, and a photomultiplier tube is used to detect the resulting fluorescence or scattering.	1) High quantum efficiency 2) High stability 3) Low dark current 4) High current amplification 5) Good polarization characteristic	R6353, R6357, R6358 R928, R1477, R3788, R3896 R2368
Fluorometer While the ultimate purpose of the cell sorter is to separate cells, the fluorometer is used to analyze cells and chemical substances by measuring the fluorescence or scattered light from a cell or chromosome with regard to such factors as fluorescence spectrum, fluorescence quantum efficiency, fluorescence anisotropy (polarization) and fluorescence lifetime.		

Applications	Required Major Characteristics	Applicable PMT
Medical Applications		
Gamma Camera The gamma camera takes an image of a radioisotope-labeled reagent injected into the body of a patient to locate abnormalities. This equipment starts from a scintillation scanner and has been gradually improved. Its detection section uses a large diameter NaI(Tl) scintillator and light-guide coupled to an array of photomultiplier tubes.	1) High energy resolution 2) Good uniformity 3) High stability 4) Uniform current amplification	R6231-01 R6234-01 R6235-01 R6236-01 R1307-01 R6233-01 R6237-01
Positron CT The positron CT provides tomographic images by detecting coincident gamma-ray emission accompanying annihilation of a positron emitted from a tracer radioisotope (^{11}C, ^{15}O, ^{13}N, ^{18}F, etc.) injected into the body. Photomultiplier tubes coupled to scintillators are used to detect these gamma-rays.	1) High energy resolution 2) High stability 3) High speed response 4) Compact size	R1635, R5900U-00-C8 R1450 R5800 R1548 R6427
Liquid Scintillation Counter Liquid scintillation counters are used for tracer analysis in age measurement and biochemical research. A sample containing radioisotopes is dissolved in a solution containing an organic scintillator, and it is placed in the center between a pair of photomultiplier tubes. These tubes simultaneously detect the emission of the organic scintillator.	1) High quantum efficiency 2) Low noise of thermionic emission 3) Less glass scintillation at the faceplate and bulb 4) Fast response time 5) High pulse linearity	R331, R331-05
In-Vitro Assay In-vitro assay is used for physical checkups, diagnosis, and evaluation of drug potency by making use of specificity of the antigen/antibody reaction characteristics of tiny amounts of insulin, hormones, drugs and viruses which are contained in blood or urine. Photomultiplier tubes are used to measure optically the amount of antigens labeled by radioisotopes, enzymes, fluorescent chemiluminescent or bioluminescent substances. • Radioimmunoassay (RIA) Uses radioactive isotopes for labeling.	1) High quantum efficiency 2) High stability 3) Low dark current	R647 R1166, R5611-01 R1924
• Enzymeimmunoassay (EIA) Uses enzymes for labeling and measures resulting chemiluminescence or bioluminescence. • Fluoroimmunoassay/chemiluminescent imunoassay Uses fluorescent or chemiluminescent substances for labeling.		R6350, R6352, R6353 R6356, R6357 R4220, R928, R3788 R647, R1463 R1925 R6095, R374
Others • X-ray phototimer In X-ray examination, this equipment automatically controls the exposure to an X-ray film. The X-ray transmitting through a subject is converted into visible light by a phosphor screen. A photomultiplier tube is used to detect this light and provide an electrical signal. When the accumulated electrical signal reaches a preset level, X-ray irradiation is shut off, making it possible to obtain an optimum film density.	1) High sensitivity 2) Low dark current 3) High stability	R6350 931A, R105

Applications	Required Major Characteristics	Applicable PMT
Radiation Measurement		
Area Monitor The area monitor is designed to continuously measure a change in environmental radiation levels. It uses a photomultiplier tube coupled to a scintillator, to monitor low-level alpha ray or gamma ray.	1) Long term stability 2) Low background noise 3) Good plateau characteristic	R1306, R6231 R329-02, R4607-01 R1307, R6233 R877, R877-01
Survey Meter The survey meter measures low-level gamma ray or beta ray using a photomultipliter tube coupled to a scintillator.	1) Long term stability 2) Low background noise 3) Good plateau characteristic	R1635 R647 R1924 R6095
Resource Inquiry		
Oil Well Logging Oil well logging is used to locate an oil deposit and determine its size. A probe containing a radiation source and a scintillator/photomultiplier tube is lowered into an oil well as it is being drilled. The scattered radiation or natural radiation from the geological formation are detected and analyzed, to determine the type and density of the rock that surrounds the well.	1) Stable operation at high temperature up to 175 °C 2) Rugged structure 3) Good plateau characteristic	R4177-01, R1281 R3991 R1288, R1288-01
Industrial Measurement		
Thickness Meter Using a radiation source and a scintillator/photomultiplier tube, a product thickness can be measured on factory production lines for paper, plastic, steel sheet, etc. Beta-rays are used as a radiation source in measurement of products with a small density, such as rubber, plastic, and paper. Gamma-rays are used for products with a large density, like steel sheet. (X-ray fluorescence spectrometers are used in measurement of film thickness for plating, evaporation, etc.)	1) Wide dynamic range 2) High energy resolution	R647-01, R5800 R6095 R580 R1306, R6231 R329-02
Semiconductor Inspection System This is widely used for semiconductor wafer inspection and pattern recognition such as semiconductor mask alignment. For wafer inspection, the wafer is scanned by a laser beam, and scattered light caused by dirt or defects is detected by a photomultiplier tube.	1) High quantum efficiency at wavelength of interest 2) Good uniformity 3) Low spike noise	R928, R1477, R3896 R647, R1463
Photography and Printing		
Color Scanner To prepare color pictures and photographs for printing, the color scanner is used to separate the original colors into the three primary colors (RGB) and black. It uses photomultiplier tubes combined with RGB filters, and provides color separation as image data.	1) High quantum efficiency at wavelengthes of RGB 2) Low dark noise 3) Fast fall time 4) High stability 5) Good repeatability with change in input signal	R3788 R3810, R3811 R647, R1463 R1924, R1925

High Energy Physics

Collision Experiment

Applications	Required Major Characteristics	Applicable PMT
Hodoscope Photomuliplier tuubes are coupled to the ends of long, thin plastic scintillators arranged orthogonally in two layers. They measure the time and position at which charged particles pass through the scintillators.	1) Fast time response 2) Compact size 3) Immunity to magnetic fields	R1635 (H3164-10) R647-01 (H3165-10) R1450 (H6524) R1166 (H6520)
TOF Counter TOF counters consisting of plastic scintillators and photomultiplier tubes are arranged along paths of secondary particles which are generated by collision reactions. Velocities of these particles are measured by time differences between collision time and detection times.		R5800 R1635 (H3164-10) R1450 (H6524) R4998 (H6533), R5505 (H6152-01) R1828-01 (H1949-51), R2083 (H2431-50) R5924 (H6614-01)
Cherenkov Counter A Cherenkov counter identifies secondary particles which generated by collision reactions. Cherenkov lights emitted from a charged particle which has energy more than a constant level and goes through a radiator like gas or silicon aerogel are detected. A velocity of a charged particle is mesured by an angle of its cherenkov lights.	1) High Quantum efficiency 2) Good single photon defectivity 3) High current amplification 4) Fast time response 5) Immunity to magnetic fields	R2256-02 (H6521) R5113-02 (H6522) R2059 (H3177-51) R1584 (H6528) R5924 (R6614-01)
Calorimeter The calorimeter measures the accurate direction and energy of secondary particles emitted from the collision reaction of electrons and positrons.	1) High pulse linearity 2) High energy resolution 3) High stability 4) Immunity to magnetic fields	R580 (H3178-51) R329-02 (H6410) R5924 (H6614-01) R6091 (H6559)

Neutrino and Proton Decay Experiment, Cosmic Ray Detection

Applications	Required Major Characteristics	Applicable PMT
Neutrino Experiment A research of solar neutrinos or particle astrophysics is performed in a neutrino experiment. Its observation system consists of a large size radiator surrounded by a number of large-diameter photomultiplier tubes. Cherenkov light which occurs from interactions of neutrinos or other particles and a radiator are detected. The directions and energies of the particles are measured.	1) Large photocathode area 2) Fast Time Response 3) High stability 4) Low dark count	R5912 R3600-02 (R3600-06)
Neutrino and Proton Decay Experiment In the neutrino and proton decay experiment which is performed at KAMIOKA in Japan, 11200 of 20 " dimeter photomultiplier tubes are set covering all directions of a huge tank storing around 50000 t of pure water. Cherenkov light emitted by solar neutrino or proton decay are measured.		
Air Shower Counter When cosmic rays collide with the earth's atmosphere, secondary particles are created by the interaction of the cosmic rays and atmospheric atoms. These secondary particles generate more secondary particles, which continue to increase in a geometrical progression. This is called an air shower. The gamma rays and Cherenkov light emitted in this air shower is detected by photomultiplier tubes lined up in a lattice array on the ground.		R1166 (H6520) R580 (H3178-51) R329-02 (H6410) R1828-01 (H1949-51) R6091 (H6559) R1250 (H6527)

The assembly type is given in parentheses.

Aerospace

Applications	Required Major Characteristics	Applicable PMT
Measurement of X-rays from Outer Space X-rays from outer space include information on the enigmas of space. As an example, the X-ray observation satellite "Asuka", developed by a group of the ISAS (Institute of Space and Astronomical Science - Japan), uses a gas-scintillation proportional counter coupled to a position-sensitive photomultiplier tube, to measure X-rays from supernovas, etc.	1) High energy resolution 2) Rugged structure	R2486
Measurement of Scattered Light from Fixed Stars and Interstellar Dust Ultraviolet rays from space contain a lot of information about the surface temperature of the stars and interstellar substances. However, these ultraviolet rays are absorbed by the earth's atmosphere, so it is impossible to measure them from the earth surface. Photomultiplier tubes are mounted in rockets or artificial satellites, to measure ultraviolet rays with wavelengthes shorter than 300 nm.	1) Rugged structure 2) Sensitivity in VUV to UV range (solar blind response: see page 4 for Cs-Te, Cs-I photocathodes)	R1080, R976 R6834, R6835, R6836

Lasers

Applications	Required Major Characteristics	Applicable PMT
Laser Radar The laser radar is used in such applications as atmospheric measurement which uses a highly-accurate range finding or aerosol scattering.	1) Fast response time 2) Low dark count 3) High current amplification	R3809U Series, R5916U Series R3234-01, R3237-01
Fluorescence Lifetime Measurement The laser is used as an excitation light for fluorescence lifetime measurement. The molecular structure of a substance can be studied by measuring temporal intensity changes in the emitted fluorescence.		R3809U Series, R5916U Series

Plasma

Applications	Required Major Characteristics	Applicable PMT
Plasma Measurement Photomultiplier tubes are being used in the electron density and electron temperature measurement system for plasma in the Tokamak-type nuclear fusion test reactor in Japan. Photomultiplier tubes and MCPs are also used in similar measurements for plasma using Thompson scattering and the Doppler effect, in observation of spatial distribution of plasma, and in measurements of impurities in plasma for the purpose of impurity and ion control.	1) High detectivity at low light level 2) High quantum efficiency 3) Gate operation	R636-10 R943-02

Side On Type Photomultiplier Tubes

(at 25 °C)

13 mm (1/2 ") Dia. Types

Ⓐ Type No.	Remarks	Spectral Response: Ⓑ Curve Code	Spectral Response: Range (nm)	Spectral Response: Peak Wave-length (nm)	Ⓒ Photo-cathode Material	Ⓓ Window Material	Ⓔ Out-line No.	Ⓕ Dynode Structure / No. of Stages	Ⓖ Socket / Socket Assembly	Ⓗ Maximum Ratings: Anode to Cathode Voltage (Vdc)	Maximum Ratings: Ⓙ Average Anode Current (mA)	Cathode Sensitivity: Luminous Min. (μ A/lm)	Cathode Sensitivity: Luminous Typ. (μ A/lm)
R6350	For UV to visible range, general purpose	350U (S-5)	185 to 650	340	Sb-Cs	U	1	CC/9	E678-11U*/1	1250	0.01	20	40
R6351	Fused silica window type of R6350	350S	160 to 650	340	Sb-Cs	Q	2	CC/9	E678-11U*/1	1250	0.01	20	40
R6352	High sensitivity variant of R6350	452U	185 to 750	420	BA	U	1	CC/9	E678-11U*/1	1250	0.01	80	120
R6353	Low dark current bialkali photo-cathode	456U	185 to 680	400	LBA	U	1	CC/9	E678-11U*/1	1250	0.01	30	70
R6355	For UV to near IR range, general purpose	550U	185 to 850	530	MA	U	1	CC/9	E678-11U*/1	1250	0.01	80	150
R6356	High sensitivity variant of R6355	560U	185 to 900	600	MA	U	1	CC/9	E678-11U*/1	1250	0.01	140	250
R6357	High sensitivity variant of R6356, Meshless type	–	185 to 900	450	MA	U	3	CC/9	E678-11U*/1	1250	0.01	350	500
R6358	Low dark current multialkali photo-cathode	561U	185 to 830	530	MA	U	1	CC/9	E678-11U*/1	1250	0.01	140	200

Cathode Sensitivity: Blue Sensitivity Index (CS 5-58) Typ.	Red / White Ratio Typ.	Ⓚ Radiant Typ. (mA/W)	Ⓛ Anode to Cathode Supply Voltage (Vdc)	Ⓜ Anode Characteristics: Anode Sensitivity Luminous Min. (A/lm)	Luminous Typ. (A/lm)	Radiant Typ. (A/W)	Gain Typ.	Anode Dark Current (After 30 min.) Typ. (nA)	Anode Dark Current Max. (nA)	Time Response: Rise Time Typ. (ns)	Electron Transit Time Typ. (ns)	Notes	Ⓐ Type No.
5.0	–	48	1000 ⑩	50	300	3.6×10^5	7.5×10^6	0.5	5	1.4	15	Photon counting type: R6350P : $10\ s^{-1}$(cps) Typ.	R6350
5.0	–	48	1000 ⑩	50	300	3.6×10^5	7.5×10^6	0.5	5	1.4	15		R6351
10.0	–	90	1000 ⑩	100	700	5.2×10^5	5.8×10^6	1	10	1.4	15		R6352
6.5	–	65	1000 ⑩	100	400	3.7×10^5	5.7×10^6	0.1	2	1.4	15	Photon counting type: R6353P : $10\ s^{-1}$(cps)Typ.	R6353
6.0	0.15	45	1000 ⑩	100	600	1.8×10^5	4.0×10^6	1	10	1.4	15		R6355
7.0	0.3	60	1000 ⑩	400	2500	6.0×10^5	1.0×10^7	1	10	1.4	15		R6356
13.0	0.4	105	1000 ⑩	1000	2000	4.2×10^5	4.0×10^6	2	10	1.4	15		R6357
7.5	0.15	70	1000 ⑩	300	700	2.5×10^5	3.5×10^6	0.1	1	1.4	15	Photon counting type: R6358P : $20\ s^{-1}$(cps) Typ.	R6358

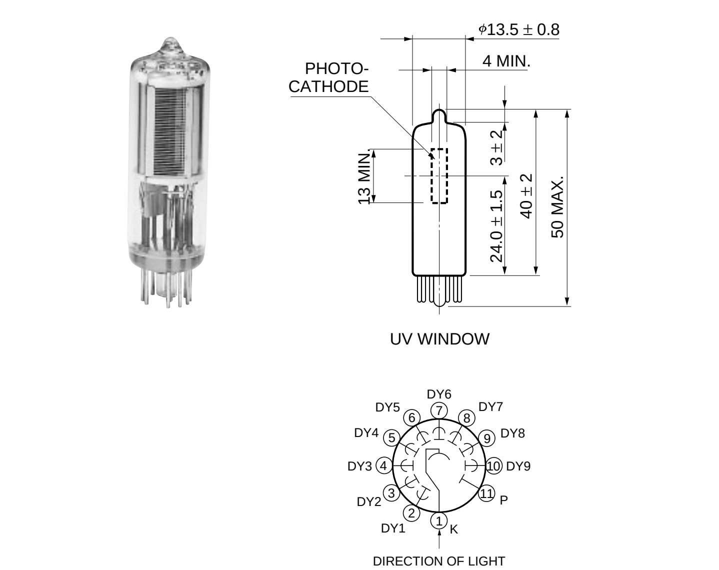
13 mm (1/2 ") Dia. Subminiature Types

Ⓐ Type No.	Remarks	Curve Code	Range (nm)	Peak Wave-length (nm)	Photo-cathode Material	Window Material	Out-line No.	Dynode Structure / No. of Stages	Socket / Socket Assembly	Anode to Cathode Voltage (Vdc)	Average Anode Current (mA)	Luminous Min. (μ A/lm)	Luminous Typ. (μ A/lm)
R3810	For UV to visible range, general purpose	350U (S-5)	185 to 650	340	Sb-Cs	U	4	CC/9	E678-11U*/1	1250	0.01	20	40
R3811	Multialkali photocathode variant of R3810	550U	185 to 850	530	MA	U	4	CC/9	E678-11U*/1	1250	0.01	50	150

Blue Sensitivity Index (CS 5-58) Typ.	Red / White Ratio Typ.	Radiant Typ. (mA/W)	Anode to Cathode Supply Voltage (Vdc)	Luminous Min. (A/lm)	Luminous Typ. (A/lm)	Radiant Typ. (A/W)	Gain Typ.	Dark Current Typ. (nA)	Dark Current Max. (nA)	Rise Time Typ. (ns)	Electron Transit Time Typ. (ns)	Notes	Ⓐ Type No.
5.0	–	48	1000 ⑩	50	300	3.6×10^5	7.5×10^6	0.5	5	1.4	15	Photon counting type: R3810P : $5\ s^{-1}$(cps) Typ.	R3810
6.0	0.15	45	1000 ⑩	50	200	5.9×10^4	1.3×10^6	1	10	1.4	15		R3811

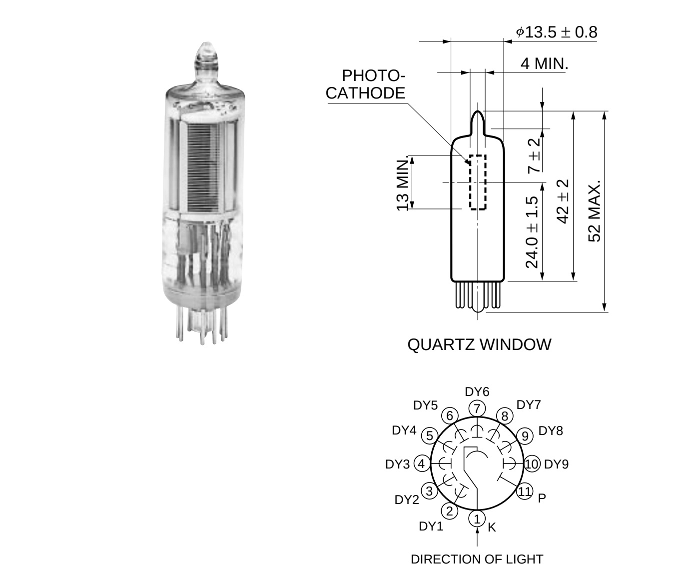
(Unit: mm)

1 R6350, R6352, R6353 etc.



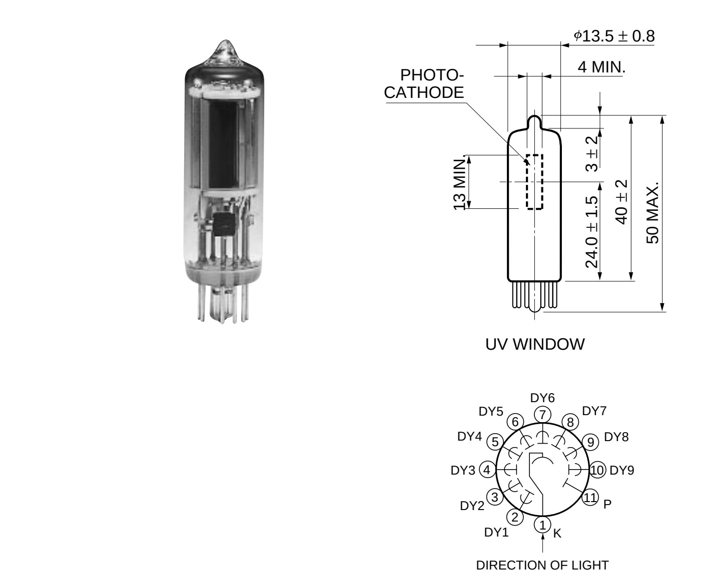
TPMSA0034EB

2 R6351



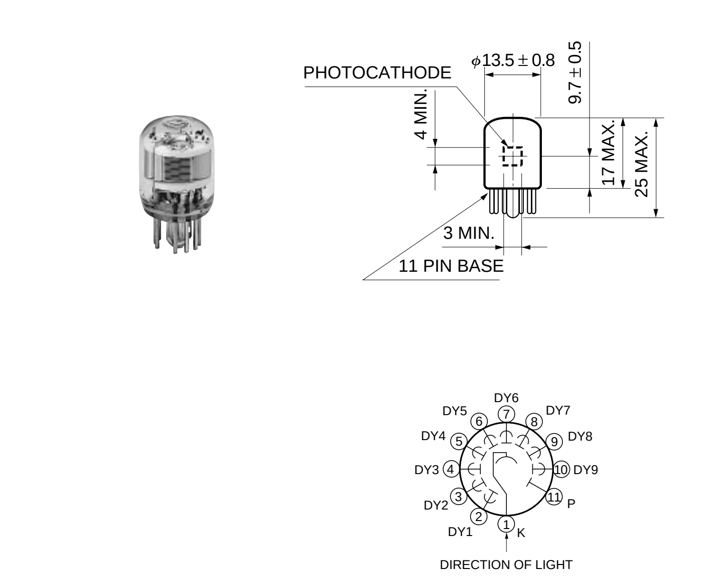
TPMSA0034EA

3 R6357



TPMSA0034EB

4 R3810, R3811



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Side On Type Photomultiplier Tubes

(at 25 °C)

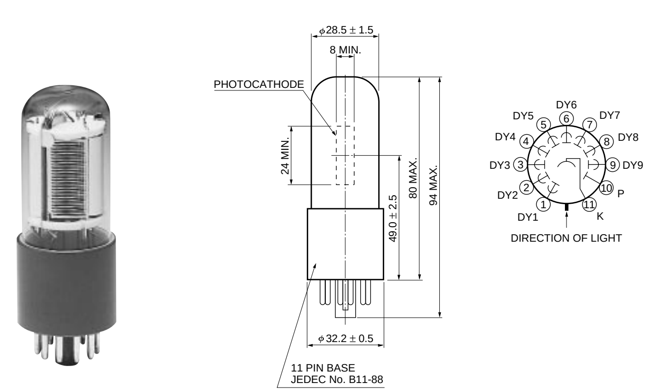
28 mm (1-1/8 ") Dia. Types with UV to Visible Sensitivity

Type No. (A)	Remarks	Spectral Response (B) Curve Code	Spectral Response Range (nm)	Spectral Response Peak Wavelength (nm)	(C) Photocathode Material	(D) Window Material	(E) Outline No.	(F) Dynode Structure / No. of Stages	(G) Socket / Socket Assembly	Maximum Ratings (H) Anode to Cathode Voltage (Vdc)	Maximum Ratings (J) Average Anode Current (mA)	Cathode Sensitivity Luminous Min. (µA/lm)	Cathode Sensitivity Luminous Typ. (µA/lm)
931A	For visible range, general purpose	350K (S-4)	300 to 650	400	Sb-Cs	K	1	CC/9	E678-11A■/②③	1250	0.1	25	40
931B	Bialkali photocathode, high stability	453K	300 to 650	400	BA	K	1	CC/9	E678-11A■/②③	1250	0.1	30	60
1P21	Low dark current variant of R105	350K (S-4)	300 to 650	400	Sb-Cs	K	1	CC/9	E678-11A■/②③	1250	0.1	25	40
R105	High gain and low dark current variant of 931A				Sb-Cs	K	1	CC/9	E678-11A■/②③	1250	0.1	25	40
1P28	For UV to visible range, general purpose	350U (S-5)	185 to 650	340	Sb-Cs	U	1	CC/9	E678-11A■/②③	1250	0.1	25	40
R212	High gain and low dark current variant of 1P28				Sb-Cs	U	1	CC/9	E678-11A■/②③	1250	0.1	25	40
R1527	Low dark current bialkali photocathode	456U	185 to 680	400	LBA	U	1	CC/9	E678-11A■/②③	1250	0.1	40	60
R4220	High sensitivity variant of R1527	456U	185 to 710	410	LBA	U	1	CC/9	E678-11A■/②③	1250	0.1	80	100
R3788	High sensitivity variant of R212	452U	185 to 750	420	BA	U	1	CC/9	E678-11A■/②③	1250	0.1	100	120
R2693	Transmission-mode bialkali photocathode	430U	185 to 650	375	LBA	U	2	CC/9	E678-11A■/②③	1250	0.1	30	50
*R7446	Low dark current bialkali photocathode	–	160 to 680	400	LBA	Q	1	CC/9	E678-11A■/②③	1250	0.1	40	60

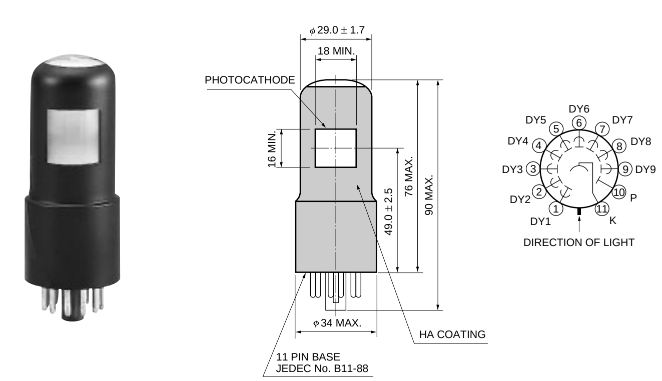
Type No. (A)	Cathode Sensitivity Blue Sensitivity Index (CS 5-58) Typ.	Cathode Sensitivity Red / White Ratio Typ.	(K) Cathode Sensitivity Radiant Typ. (mA/W)	(L) Anode to Cathode Supply Voltage (Vdc)	Anode Characteristics (M) Anode Sensitivity Luminous Min. (A/lm)	Anode Sensitivity Luminous Typ. (A/lm)	Anode Sensitivity Radiant Typ. (A/W)	Gain Typ.	Anode Dark Current (After 30 min.) Typ. (nA)	Anode Dark Current (After 30 min.) Max. (nA)	Time Response Rise Time Typ. (ns)	Time Response Electron Transit Time Typ. (ns)	Notes
931A	5.0	–	48	1000 ⑩	50	400	4.8×10^5	1.0×10^7	5	50	2.2	22	
931B	7.1	–	60	1000 ⑩	50	600	6.6×10^5	1.0×10^7	5	50	2.2	22	UV glass window type: R1516
1P21	5.0	–	48	1000 ⑩	50	250	3.0×10^5	6.25×10^6	1	5	2.2	22	
R105	5.0	–	48	1000 ⑩	50	400	4.8×10^5	1.0×10^7	1	10	2.2	22	High gain type: R105UH
1P28	5.0	–	48	1000 ⑩	20	400	4.8×10^5	1.0×10^7	5	50	2.2	22	
R212	5.0	–	48	1000 ⑩	50	300	3.6×10^5	7.5×10^6	1	10	2.2	22	Fused silica window type:R106
R1527	6.4	–	60	1000 ⑩	200	400	4.0×10^5	6.7×10^6	0.1	2	2.2	22	Photon counting type: R1527P : 10 s^{-1}(cps) Typ.
R4220	8.0	–	70	1000 ⑩	1000	1200	8.4×10^5	1.2×10^7	0.2	2	2.2	22	Fused silica window type:R7447
R3788	10.0	0.01	90	1000 ⑩	500	1200	9.0×10^5	1.0×10^7	5	50	2.2	22	Synthetic silica window type : R4332
R2693	7.0	–	62	1000 ⑩	100	300	3.7×10^5	6.0×10^6	0.5	5	1.2	18	Photon counting type:R2693P :15 s^{-1}(cps) Type.
R7446*	6.4	–	60	1000 ⑩	200	400	4.0×10^5	6.7×10^6	0.1	2	2.2	22	Photon counting type: R7446P : 10 s^{-1}(cps) Typ.

Unit: mm

1 931A, 931B, 1P28, R3788, etc.



2 R2693



Side On Type Photomultiplier Tubes

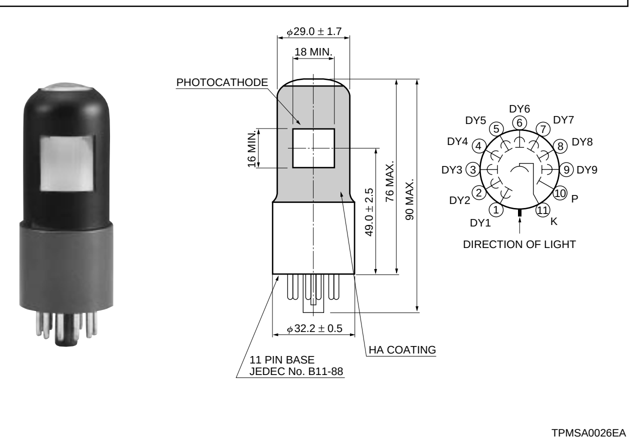
(at 25 °C)

(A) Type No.	Remarks	Spectral Response (B) Curve Code	Spectral Response Range (nm)	Spectral Response Peak Wavelength (nm)	(C) Photocathode Material	(D) Window Material	(E) Outline No.	(F) Dynode Structure / No. of Stages	(G) Socket / Socket Assembly	(H) Maximum Ratings Anode to Cathode Voltage (Vdc)	(J) Maximum Ratings Average Anode Current (mA)	Cathode Sensitivity Luminous Min. (µ A/lm)	Cathode Sensitivity Luminous Typ. (µ A/lm)
28 mm (1-1/8 ") Dia. Types with UV to Near IR Sensitivity													
R2368	Transmission-mode multialkali photocathode	500U	185 to 850	420	MA	U	1	CC/9	E678-11A■/2 3	1250	0.1	80	150
R928	For UV to near IR range, high sensitivity	562U	185 to 900	400	MA	U	3	CC/9	E678-11A■/2 3	1250	0.1	140	250
R2949	For UV to near IR range, low dark count	552U	185 to 900	400	MA	U	6	CC/9	E678-11A■/2 3	1250	0.1	140	200
R1477-06	High sensitivity variant of R928	554U	185 to 900	450	MA	U	7	CC/9	E678-11A■/2 3	1250	0.1	350	375
R3896	High sensitivity variant of R1477-06	555U	185 to 900	450	MA	U	7	CC/9	E678-11A■/2 3	1250	0.1	475	525
R4632	High sensitivity in 400 nm to 700 nm range, low dark count	556U	185 to 850	430	MA	U	3	CC/9	E678-11A■/2 3	1250	0.1	140	200
R636-10	GaAs photocathode, high quantum efficiency	650U	185 to 930	300 to 800	GaAs(Cs)	U	4	CC/9	E678-11A■/2 3	1500	0.001	400	550
R2658	InGaAs photocathode, for UV to 1010 nm range	850U	185 to 1010	400	InGaAs (Cs)	U	5	CC/9	E678-11A■/2 3	1500	0.001	50	100
R5108	For near IR range	700K (S-1)	400 to 1200	800	Ag-O-Cs	K	2	CC/9	E678-11A■/2 3	1500	0.1	10	25

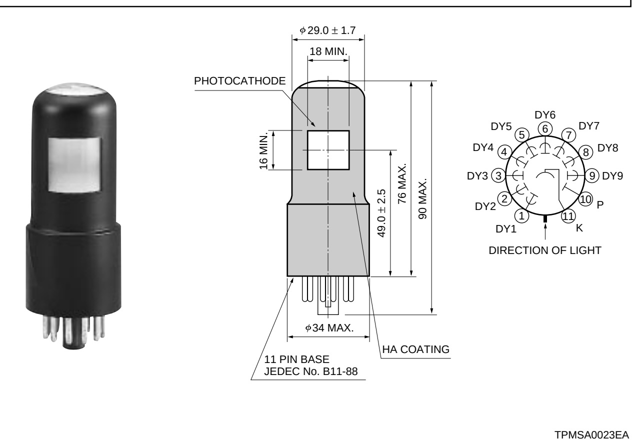
Cathode Sensitivity Blue Sensitivity Index (CS 5-58) Typ.	Cathode Sensitivity Red / White Ratio Typ.	(K) Cathode Sensitivity Radiant Typ. (mA/W)	(L) Anode to Cathode Supply Voltage (Vdc)	(M) Anode Characteristics: Anode Sensitivity Luminous Min. (A/lm)	Anode Sensitivity Luminous Typ. (A/lm)	Anode Sensitivity Radiant Typ. (A/W)	Gain Typ.	Anode Dark Current (After 30 min.) Typ. (nA)	Anode Dark Current (After 30 min.) Max. (nA)	Time Response Rise Time Typ. (ns)	Time Response Electron Transit Time Typ. (ns)	Notes	(A) Type No.
–	0.15	64	1000 (10)	50	200	8.3×10^4	1.3×10^6	5	50	1.2	18		R2368
8.0	0.3	74	1000 (10)	400	2500	7.4×10^5	1.0×10^7	3	50	2.2	22	Fused silica window type: R955	R928
7.5	0.3	68	1000 (10)	1000	2000	6.8×10^5	1.0×10^7	300 [h]	500 [h]	2.2	22		R2949
10.0	0.35	80	1000 (10)	1000	2000	4.2×10^5	5.3×10^6	3	50	2.2	22		R1477-06
15.0	0.4	90	1000 (10)	3000	5000	8.6×10^5	9.5×10^6	10	50	2.2	22		R3896
7.5	0.15	80	1000 (10)	300	700	2.8×10^5	3.5×10^6	50 [h]	100 [h]	2.2	22		R4632
9.0	0.53	62	1250 (10)	100	250	2.8×10^4	4.5×10^5	0.1 [f]	2 [f]	2.0	20	Fused silica window type : R758-10	R636-10
4.5	0.4	1 (at 1µ m)	1250 (10)	5	16	1.6×10^2	1.6×10^5	1	10	2.0	20	Photon counting type: R2658P	R2658
–	–	2.2	1250 (10)	3.5	7.5	6.6×10^3	3.0×10^5	350 [e]	1000 [e]	1.2	18		R5108

(Unit: mm)

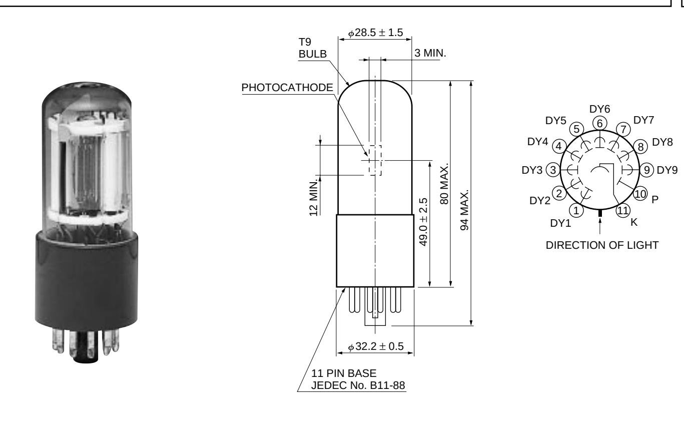
1 R2368



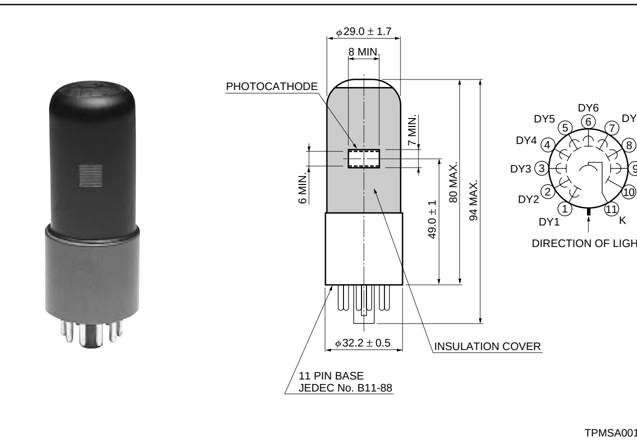
2 R5108



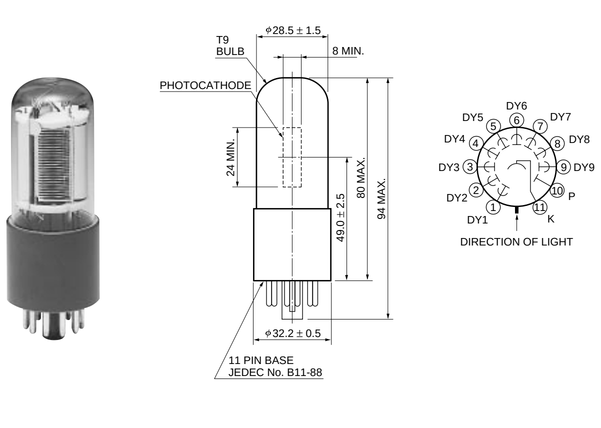
5 R2658



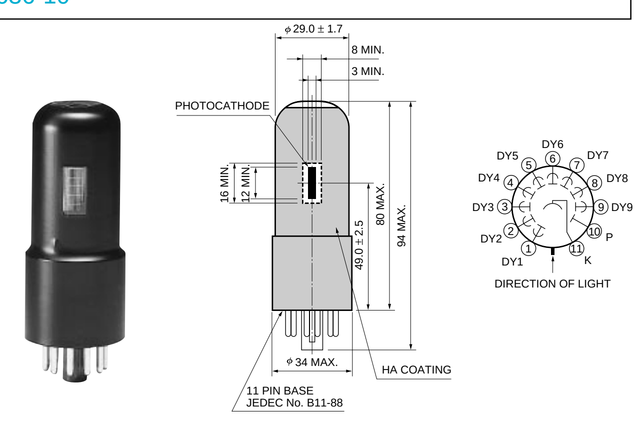
6 R2949



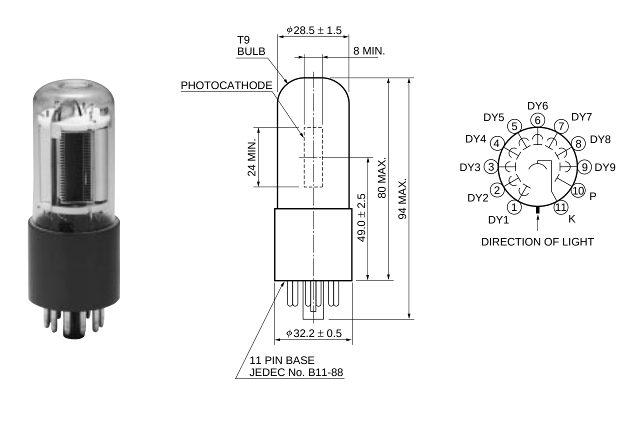
3 R928, R4632



4 R636-10



7 R1477-06, R3896



Side-On and Dormer Window Type Photomultiplier Tubes

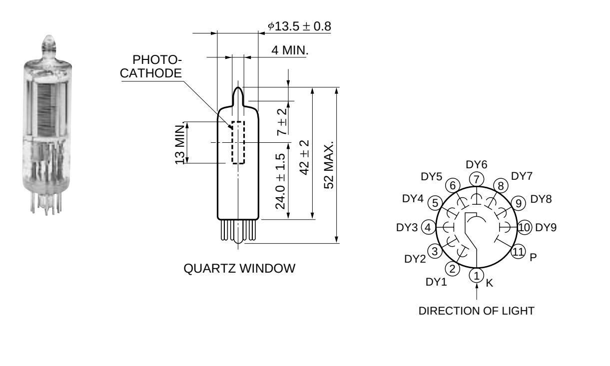
(at 25 °C)

Type No. (A)	Remarks	Spectral Response: Curve Code (B)	Spectral Response: Range (nm)	Spectral Response: Peak Wavelength (nm)	Photocathode Material (C)	Window Material (D)	Outline No. (E)	Dynode Structure / No. of Stages (F)	Socket / Socket Assembly (G)	Maximum Ratings (H): Anode to Cathode Voltage (Vdc)	Maximum Ratings: Average Anode Current (J) (mA)	Cathode Sensitivity Luminous Min. (µ A/lm)	Cathode Sensitivity Luminous Typ. (µ A/lm)
13 mm (1/2 ") Dia. Compact Types with Solar Blind Response													
R7511	For VUV range, MgF_2 window	150M	115 to 195	130	Cs-I	MF	2	CC/9	E678-11U★	1250	0.01	–	–
R6354	For UV range	250S	160 to 320	230	Cs-Te	Q	1	CC/9	E678-11U★/1	1250	0.01	–	–
R7311	For UV range, MgF_2 window	250M	115 to 320	200	Cs-Te	MF	2	CC/9	E678-11U★	1250	0.01	–	–
28 m (1-1/8 ") Dia. Types with Solar Blind Response													
R1259	For VUV range, MgF_2 window	150M	115 to 195	120	Cs-I	MF	3	CC/9	E678-11A■	1250	0.1	–	–
* R7154	For UV range	250S	160 to 320	230	Cs-Te	Q	4	CC/9	E678-11A■/2 3	1250	0.1	–	–
R1220	For UV range, MgF_2 window	250M	115 to 320	200	Cs-Te	MF	3	CC/9	E678-11A■	1250	0.1	–	–
38 mm (1-1/2 ") Dia. Dormer Window Types													
R1923	Multialkali photocathode, temporary base	558K	300 to 800	530	MA	K	5	CC/10	E678-12A■	2000	0.1	200	300

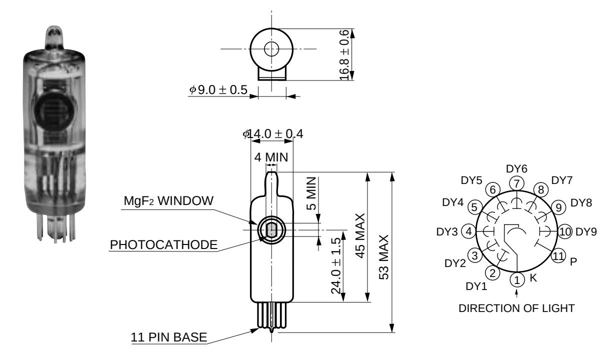
Cathode Sensitivity: Blue Sensitivity Index (CS 5-58) Typ.	Cathode Sensitivity: Red / White Ratio Typ.	Cathode Sensitivity: Radiant Typ. (K) (mA/W)	Anode to Cathode Supply Voltage (L) (Vdc)	Anode Characteristics (M): Anode Sensitivity Luminous Min. (A/lm)	Anode Sensitivity Luminous Typ. (A/lm)	Anode Sensitivity Radiant Typ. (A/W)	Gain Typ.	Anode Dark Current (After 30 min.) Typ. (nA)	Anode Dark Current (After 30 min.) Max. (nA)	Time Response: Rise Time Typ. (ns)	Time Response: Electron Transit Time Typ. (ns)	Notes	Type No. (A)
–	–	26 ⓐ	1000 ⑩	–	–	5.2×10^4 ⓐ	2.0×10^6	0.3	3	1.4	15		R7511
–	–	62 ⓑ	1000 ⑩	–	–	1.8×10^5 ⓑ	3.0×10^6	0.5	5	1.4	15		R6354
–	–	40 ⓑ	1000 ⑩	–	–	2.8×10^5 ⓑ	7.0×10^6	0.3	3	1.4	15		R7311
–	–	26 ⓐ	1000 ⑩	–	–	3.1×10^4 ⓐ	1.2×10^6	1	10	2.2	22	Sharp-cut UV type : R2032	R1259
–	–	62 ⓑ	1000 ⑩	–	–	6.2×10^5 ⓑ	1.0×10^7	1	10	2.2	22		R7154*
–	–	40 ⓑ	1000 ⑩	–	–	4.0×10^5 ⓑ	1.0×10^7	1	10	2.2	22		R1220
8.0	0.12	89	1250 ⑯	5	15	4.4×10^3	5.0×10^4	1	10	2.2	22		R1923

(Unit: mm)

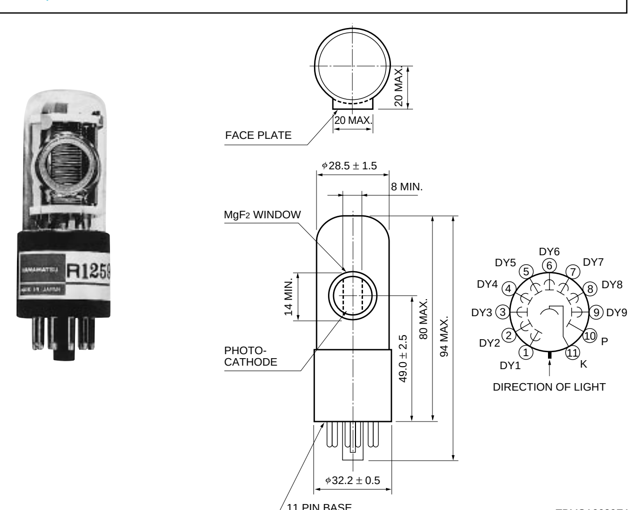
1 R6354



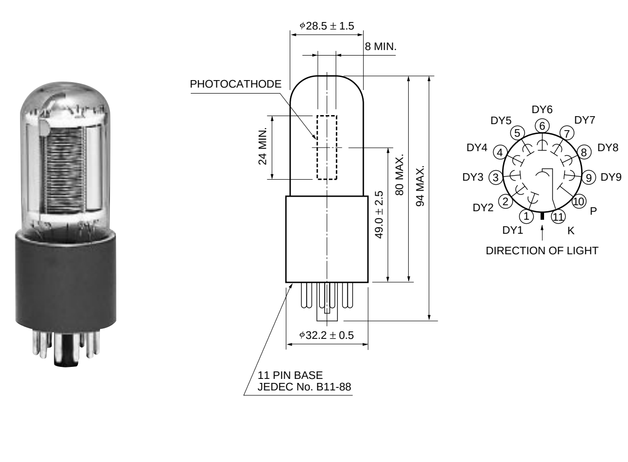
2 R7511, R7311



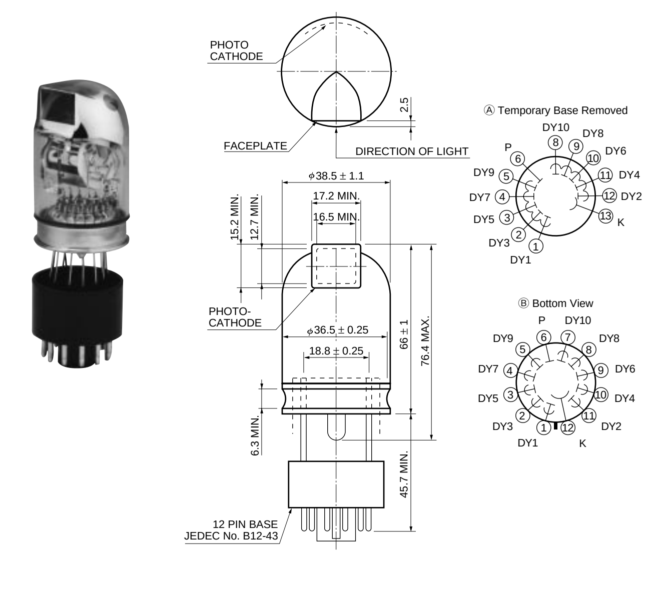
3 R1259, R1220



4 R7154



5 R1923



Head On Type Photomultiplier Tubes

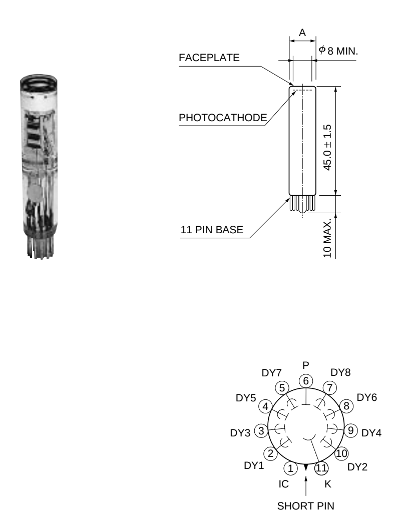
(at 25 °C)

Type No. (A)	Remarks	Spectral Response: Curve Code (B)	Spectral Response: Range (nm)	Spectral Response: Peak Wave-length (nm)	Photo-cathode Material (C)	Window Material (D)	Out-line No. (E)	Dynode Structure / No. of Stages (F)	Socket / Socket Assembly (G)	Maximum Ratings (H): Anode to Cathode Voltage (Vdc)	Maximum Ratings: Average Anode Current (J) (mA)	Cathode Sensitivity: Luminous Min. (µ A/lm)	Cathode Sensitivity: Luminous Typ. (µ A/lm)
10 mm (3/8 ") Dia. Types													
R1893	Subminiature size, for UV range	200S	160 to 320	240	Cs-Te	Q	1	L/8	E678-11N*/4	1500	0.01	–	–
R1635	For visible range and scintillation counting	400K	300 to 650	420	BA	K	1	L/8	E678-11N*/4	1500	0.03	60	95
R2496	For UV to visible range, fast time response	400S	160 to 650	420	BA	Q	1	L/8	E678-11N*/5	1500	0.03	60	95
R1894	For UV to near IR range, general purpose	500K (S-20)	300 to 850	420	MA	K	1	L/8	E678-11N*/4	1500	0.03	80	120
13 mm (1/2 ") Dia. Types													
R1081	For VUV range, MgF_2 window	100M	115 to 200	140	Cs-I	MF	4	L/10	E678-12A*	2250	0.01	–	–
R1080	For UV range, MgF_2 window	200M	115 to 320	240	Cs-Te	MF	4	L/10	E678-12A*	1250	0.01	–	–
R759	For UV range	200S	160 to 320	240	Cs-Te	Q	3	L/10	E678-13A*/7	1250	0.01	–	–
R647	For visible range and scintillation counting	400K	300 to 650	420	BA	K	3	L/10	E678-13A*/7	1250	0.1	40	100
R4124	For visible range, fast time response	400K	300 to 650	420	BA	K	5	L/10	E678-13A*/9	1250	0.03	40	95
R2557	Low noise bialkali photocathode	402K	300 to 650	375	LBA	K	3	L/10	E678-13A*/8	1500	0.03	25	40
R4177-01	High temperature, ruggedized type	401K	300 to 650	375	HBA	K	2	L/10	E678-13A*	1800	0.02	20	40
R1463	Multialkali photocathode for UV to near IR range	500U	185 to 850	420	MA	U	3	L/10	E678-13A*/7	1250	0.03	80	120

Cathode Sensitivity: Blue Sensitivity Index (CS 5-58) Typ.	Cathode Sensitivity: Red / White Ratio Typ.	Cathode Sensitivity: Radiant Typ. (K) (mA/W)	Anode to Cathode Supply Voltage (L) (Vdc)	Anode Characteristics (M): Anode Sensitivity, Luminous Min. (A/lm)	Anode Sensitivity, Luminous Typ. (A/lm)	Anode Sensitivity, Radiant Typ. (A/W)	Gain Typ.	Anode Dark Current (After 30 min.) Typ. (nA)	Anode Dark Current (After 30 min.) Max. (nA)	Time Response: Rise Time Typ. (ns)	Time Response: Electron Transit Time Typ. (ns)	Notes	Type No. (A)
10 mm (3/8 ") Dia. Types													
–	–	24 (b)	1250 (1)	1.2×10^3 (b) (A/W)	–	3.6×10^3 (b)	1.5×10^5	0.5	2.5	0.8	7.8		R1893
9.5	–	76	1250 (1)	30	100	8.0×10^4	1.1×10^6	1	50	0.8	9.0	Photon counting type: R1635P UV glass window type: R3878	R1635
9.5	–	76	1250 (5)	30	100	8.0×10^4	1.1×10^6	2	50	0.7	9.0		R2496
–	0.2	51	1250 (1)	10	50	2.1×10^4	4.2×10^5	2	20	0.8	7.8		R1894
13 mm (1/2 ") Dia. Types													
–	–	9.8 (a)	2000 (13)	2×10^2 (a) (A/W)	–	9.8×10^2 (a)	1.0×10^5	0.03	0.05	1.8	18		R1081
–	–	28 (b)	1000 (13)	4×10^3 (b) (A/W)	–	1.4×10^4 (b)	5.0×10^5	0.3	1	2.5	24		R1080
–	–	28 (b)	1000 (13)	4×10^3 (b) (A/W)	–	1.4×10^4 (b)	5.0×10^5	0.3	1	2.5	24		R759
9.5	–	76	1000 (13)	30	100	7.6×10^4	1.0×10^6	1	15	2.5	24	Photon counting type: R647P UV glass window type: R960 Synthetic silica window type: R760	R647
9.5	–	76	1000 (19)	30	100	8.0×10^4	1.1×10^6	1	15	1.1	12	UV glass window type: R4141	R4124
5.5	–	50	1250 (16)	50	200	2.5×10^5	5.0×10^6	10 (h)	30 (h)	2.2	22		R2557
6.0	–	51	1500 (13)	10	20	2.5×10^4	5.0×10^5	0.5	10	2.0	20		R4177-01
–	0.2	51	1000 (13)	30	120	5.1×10^4	1.0×10^6	4	20	2.5	24	Photon counting type: R1463P	R1463

(Unit: mm)

1 R1893, R1635, R2496, R1894

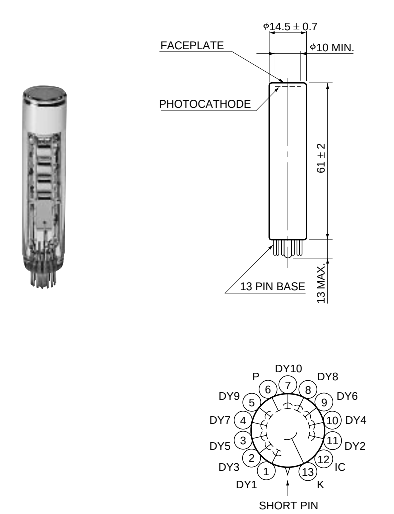


	R1635	R1893, R2496	Others
A	φ9.7 ± 0.4	φ10.5 ± 0.5	φ9.7 ± 0.4

R2496 has a plano-concave faceplate.

TPMHA0100EA

2 R4177-01



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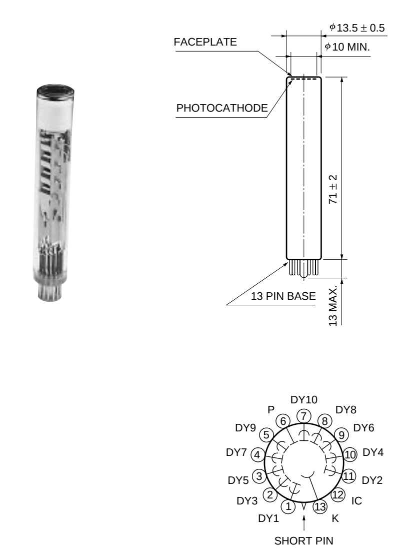
3 R647, R2557, R1463, R759



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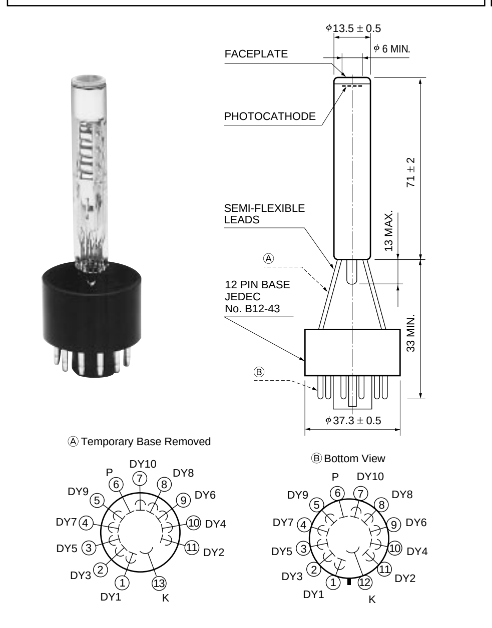
4 R1080, R1081



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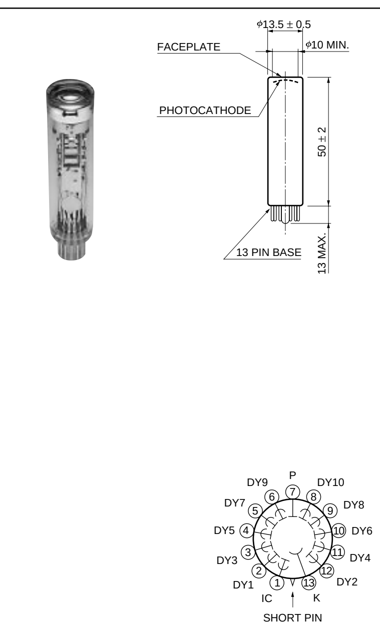
5 R4124



TPMHA0102EA

Head-On Type Photomultiplier Tubes

(at 25 °C)

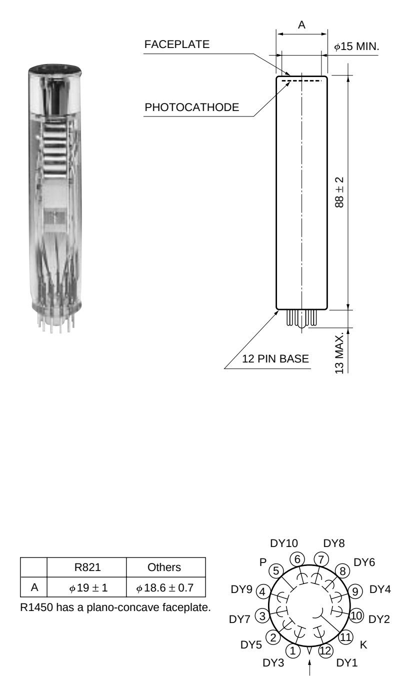
19 mm (3/4 ") Dia. Types

Type No. (A)	Remarks	Spectral Response: Curve Code (B)	Spectral Response: Range (nm)	Spectral Response: Peak Wavelength (nm)	Photocathode Material (C)	Window Material (D)	Outline No. (E)	Dynode Structure / No. of Stages (F)	Socket / Socket Assembly (G)	Maximum Ratings (H): Anode to Cathode Voltage (Vdc)	Maximum Ratings: Average Anode Current (mA) (J)	Cathode Sensitivity: Luminous Min. (µ A/lm)	Cathode Sensitivity: Luminous Typ. (µ A/lm)
R972	For VUV range, MgF_2 window	100M	115 to 200	140	Cs-I	MF	2	L/10	E678-12A*	2250	0.01	–	–
R821	For UV range, synthetic silica window	200S	160 to 320	240	Cs-Te	Q	1	L/10	E678-12L*/13 14 15	1250	0.01	–	–
R1166	For visible range and scintillation counting	400K	300 to 650	420	BA	K	1	L/10	E678-12L*/13 14 15	1250	0.1	70	105
R2801	Low noise bialkali photocathode	402K		375	LBA	K	1	L/10	E678-12L*/13 14 15	1500	0.1	30	45
R1450	Small TTS, for scintillation counting	400K		420	BA	K	1	L/10	E678-12L*/17	1800	0.1	70	115
R3478	For visible range, fast time response				BA	K	6	L/8	E678-12L*/11 12	1800	0.1	70	115
R5611-01	For visible range, low profile				BA	K	5	CC/10	E678-12A*	1250	0.1	60	90
R3991	High temperature, ruggedized type, low profile	401K		375	HBA	K	5	CC/10	E678-12A*	1800	0.02	20	40
R1281	High temperature photocathode				HBA	K	3	L/10	E678-12A*	1800	0.02	20	40
R1617	Multialkali photocathode for visible to near IR range	500K (S-20)	300 to 850	420	MA	K	1	L/10	E678-12L*/13 14 15	1250	0.1	80	120
R1464	Multialkali photocathode for UV to near IR range	500U	185 to 850		MA	U	1	L/10	E678-12L*/13 14 15	1250	0.1	80	120
R1878	For photon counting in visible to near IR range	500K (S-20)	300 to 850		MA	K	4	L/10	E678-12L*/16	1500	0.1	80	120
R632-01	For near IR range, QE=0.05 % Typ. at 1.06 µm	700K (S-1)	400 to 1200	800	Ag-O-Cs	K	1	L/10	E678-12L*/13 14 15	1500	0.01	10	20

Cathode Sensitivity: Blue Sensitivity Index (CS 5-58) Typ.	Cathode Sensitivity: Red / White Ratio Typ.	Cathode Sensitivity: Radiant Typ. (mA/W) (K)	Anode to Cathode Supply Voltage (Vdc) (L)	Anode Characteristics (M): Anode Sensitivity Luminous Min. (A/lm)	Anode Sensitivity Luminous Typ. (A/lm)	Anode Sensitivity Radiant Typ. (A/W)	Gain Typ.	Anode Dark Current (After 30 min.) Typ. (nA)	Anode Dark Current (After 30 min.) Max. (nA)	Time Response: Rise Time Typ. (ns)	Time Response: Electron Transit Time Typ. (ns)	Notes	Type No. (A)
–	–	9.8 (a)	2000 (15)	2×10^2 (a) (A/W)	–	9.8×10^2 (a)	1.0×10^5	0.03	0.05	1.6	17	Cs-Te photocathode type: R976	R972
–	–	28 (b)	1000 (15)	4×10^3 (b) (A/W)	–	1.0×10^4 (b)	3.6×10^5	0.3	0.5	2.5	27		R821
10.5	–	85	1000 (15)	10	100	8.1×10^4	9.5×10^5	1	5	2.5	27	Synthetic silica window type: R762 UV glass window type: R750	R1166
6.0	–	55	1250 (15)	50	300	3.7×10^5	6.7×10^6	15 (h)	45 (h)	2.2	25		R2801
11.0	–	88	1500 (17)	100	200	1.5×10^5	1.7×10^6	3	50	1.8	19		R1450
11.0	–	88	1700 (6)	100	200	1.5×10^5	1.7×10^6	10	300	1.3	14	Synthetic silica window type: R2076	R3478
10.5	–	85	1000 (18)	10	50	4.7×10^4	5.5×10^5	3	20	1.5	17	Button stem type: R5611	R5611-01
6.0	–	51	1500 (18)	5	15	1.9×10^4	3.75×10^5	0.1	10	1.0	13		R3991
6.0	–	50	1500 (15)	20	50	6.5×10^4	1.3×10^6	0.5	10	1.9	21	Button stem type: R1281-02	R1281
–	0.2	51	1000 (15)	30	120	5.1×10^4	1.0×10^6	4	20	2.5	27		R1617
–	0.2	51	1000 (15)	30	120	5.1×10^4	1.0×10^6	4	20	2.5	27	Synthetic silica window type: R2027	R1464
–	0.2	51	1000 (16)	30	150	6.1×10^4	1.2×10^6	100 (h)	250 (h)	1.7	24	Bialkali photocathode type: R2295	R1878
–	0.14 (d)	1.9	1250 (15)	5	10	9.5×10^2	5.0×10^5	800 (e)	2000 (e)	2.2	25		R632-01

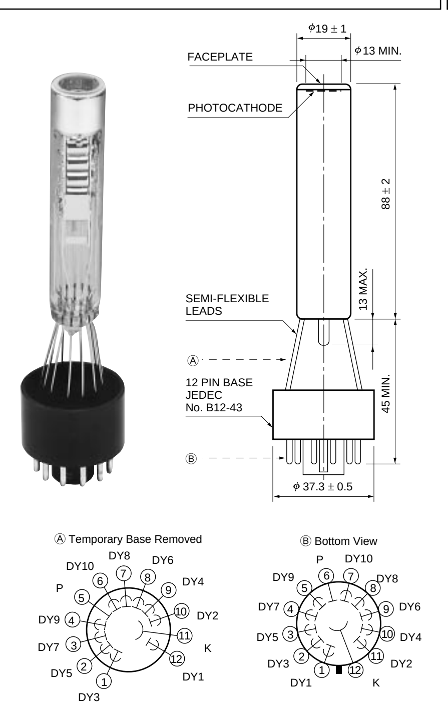
(Unit: mm)

1 R821, R1450, etc.



TPMHA0012EB

2 R972



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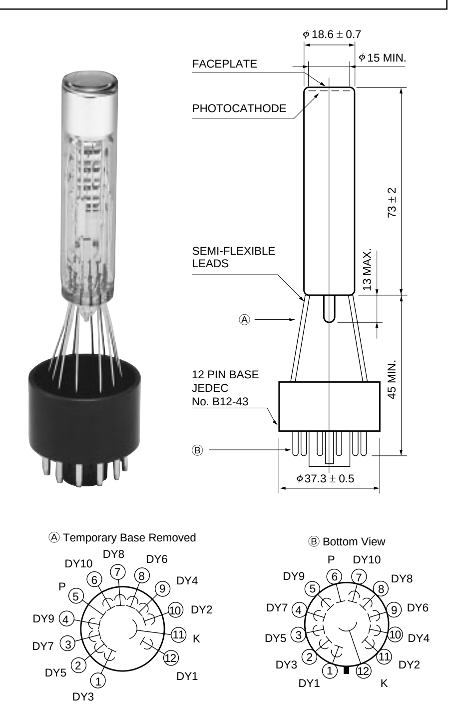
3 R1281



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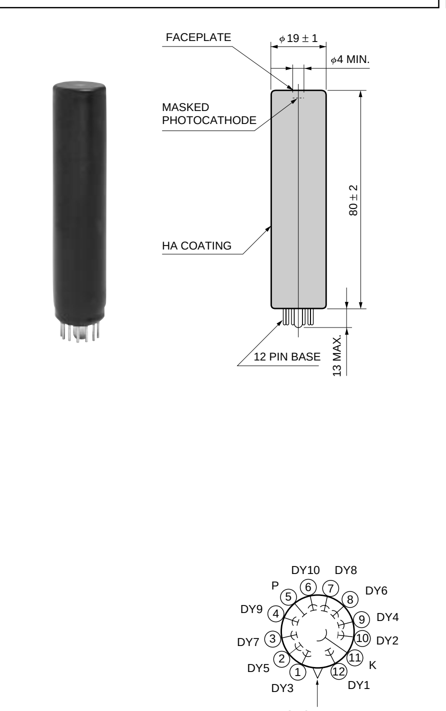
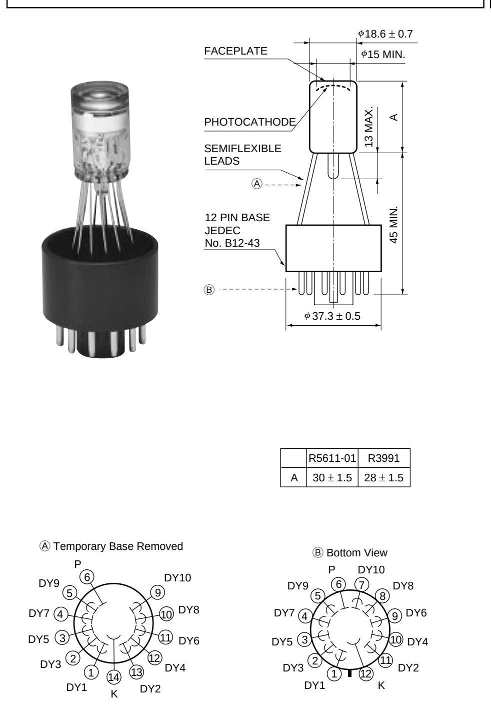
4 R1878



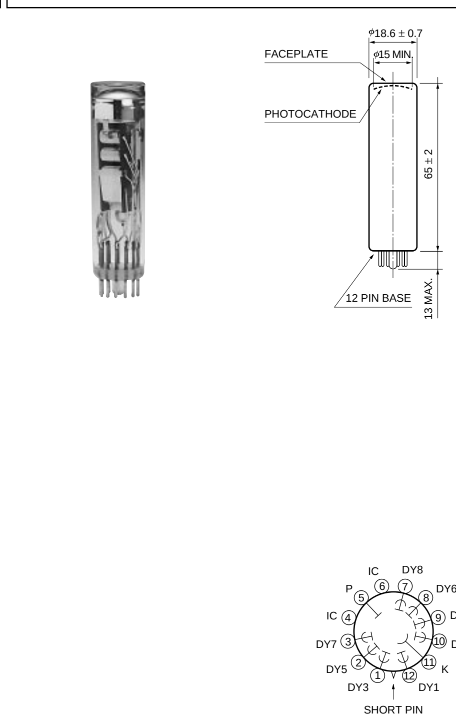
TPMHA0027EA

5 R5611-01, R3991



TPMHA0036EA

6 R3478



TPMHA0119EA

Head-On Type Photomultiplier Tubes

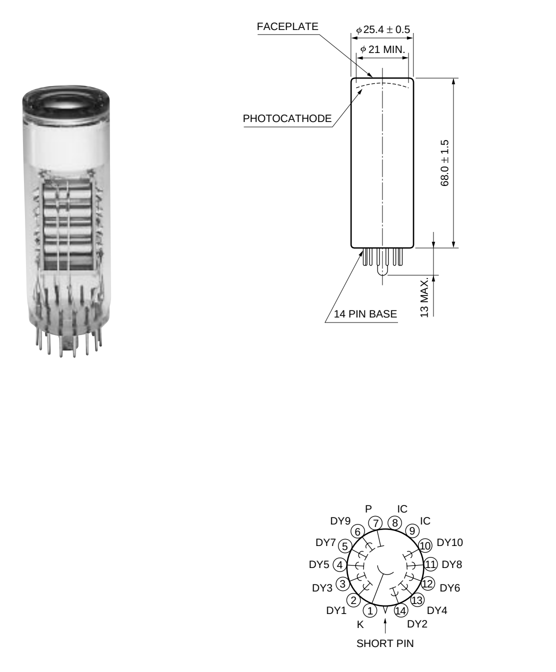
(at 25 °C)

Type No. (A)	Remarks	Spectral Response: Curve Code (B)	Spectral Response: Range (nm)	Spectral Response: Peak Wavelength (nm)	Photocathode Material (C)	Window Material (D)	Outline No. (E)	Dynode Structure / No. of Stages (F)	Socket / Socket Assembly (G)	Maximum Ratings (H): Anode to Cathode Voltage (Vdc)	Maximum Ratings: Average Anode Current (J) (mA)	Cathode Sensitivity: Luminous Min. (µ A/lm)	Cathode Sensitivity: Luminous Typ. (µ A/lm)
25 mm (1 ") Dia. Types													
R5800	For scintillation counting	400K	300 to 650	420	BA	K	1	L/10	E678-14C*/18 19 20	1800	0.1	70	95
R4998	For visible range, fast time response				BA	K	4	L/10	E678-12A*	2500	0.1	60	70
25 mm (1 ") Dia. Low Profile Types													
R2078	For UV range	201S	160 to 320	240	Cs-Te	Q	2	CC/10	E678-12A*	2000	0.015	–	–
R1924	For visible range	400K	300 to 650	420	BA	K	3	CC/10	E678-14C*/18 19 20	1250	0.1	60	90
R3550	Low noise bialkali photocathode	402K		375	LBA	K	3	CC/10	E678-14C*/18 19 20	1250	0.1	30	50
R1288	High temperature, ruggedized type	401K			HBA	K	2	CC/10	E678-12A*	1800	0.02	20	40
R1925	For visible to near IR range	500K (S-20)	300 to 850	420	MA	K	3	CC/10	E678-14C*/18 19 20	1250	0.1	80	120
R5070	Prismatic window, multialkali photocathode with high sensitivity	502K	300 to 900		MA	K	3	CC/10	E678-14C*/18 19 20	1250	0.1	130	230

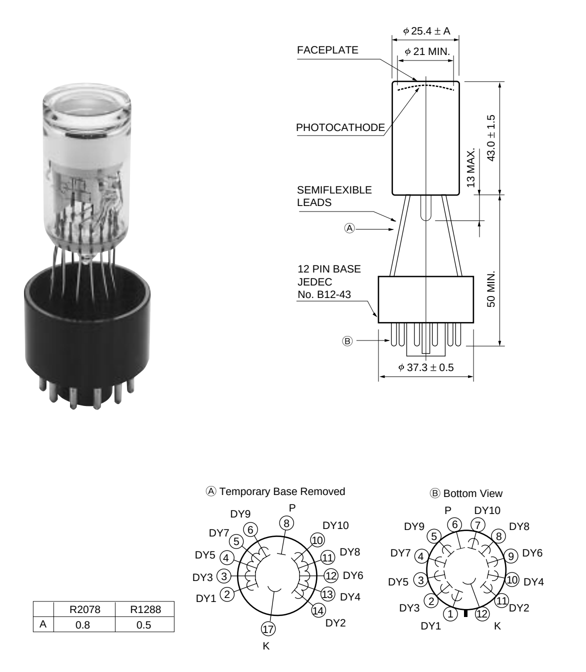
Cathode Sensitivity: Blue Sensitivity Index (CS 5-58) Typ.	Cathode Sensitivity: Red / White Ratio Typ.	Cathode Sensitivity: Radiant Typ. (K) (mA/W)	Anode to Cathode Supply Voltage (L) (Vdc)	Anode Characteristics (M): Anode Sensitivity Luminous Min. (A/lm)	Anode Sensitivity Luminous Typ. (A/lm)	Anode Sensitivity Radiant Typ. (A/W)	Gain Typ.	Anode Dark Current (After 30 min.) Typ. (nA)	Anode Dark Current (After 30 min.) Max. (nA)	Time Response: Rise Time Typ. (ns)	Time Response: Electron Transit Time Typ. (ns)	Notes	Type No. (A)
11.0	–	88	1250 (18)	–	190	2.3×10^5	2.0×10^6	2	15	1.7	22		R5800
9.0	–	72	2250 (22)	100	400	4.1×10^5	5.7×10^6	100	800	0.7	10	Synthetic silica window type : R5320 TTS: 160 ps	R4998
–	–	29 (b)	1500 (18)	4×10^3 (b) (A/W)	–	1.5×10^4 (b)	5.0×10^5	0.015	0.1	1.5	14	Dark count: 5 s^{-1}(cps) Typ.	R2078
10.5	–	85	1000 (18)	20	100	9.3×10^4	1.1×10^6	3	20	2.0	19	Photon counting type: R1924P	R1924
6.5	–	50	1000 (18)	20	100	1.2×10^5	2.0×10^6	20 (h)	60 (h)	2.0	19		R3550
6.0	–	51	1500 (18)	8	15	1.9×10^4	3.8×10^5	0.1	10	1.5	14	Button stem type: R1288-01	R1288
–	0.2	51	1000 (18)	10	30	1.3×10^4	2.5×10^5	3	20	2.0	19	Synthetic silica window type : R1926	R1925
–	0.25	65	1000 (18)	20	100	2.8×10^4	4.3×10^5	3	20	2.0	19		R5070

(Unit: mm)

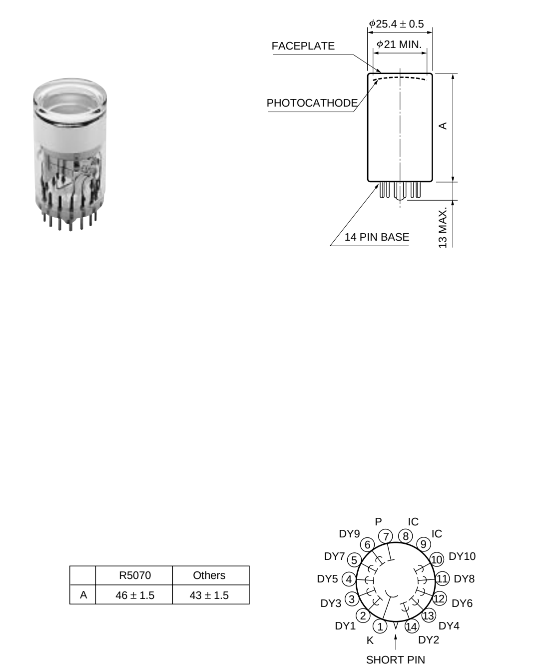
1 R5800



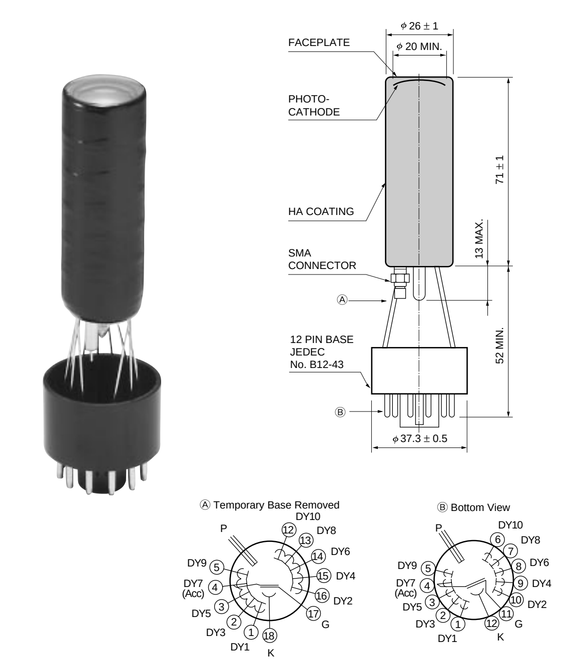
2 R2078, R1288



3 R1924, R1925, R3550, R5070



4 R4998



Head-On Type Photomultiplier Tubes

(at 25 °C)

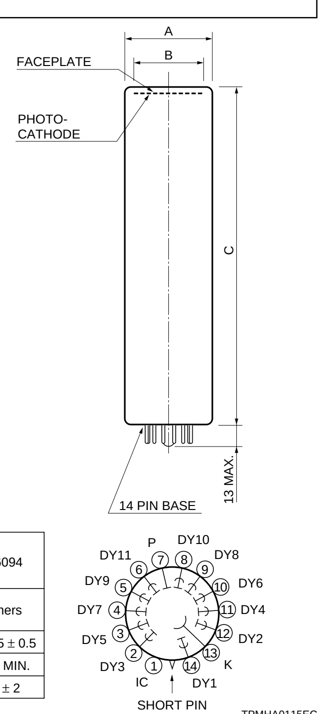
Type No. (A)	Remarks	Spectral Response: Curve Code (B)	Spectral Response: Range (nm)	Spectral Response: Peak Wavelength (nm)	Photocathode Material (C)	Window Material (D)	Outline No. (E)	Dynode Structure / No. of Stages (F)	Socket / Socket Assembly (G)	Maximum Ratings (H): Anode to Cathode Voltage (Vdc)	Maximum Ratings: Average Anode Current (J) (mA)	Cathode Sensitivity Luminous Min. (µA/lm)	Cathode Sensitivity Luminous Typ. (µA/lm)
28 mm (1-1/8 ") Dia. Types													
R6835	For VUV range, MgF_2 window	100M	115 to 200	140	Cs-I	MF	1	B + L/11	E678-14C*	2500	0.01	–	–
R6836	For UV range, MgF_2 window	200M	115 to 320	240	Cs-Te	MF	1	B + L/11	E678-14C*	1500	0.01	–	–
R6834	For UV range, low profile	200S	160 to 320		Cs-Te	Q	2	B + L/11	E678-14C*/24 25	1500	0.01	–	–
R6095	For visible range and scintillation counting	400K	300 to 650	420	BA	K	1	B + L/11	E678-14C*/24 25	1500	0.1	60	95
R6427	For visible range, fast time response				BA	K	3	L/10	E678-14C*/22 23	2000	0.2	60	95
R374	Multialkali photocathode for UV to near IR range	500U	185 to 850		MA	U	1	B/11	E678-14C*/24 25	1500	0.1	80	150
R5929	Prismatic window, high cathode sensitivity	502K	300 to 900		MA	K	1	B/11	E678-14C*/24 25	1500	0.1	130	230
R2228	Extended red multialkali photocathode	501K		600	MA	K	1	B/11	E678-14C*/24 25	1500	0.1	100	200
R316-02	For near IR range, QE=0.06 % Typ. at 1.06 µm	700K (S-1)	400 to 1200	800	Ag-O-Cs	K	1	B/11	E678-14C*/24 25	1500	0.01	10	20
28 mm (1-1/8 ") Dia. Low Profile Type													
R3998-02	For visible range and scintillation counting	400K	300 to 650	420	BA	K	4	B + L/9	E678-14C*	1500	0.1	60	90

Cathode Sensitivity: Blue Sensitivity Index (CS 5-58) Typ.	Cathode Sensitivity: Red / White Ratio Typ.	Cathode Sensitivity: Radiant Typ. (K) (mA/W)	Anode to Cathode Supply Voltage (L) (Vdc)	Anode Characteristics (M): Anode Sensitivity Luminous Min. (A/lm)	Anode Sensitivity Luminous Typ. (A/lm)	Anode Sensitivity Radiant Typ. (A/W)	Gain Typ.	Anode Dark Current (After 30 min.) Typ. (nA)	Anode Dark Current (After 30 min.) Max. (nA)	Time Response: Rise Time Typ. (ns)	Time Response: Electron Transit Time Typ. (ns)	Notes	Type No. (A)
–	–	12 [a]	2000 (26)	–	–	1.2×10^3 [a]	1.0×10^5	0.03	0.05	2.8	22		R6835
–	–	28 [b]	1000 (26)	4Å~10^3 [b] (A/W)	–	1.4×10^4 [b]	5.0×10^5	0.3	1	4	30		R6836
–	–	28 [b]	1000 (26)	4Å~10^3 [b] (A/W)	–	1.4×10^4 [b]	5.0×10^5	0.3	1	4	30		R6834
11.0	–	88	1000 (26)	50	200	1.8×10^5	2.1×10^6	2	10	4	30	Low profile type : R6094	R6095
11.0	–	88	1500 (21)	–	475	4.4×10^5	5.0×10^6	10	200	1.7	16	UV glass window type: R7056 Synthetic silica window type: R7057	R6427
–	0.2	64	1000 (26)	20	80	3.4×10^4	5.3×10^5	3	15	15	60	Synthetic silica window type: R376 High gain type: R1104	R374
–	0.25	65	1000 (26)	30	180	5.1×10^4	7.8×10^5	5	25	15	60		R5929
–	0.3	40	1000 (26)	20	150	3.0×10^4	7.5×10^5	8	30	15	60		R2228
–	0.14 [d]	1.9	1250 (26)	5	10	9.5×10^2	5.0×10^5	2000 [e]	5000 [e]	10	50		R316-02
10.5	–	85	1000 (11)	50	120	1.1×10^5	1.3×10^6	2	10	3.4	23		R3998-02

(Unit: mm)

1 R6835, R6836, etc.

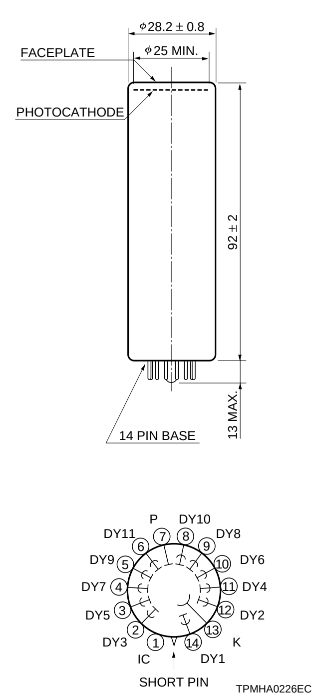
R6835 R6836 R6095 R374 etc.



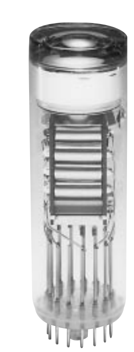
Type No.	R6835 R6836	R6095, R374 R316-02, R2228 R5929 etc.	R6094
Bulb	MgF_2 and Silica bulb	Others	Others
A	φ28.2 ± 0.8	φ28.5 ± 0.5	φ28.5 ± 0.5
B	φ23 MIN.	φ25 MIN.	φ25 MIN.
C	92 ± 2	112 ± 2	92 ± 2

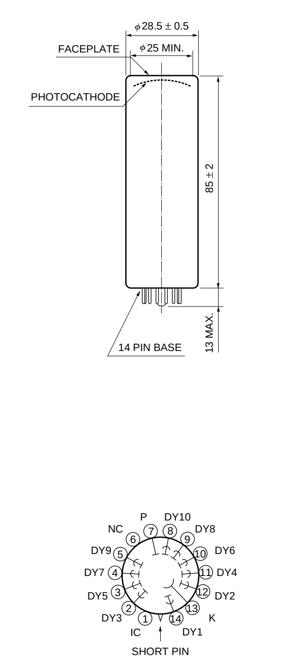
R2228 has a plano-concave faceplate.

2 R6834

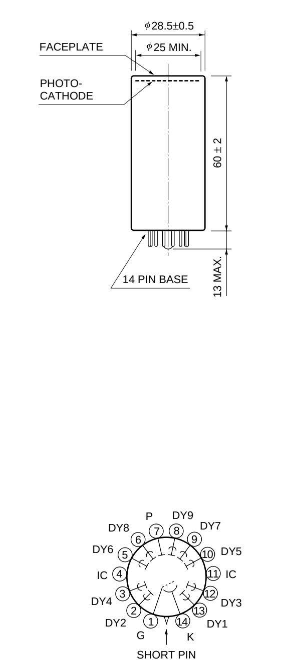


3 R6427





4 R3998-02



Head-On Type Photomultiplier Tubes

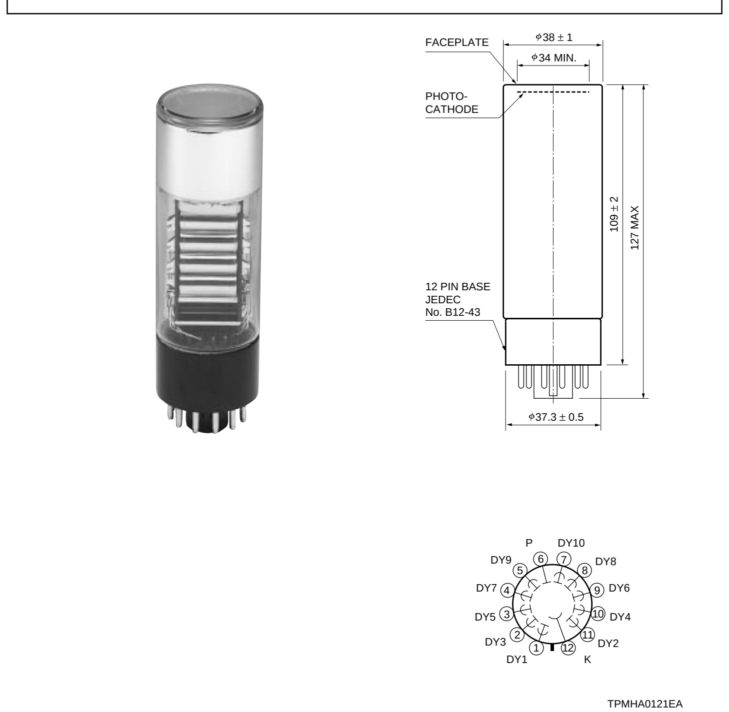
(at 25 °C)

Ⓐ Type No.	Remarks	Spectral Response Ⓑ Curve Code	Spectral Response Range (nm)	Spectral Response Peak Wave-length (nm)	Ⓒ Photo-cathode Material	Ⓓ Window Material	Ⓔ Out-line No.	Ⓕ Dynode Structure / No. of Stages	Ⓖ Socket / Socket Assembly	Maximum Ratings Ⓗ Anode to Cathode Voltage (Vdc)	Maximum Ratings Ⓙ Average Anode Current (mA)	Cathode Sensitivity Luminous Min. (µ A/lm)	Cathode Sensitivity Luminous Typ. (µ A/lm)
38 mm (1-1/2 ") Dia. Types													
R980	For visible range and scintillation counting	400K	300 to 650	420	BA	K	2	CC/10	E678-12A*/27 28	1250	0.1	70	100
R3886	For scintillation counting, low profile	400K	300 to 650	420	BA	K	4	CC/10	E678-12A*/27 28	1250	0.1	70	90
R580	For scintillation counting, fast time response	400K	300 to 650	420	BA	K	1	L/10	E678-12A*/27 28	1750	0.1	70	95
R1705	High temperature, ruggedized type	401K	300 to 650	375	HBA	K	3	CC/10	E678-12A*/27 28	1800	0.02	20	40
R1387	Multialkali photocathode for visible to near IR range	500K (S-20)	300 to 850	420	MA	K	2	CC/10	E678-12A*/27 28	1250	0.2	80	150
R2066	Extended red multialkali photocathode	501K	300 to 900	600	MA	K	2	CC/10	E678-12A*/27 28	1500	0.2	120	200
R1767	For near IR range, QE=0.08 % Typ. at 1.06 µm	700K (S-1)	400 to 1200	800	Ag-O-Cs	K	2	CC/10	E678-12A*/27 28	1500	0.01	10	25

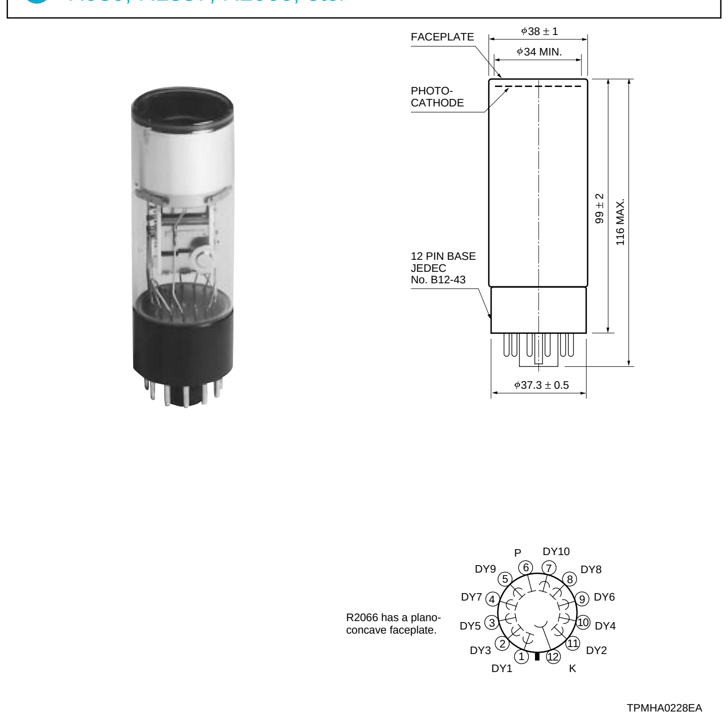
Cathode Sensitivity Blue Sensitivity Index (CS 5-58) Typ.	Cathode Sensitivity Red / White Ratio Typ.	Ⓚ Radiant Typ. (mA/W)	Ⓛ Anode to Cathode Supply Voltage (Vdc)	Ⓜ Anode Characteristics: Anode Sensitivity Luminous Min. (A/lm)	Anode Sensitivity Luminous Typ. (A/lm)	Anode Sensitivity Radiant Typ. (A/W)	Gain Typ.	Anode Dark Current (After 30 min.) Typ. (nA)	Anode Dark Current (After 30 min.) Max. (nA)	Time Response Rise Time Typ. (ns)	Time Response Electron Transit Time Typ. (ns)	Notes	Ⓐ Type No.
11.5	–	90	1000 ⑯	10	35	3.3×10^4	3.7×10^5	3	5	2.8	40		R980
10.5	–	85	1000 ⑯	10	45	4.3×10^4	5.0×10^5	3	5	2.5	32		R3886
11.0	–	88	1250 ⑯	10	100	9.7×10^4	1.1×10^6	3	20	2.7	37		R580
6.0	–	51	1500 ⑯	5	20	2.5×10^4	5.0×10^5	0.5	10	2.0	35		R1705
–	0.2	64	1000 ⑯	10	50	2.1×10^4	3.3×10^5	4	25	2.8	40	UV glass window type: R1508 Synthetic silica window type: R1509	R1387
–	0.3	40	1000 ⑯	20	50	1.0×10^4	2.5×10^5	8	30	2.8	40		R2066
–	0.14ⓓ	2.4	1250 ⑯	1	5	4.8×10^2	2.0×10^5	7000ⓔ	20000ⓔ	2.2	37		R1767

(Unit: mm)

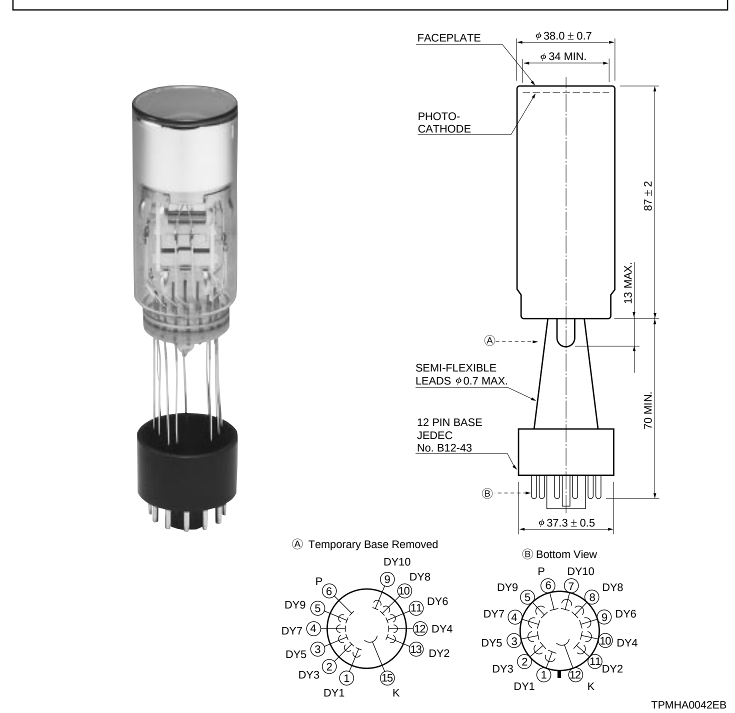
1 R580



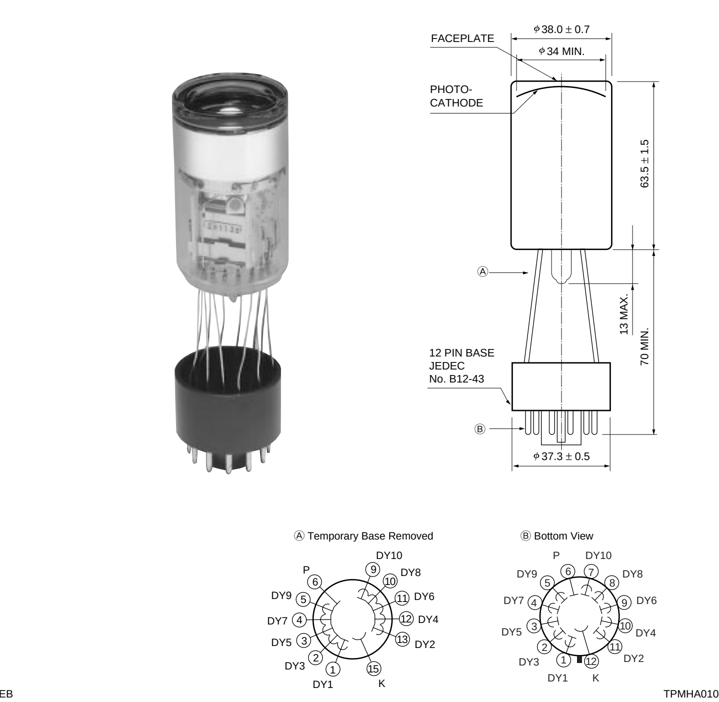
2 R980, R1387, R2066, etc.



3 R1705



4 R3886



Head-On Type Photomultiplier Tubes

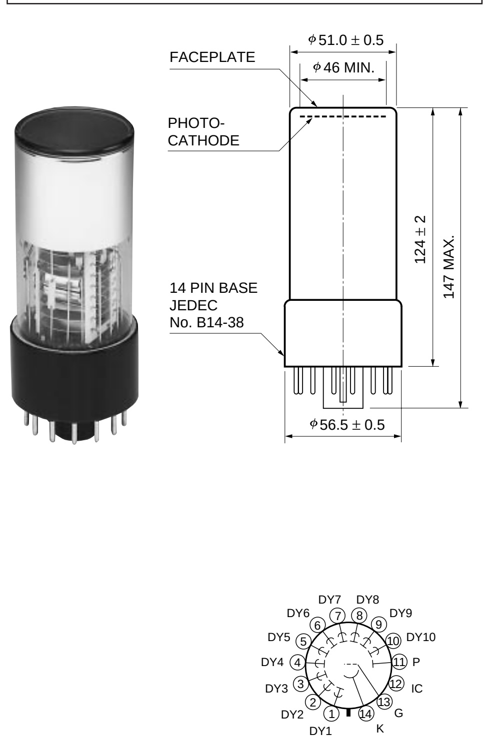
(at 25 °C)

Type No. (A)	Remarks	Spectral Response: Curve Code (B)	Spectral Response: Range (nm)	Spectral Response: Peak Wave-length (nm)	Photo-cathode Material (C)	Window Material (D)	Out-line No. (E)	Dynode Structure / No. of Stages (F)	Socket / Socket Assembly (G)	Maximum Ratings (H): Anode to Cathode Voltage (Vdc)	Maximum Ratings: Average Anode Current (J) (mA)	Cathode Sensitivity: Luminous Min. (µ A/lm)	Cathode Sensitivity: Luminous Typ. (µ A/lm)
51 mm (2 ") Dia. Types with Plastic Base													
R6231	For visible range and scintillation counting, low profile type				BA	K	❹	B + L/8	E678-14V■	1500	0.1	80	110
R1306	For visible range and scintillation counting				BA	K	❸	B/8	E678-14V■/30	1500	0.1	80	110
R2154-02	For visible range and scintillation counting	400K	300 to 650	420	BA	K	❷	L/10	E678-14V■/31	1750	0.1	60	90
R1828-01	For visible range, fast time response				BA	K	❺	L/12	E678-20A★/36	3000	0.2	60	90
R3234-01	For photon counting, fast time response				BA	K	❻	L/12	E678-20A★	2500	0.1	60	80
R550	For visible to near IR range	500K (S-20)	300 to 850		MA	K	❶	B/10	E678-14V■/29 32	1500	0.3	100	150

Type No. (A)	Cathode Sensitivity: Blue Sensitivity Index (CS 5-58) Typ.	Cathode Sensitivity: Red / White Ratio Typ.	Cathode Sensitivity: Radiant Typ. (K) (mA/W)	Anode to Cathode Supply Voltage (L) (Vdc)	Anode Characteristics (M): Anode Sensitivity Luminous Min. (A/lm)	Anode Sensitivity Luminous Typ. (A/lm)	Anode Sensitivity Radiant Typ. (A/W)	Gain Typ.	Anode Dark Current (After 30 min.) Typ. (nA)	Anode Dark Current (After 30 min.) Max. (nA)	Time Response: Rise Time Typ. (ns)	Time Response: Electron Transit Time Typ. (ns)	Notes
R6231	12.0	–	95	1000 ⑧	3	30	2.6×10^4	2.7×10^5	2	20	5.0	48	For gamma cameras: R6231-01
R1306	12.0	–	95	1000 ②	3	30	2.6×10^4	2.7×10^5	2	20	7.0	60	Synthetic silica window type : R2220
R2154-02	10.5	–	85	1250 ⑯	20	90	8.5×10^4	1.0×10^6	5	20	3.4	31	Multialkali photocathode type : R3256
R1828-01	10.5	–	85	2500 ㉜	200	1800	1.7×10^6	2.0×10^7	50	400	1.3	28	Synthetic silica window type : R2059
R3234-01	9.0	–	72	2000 ㊲	500	2000	2.0×10^6	2.5×10^7	1	10	1.3	28	Synthetic silica type: R3235-01 Multialkali type: R3237-01
R550	–	0.2	64	1000 ⑭	20	100	4.3×10^4	6.7×10^5	10	30	9.0	70	

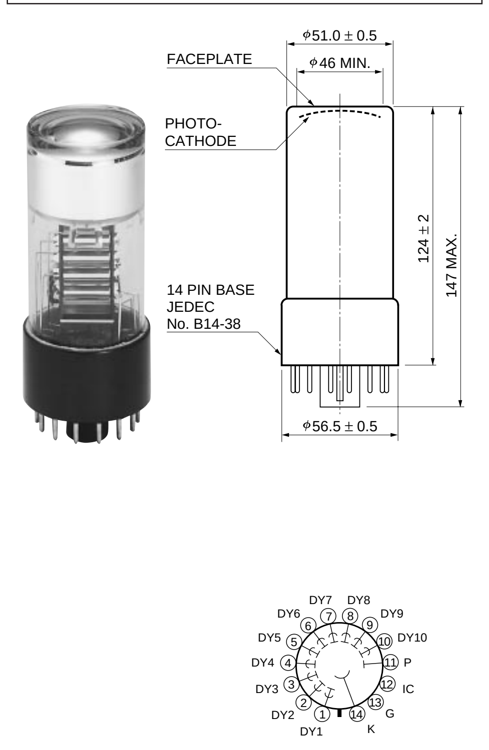
(Unit: mm)

❶ R550



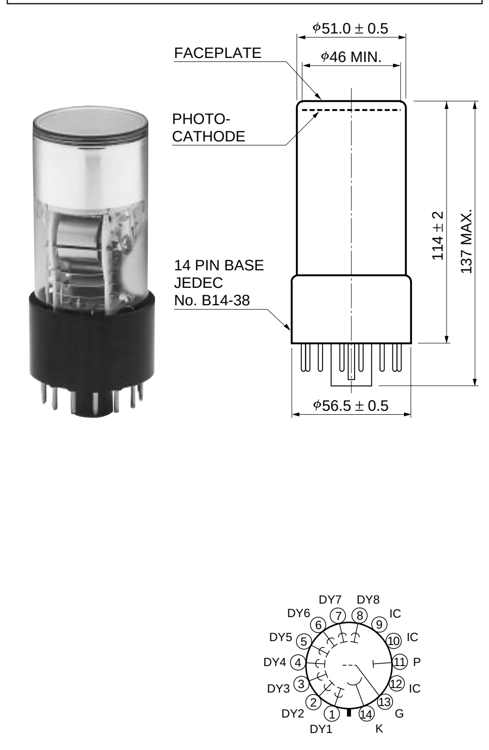
TPMHA0210EB

❷ R2154-02



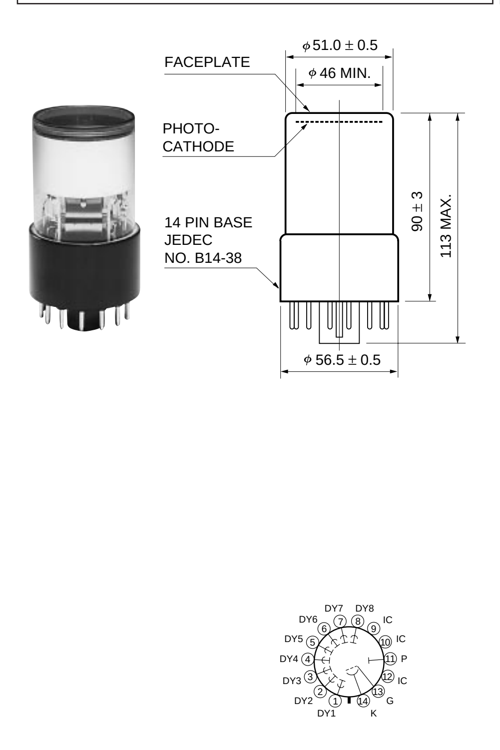
TPMHA0296EA

❸ R1306



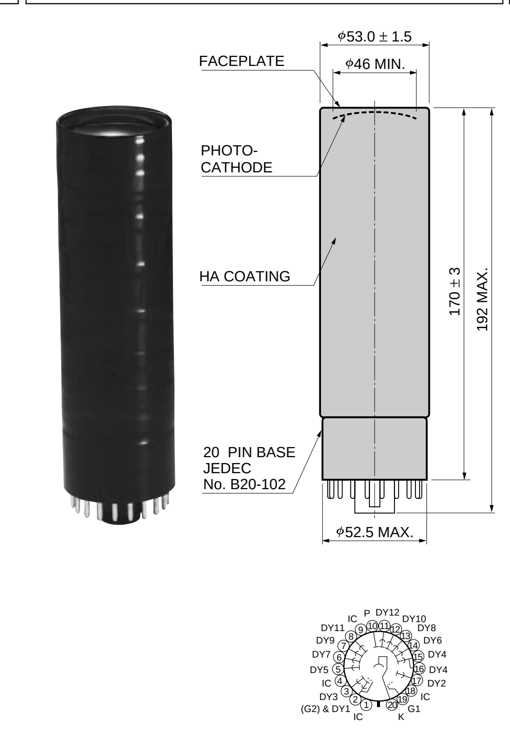
TPMHA0089EB

❹ R6231



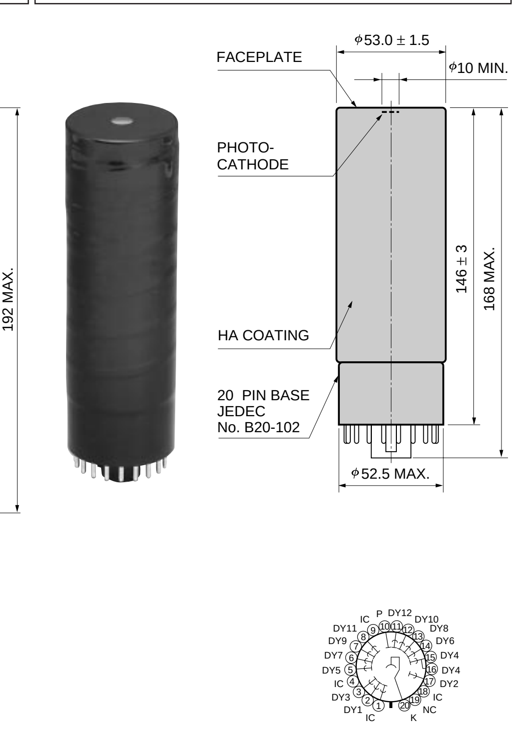
TPMHA0388EB

❺ R1828-01



TPMHA0064EC

❻ R3234-01



TPMHA0004EB

Head-On Type Photomultiplier Tubes

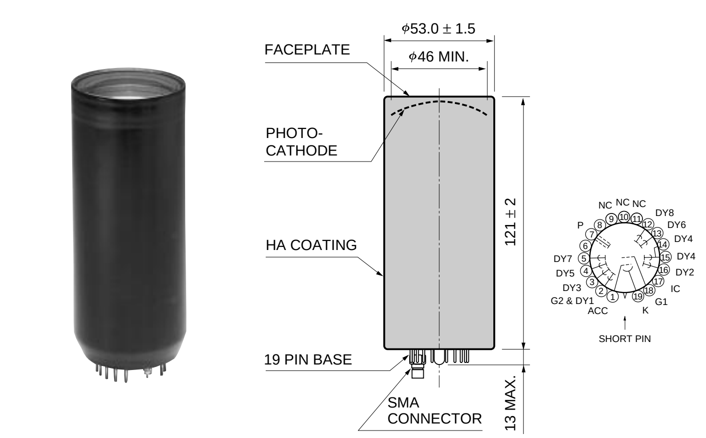
(at 25 °C)

Type No. (A)	Remarks	Spectral Response: Curve Code (B)	Spectral Response: Range (nm)	Spectral Response: Peak Wavelength (nm)	Photocathode Material (C)	Window Material (D)	Outline No. (E)	Dynode Structure / No. of Stages (F)	Socket / Socket Assembly (G)	Maximum Ratings (H): Anode to Cathode Voltage (Vdc)	Maximum Ratings: Average Anode Current (J) (mA)	Cathode Sensitivity: Luminous Min. (µ A/lm)	Cathode Sensitivity: Luminous Typ. (µ A/lm)
51 mm (2 ") Dia. Types with Glass Base													
R464	For photon counting in visible range	400K	300 to 650	420	BA	K	4	B/12	E678-21A*/35 37	1500	0.01	30	50
R329-02	For visible range and scintillation counting	400K	300 to 650	420	BA	K	2	L/12	E678-21A*/34 38	2700	0.2	60	90
R331-05	For visible range and liquid scintillation counting	400K	300 to 650	420	BA	K	3	L/12	E678-21A*/34 38	2500	0.2	60	90
R2083	For visible range, fast time response	400K	300 to 650	420	BA	K	1	L/8	E678-19F*	3500	0.2	60	80
R5496	For visible range, fast time response	400K	300 to 650	420	BA	K	6	L/10	E678-19E*	3000	0.2	60	80
R4607-01	High temperature, ruggedized type	401K	300 to 650	375	HBA	K	5	CC/10	E678-15B*	1800	0.02	20	40
R649	For photon counting in visible to near IR range	500K (S-20)	300 to 850	420	MA	K	4	B/12	E678-21A*/35 37	1500	0.01	80	120

Type No. (A)	Cathode Sensitivity: Blue Sensitivity Index (CS 5-58) Typ.	Cathode Sensitivity: Red / White Ratio Typ.	Cathode Sensitivity: Radiant Typ. (K) (mA/W)	Anode to Cathode Supply Voltage (L) (Vdc)	Anode Characteristics (M): Anode Sensitivity Luminous Min. (A/lm)	Anode Sensitivity Luminous Typ. (A/lm)	Anode Sensitivity Radiant Typ. (A/W)	Gain Typ.	Anode Dark Current (After 30 min.) Typ. (nA)	Anode Dark Current (After 30 min.) Max. (nA)	Time Response: Rise Time Typ. (ns)	Time Response: Electron Transit Time Typ. (ns)	Notes
R464	–	–	50	1000 (35)	100	300	3.0×10^5	6.0×10^6	5 (h)	15 (h)	13	70	Synthetic silica window type: R585
R329-02	10.5	–	85	1500 (34)	30	100	9.4×10^4	1.1×10^6	6	40	2.6	48	UV glass window type: R5113-02 Synthetic silica window type: R2256-02
R331-05	10.5	–	85	1500 (34)	30	120	1.1×10^5	1.3×10^6	18 (k)	25 (k)	2.6	48	Synthetic silica window type: R331
R2083	10.0	–	80	3000 (3)	50	200	2.0×10^5	2.5×10^6	100	800	0.7	16	Use of PMT assembly (H2431-50) is recommended. (See P.75)
R5496	10.0	–	80	2500 (22)	100	1000	1.0×10^6	1.3×10^7	100	800	1.5	24	TTS: 270 ps
R4607-01	6.0	–	51	1500 (16)	5	20	2.5×10^4	5.0×10^5	3	50	2.5	29	
R649	–	0.2	51	1000 (35)	100	800	3.4×10^5	6.7×10^6	200 (h)	350 (h)	13	70	

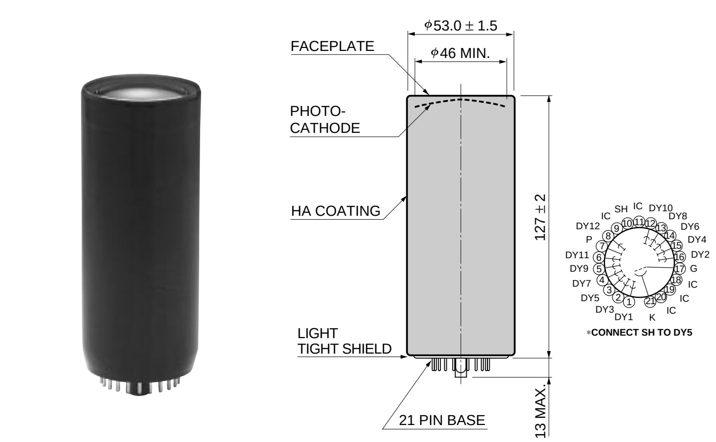
(Unit: mm)

1 R2083



TPMHA0185EC

2 R329-02



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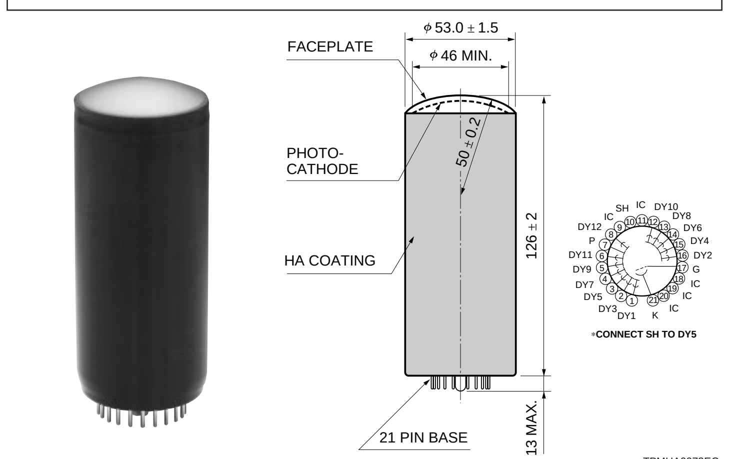
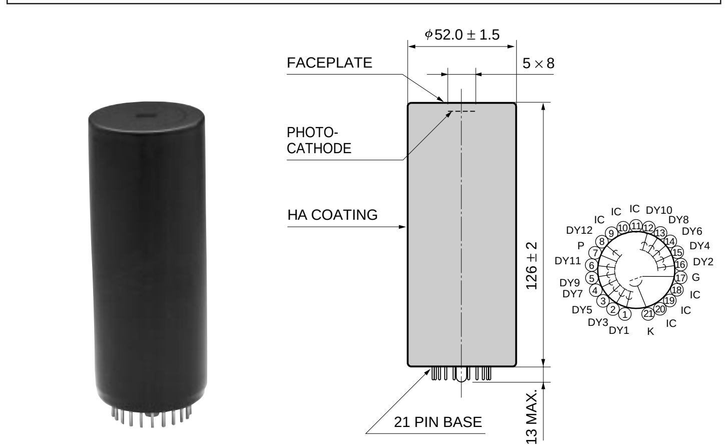
3 R331-05



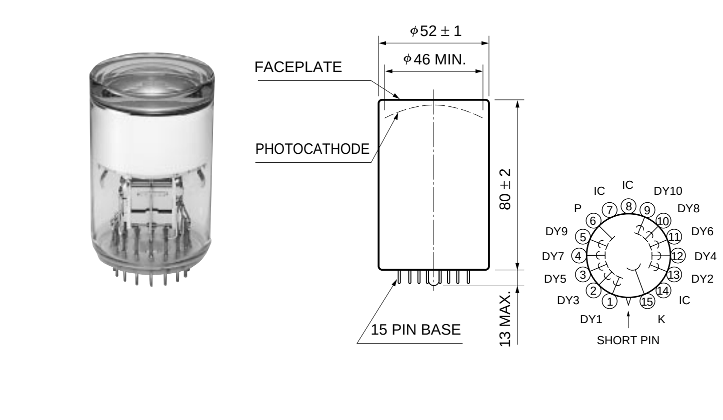
TPMHA0072EC

4 R464, R649



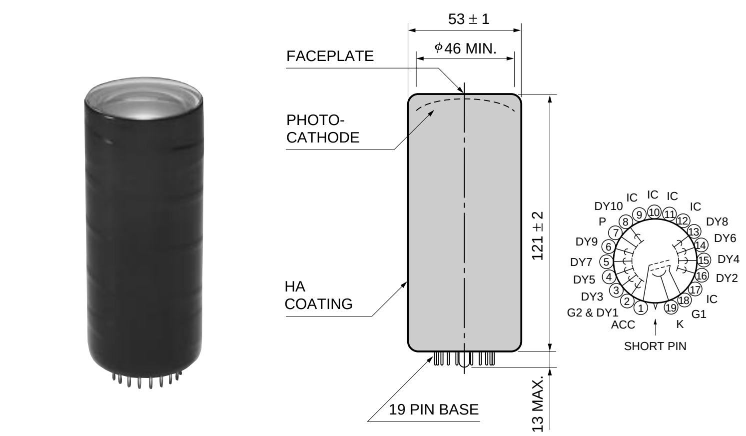
TPMHA0216EA

5 R4607-01



TPMHA0003EC

6 R5496



TPMHA0168EC

Head-On Type Photomultiplier Tubes

(at 25 °C)

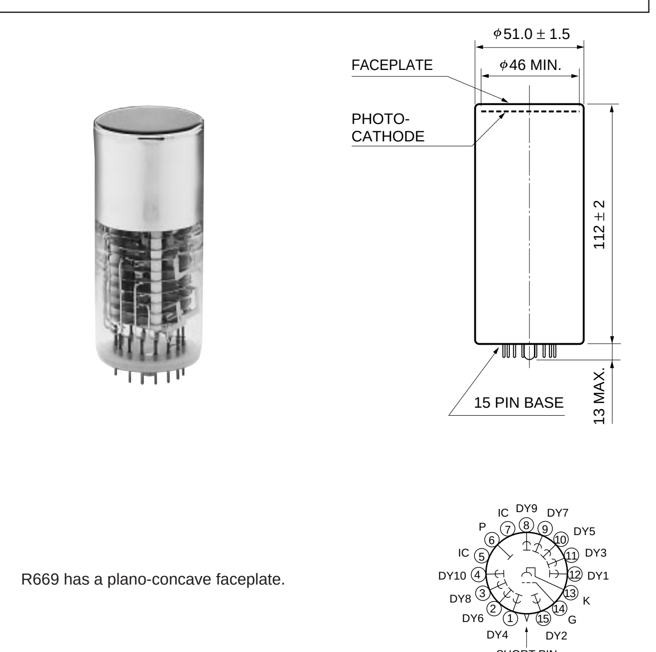
Type No. (A)	Remarks	Spectral Response: Curve Code (B)	Spectral Response: Range (nm)	Spectral Response: Peak Wave-length (nm)	Photo-cathode Material (C)	Window Material (D)	Out-line No. (E)	Dynode Structure / No. of Stages (F)	Socket / Socket Assembly (G)	Maximum Ratings (H): Anode to Cathode Voltage (Vdc)	Maximum Ratings: Average Anode Current (J) (mA)	Cathode Sensitivity Luminous Min. (µ A/lm)	Cathode Sensitivity Luminous Typ. (µ A/lm)
51 mm (2 ") Dia. Types with Glass Base													
R375	Multialkali photocathode for UV to near IR range	500S	160 to 850	420	MA	Q	1	B/10	E678-15B*/40	1500	0.1	80	150
R669	Extended red multialkali photocath-ode	501K	300 to 900	600	EMA	K	1	B/10	E678-15B*/40	1500	0.1	140	230
R943-02	GaAs photocathode for UV to 930 nm range	650S	160 to 930	300 to 800	GaAs(Cs)	Q	3	L/10	(Note) E678-21C*/33 39	2200	0.001	300	600
R3310-02	InGaAs photocathode for 300 nm to 1040 nm range	851K	300 to 1040	400	InGaAs	K	3	L/10	(Note) E678-21C*/33 39	2200	0.001	80	150
R2257	Extended red multialkali photocath-ode	501K	300 to 900	600	EMA	K	2	L/12	E678-21A*/34	2700	0.2	140	230

Cathode Sensitivity: Blue Sensitivity Index (CS 5-58) Typ.	Red / White Ratio Typ.	Radiant (K) Typ. (mA/W)	Anode to Cathode Supply Voltage (L) (Vdc)	Anode Characteristics (M): Anode Sensitivity Luminous Min. (A/lm)	Anode Sensitivity Luminous Typ. (A/lm)	Anode Sensitivity Radiant Typ. (A/W)	Gain Typ.	Anode Dark Current (After 30 min.) Typ. (nA)	Anode Dark Current Max. (nA)	Time Response: Rise Time Typ. (ns)	Time Response: Electron Transit Time Typ. (ns)	Notes	Type No. (A)
–	0.2	64	1000 (14)	20	80	3.4×10^4	5.3×10^5	5	20	9.0	70		R375
–	0.35	50	1000 (14)	20	75	1.7×10^4	3.3×10^5	7	15	9.0	70		R669
–	0.58	71	1500 (20)	150	300	3.6×10^4	5.0×10^5	20 (j)	50 (j)	3.0	23		R943-02
–	0.4	9.4 (at 852.1 nm)	1500 (20)	15	50	3.1×10^3 (at 852.1nm)	3.3×10^5	30 (j)	150 (j)	3.0	23		R3310-02
–	0.35	50	1500 (34)	15	100	2.2×10^4	4.3×10^5	30	100	2.6	48		R2257

(Note) For cooling operation, another ceramic socket, type number E678-21D (option) is recommended.

(Unit: mm)

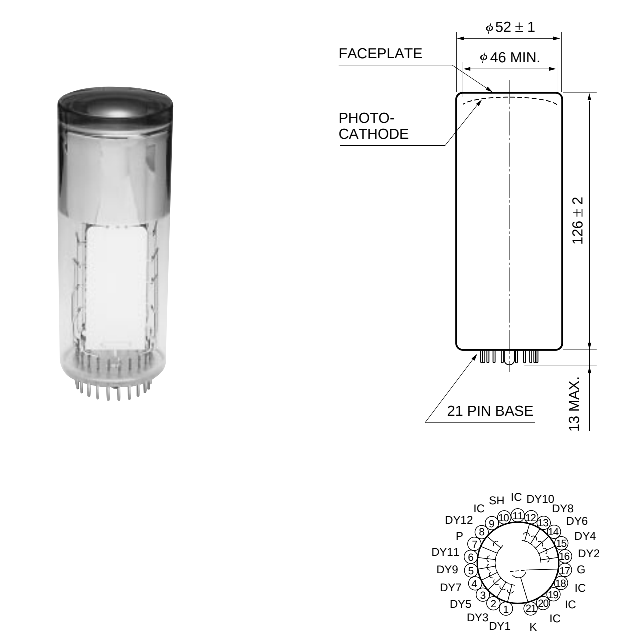
1 R375, R669



R669 has a plano-concave faceplate.

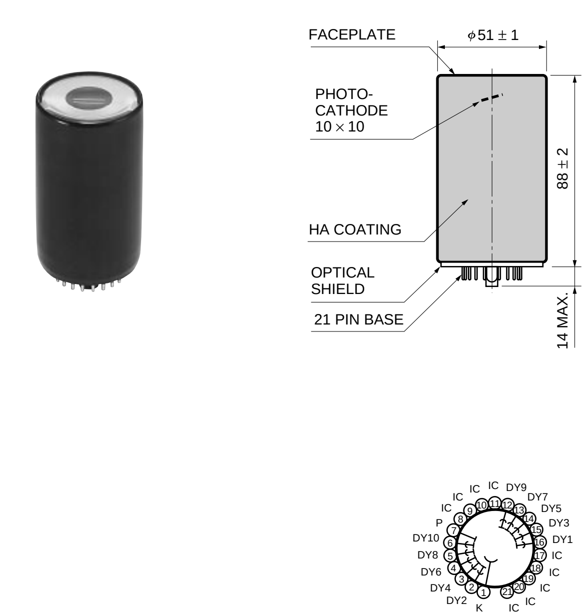
TPMHA0211EA

2 R2257



TPMHA0359EA

3 R943-02, R3310-02



TPMHA0021EC

Head-On Type Photomultiplier Tubes

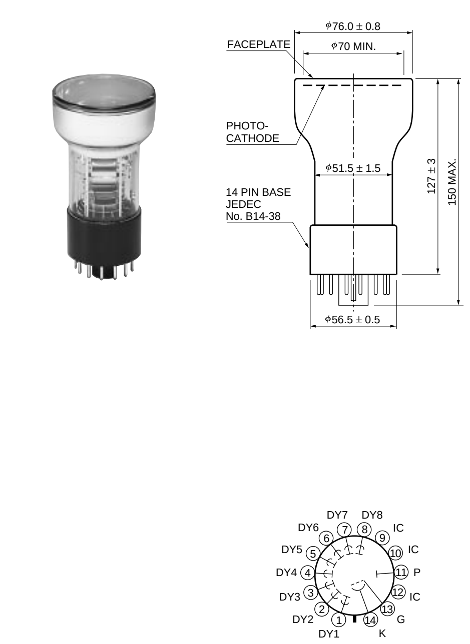
(at 25 °C)

Type No. (A)	Remarks	Spectral Response: Curve Code (B)	Spectral Response: Range (nm)	Spectral Response: Peak Wave-length (nm)	Photo-cathode Material (C)	Window Material (D)	Out-line No. (E)	Dynode Structure / No. of Stages (F)	Socket / Socket Assembly (G)	Maximum Ratings (H): Anode to Cathode Voltage (Vdc)	Maximum Ratings: Average Anode Current (J) (mA)	Cathode Sensitivity Luminous Min. (µ A/lm)	Cathode Sensitivity Luminous Typ. (µ A/lm)
76 mm (3 ") Dia. Types													
R1307	For scintillation counting, 8-stage dynodes	400K	300 to 650	420	BA	K	1	B/8	E678-14V■/30	1500	0.1	80	110
R6233	For scintillation counting, low profile type				BA	K	2	B + L/8	E678-14V■	1500	0.1	80	110
R6091	For scintillation counting, 12-stage dynodes				BA	K	3	L/12	E678-21A*	2500	0.2	60	90
127 mm (5 ") Dia. Types													
R877	For scintillation counting, 10-stage dynodes	400K	300 to 650	420	BA	K	4	B/10	E678-14V■/29 32	1500	0.1	60	80
R1250	For scintillation counting, 14-stage dynodes, fast time response				BA	K	5	L/14	E678-20A*/42 43	3000	0.2	55	70
R1513	For visible to near IR, variant of R877 with venetian blind dynodes	500K (S-20)	300 to 850		MA	K	4	VB/10	E678-14V■/29 32	2000	0.1	100	150
R1584	For scintillation counting,14-stage dynodes, fast time response	400U	185 to 650		BA	U	6	L/14	E678-20A*	3000	0.2	55	70

Cathode Sensitivity: Blue Sensitivity Index (CS 5-58) Typ.	Cathode Sensitivity: Red / White Ratio Typ.	Cathode Sensitivity: Radiant Typ. (K) (mA/W)	Anode to Cathode Supply Voltage (L) (Vdc)	Anode Characteristics (M): Anode Sensitivity Luminous Min. (A/lm)	Anode Sensitivity Luminous Typ. (A/lm)	Anode Sensitivity Radiant Typ. (A/W)	Gain Typ.	Anode Dark Current (After 30 min.) Typ. (nA)	Anode Dark Current Max. (nA)	Time Response: Rise Time Typ. (ns)	Time Response: Electron Transit Time Typ. (ns)	Notes	Type No. (A)
12.0	–	95	1000 (2)	3	30	2.6×10^4	2.7×10^5	2	20	8.0	64	K-free borosilicate glass type: R1307-07 For gamma cameras: R1307-01	R1307
12.0	–	95	1000 (8)	3	30	2.6×10^4	2.7×10^5	2	20	6.0	52	For gamma cameras: R6233-01	R6233
10.5	–	85	1500 (34)	50	450	4.3×10^5	5.0×10^6	10	60	2.6	48		R6091
10.0	–	80	1250 (14)	20	40	4.0×10^4	5.0×10^5	10	50	10.0	90	K-free borosilicate glass type: R877-01	R877
9.0	–	72	2000 (40)	300	1000	1.0×10^6	1.4×10^7	50	300	2.5	54	8-stage dynode type: R4144	R1250
–	0.2	64	1500 (14)	10	50	2.1×10^4	3.3×10^5	30	150	7.0	82		R1513
9.0	–	72	2000 (40)	300	1000	1.0×10^6	1.4×10^7	50	300	2.5	54		R1584

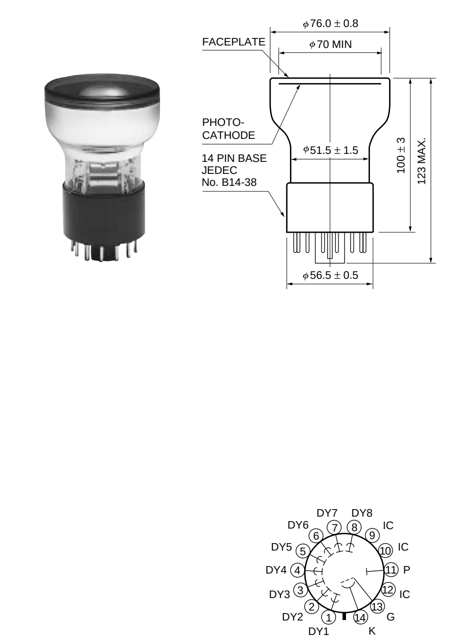
(Unit: mm)

1 R1307



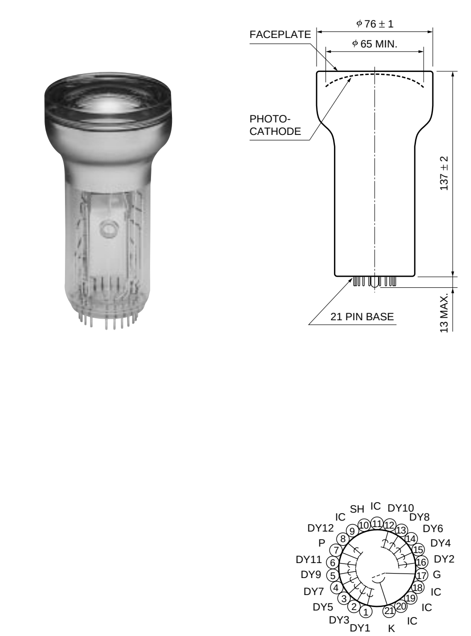
TPMHA0078EA

2 R6233



TPMHA0389EB

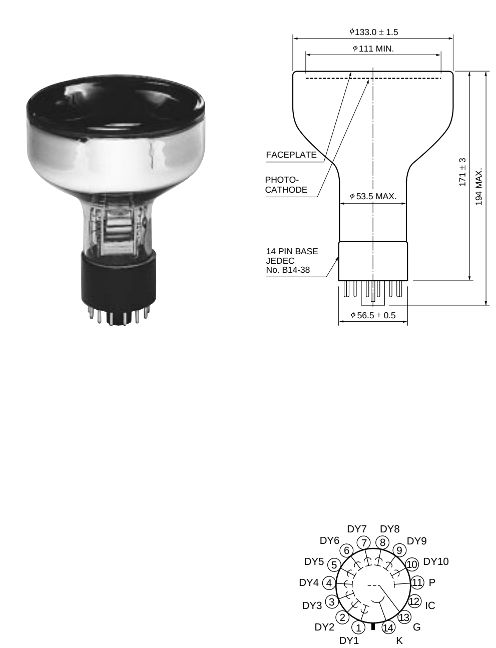
3 R6091



* CONNECT SH TO DY5

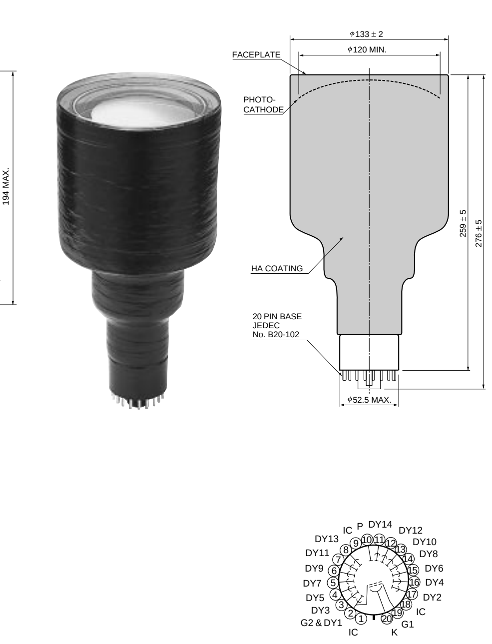
TPMHA0285EB

4 R877, R1513



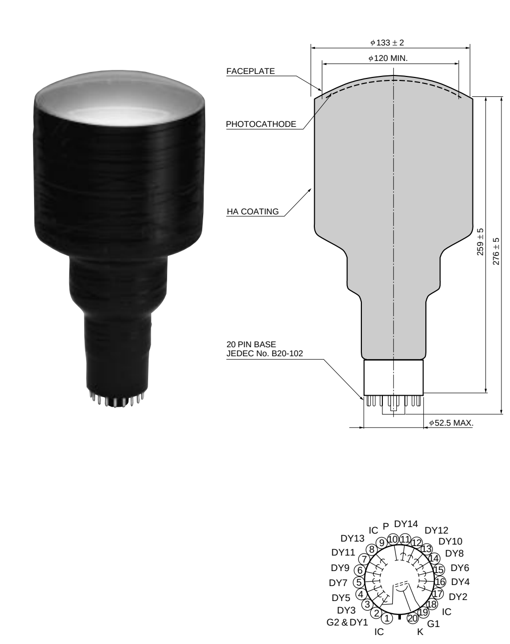
TPMHA0074EB

5 R1250



TPMHA0018EA

6 R1584



TPMHA0187EB

Hemispherical Envelope Photomultiplier Tubes

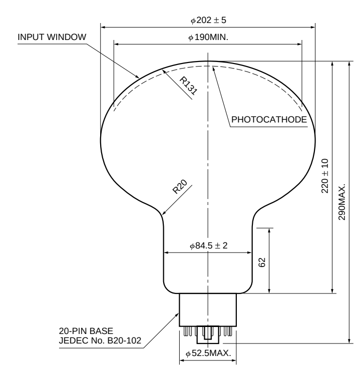
(at 25 °C)

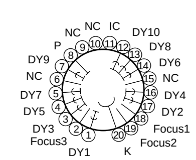
Type No. (A)	Remarks	Spectral Response: Curve Code (B)	Spectral Response: Range (nm)	Spectral Response: Peak Wave-length (nm)	Photo-cathode Material (C)	Window Material (D)	Out-line No. (E)	Dynode Structure / No. of Stages (F)	Socket / Socket Assembly (G)	Maximum Ratings (H): Anode to Cathode Voltage (Vdc)	Maximum Ratings: Average Anode Current (J) (mA)	Cathode Sensitivity Luminous Min. (µ A/lm)	Cathode Sensitivity Luminous Typ. (µ A/lm)
Hemispherical Envelope Types													
R5912	For high energy physics research, 8 " dia.	400K	300 to 650	420	BA	K	1	B + L/10	E678-20A*	1800	0.1	–	70
R3600-02	For high energy physics research, 20 " dia.	400K	300 to 650	420	BA	K	2	VB/11	E678-20A*	2500	0.1	–	60

Type No. (A)	Cathode Sensitivity: Blue Sensitivity Index (CS 5-58) Typ.	Cathode Sensitivity: Radiant Typ. (K) (mA/W)	Anode to Cathode Supply Voltage (L) (Vdc)	Anode Characteristics (M): Anode Sensitivity Luminous Min. (A/lm)	Anode Sensitivity Luminous Typ. (A/lm)	Anode Sensitivity Radiant Typ. (A/W)	Gain Typ.	Anode Dark Current (After 30 min.) Typ. (nA)	Anode Dark Current (After 30 min.) Max. (nA)	Time Response: Rise Time Typ. (ns)	Time Response: Electron Transit Time Typ. (ns)	Notes
R5912	9.0	72	1500 (25)	–	700	7.2×10^5	1.0×10^7	50	700	3.8	55	
R3600-02	8.0	65	2000 (29)	–	600	6.5×10^5	1.0×10^7	200	1000	10	95	

(Unit: mm)

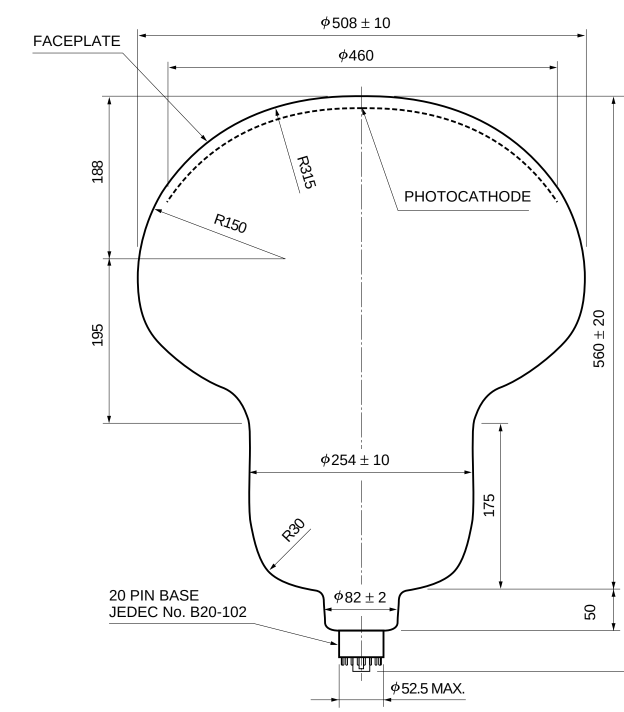
1 R5912

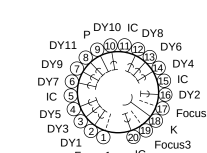




TPMHA0261EB

2 R3600-02





TPMHA0218EB

Special Envelope Photomultiplier Tubes

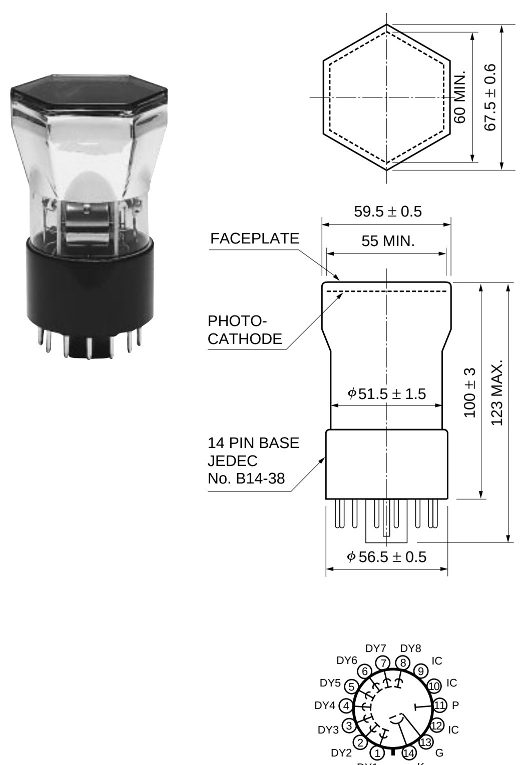
(at 25 °C)

Type No. (A)	Remarks	Spectral Response (B) Curve Code	Spectral Response Range (nm)	Spectral Response Peak Wavelength (nm)	(C) Photocathode Material	(D) Window Material	(E) Outline No.	(F) Dynode Structure / No. of Stages	(G) Socket / Socket Assembly	Maximum Ratings (H) Anode to Cathode Voltage (Vdc)	Maximum Ratings (J) Average Anode Current (mA)	Cathode Sensitivity Luminous Min. (µA/lm)	Cathode Sensitivity Luminous Typ. (µA/lm)
R6234	For scintillation counting, 60 mm dia. hexagonal faceplate, low profile	400K	300 to 650	420	BA	K	1	B + L/8	E678-14V■	1500	0.1	80	110
R6236	For scintillation counting, 60 mm × 60 mm square faceplate, low profile	400K	300 to 650	420	BA	K	2	B + L/8	E678-14V■	1500	0.1	80	110
R6235	For scintillation counting, 76 mm dia. hexagonal faceplate	400K	300 to 650	420	BA	K	3	B + L/8	E678-14V■	1500	0.1	80	110
R6237	For scintillation counting, 76 mm × 76 mm square faceplate, low profile	400K	300 to 650	420	BA	K	4	B + L/8	E678-14V■	1500	0.1	80	110

Type No. (A)	Cathode Sensitivity Blue Sensitivity Index (CS 5-58) Typ.	Cathode Sensitivity (K) Radiant Typ. (mA/W)	(L) Anode to Cathode Supply Voltage (Vdc)	Anode Characteristics (M) Anode Sensitivity Luminous Min. (A/lm)	Anode Sensitivity Luminous Typ. (A/lm)	Anode Sensitivity Radiant Typ. (A/W)	Gain Typ.	Anode Dark Current (After 30 min.) Typ. (nA)	Anode Dark Current (After 30 min.) Max. (nA)	Time Response Rise Time Typ. (ns)	Time Response Electron Transit Time Typ. (ns)	Notes
R6234	12.0	95	1000 (8)	3	30	2.6×10^4	2.7×10^5	2	20	6.0	52	For gamma cameras: R6234-01
R6236	12.0	95	1000 (8)	3	30	2.6×10^4	2.7×10^5	2	20	6.0	52	For gamma cameras: R6236-01
R6235	12.0	95	1000 (8)	3	30	2.6×10^4	2.7×10^5	2	20	6.0	52	For gamma cameras: R6235-01
R6237	12.0	95	1000 (8)	3	30	2.6×10^4	2.7×10^5	2	20	6.0	52	For gamma cameras: R6237-01

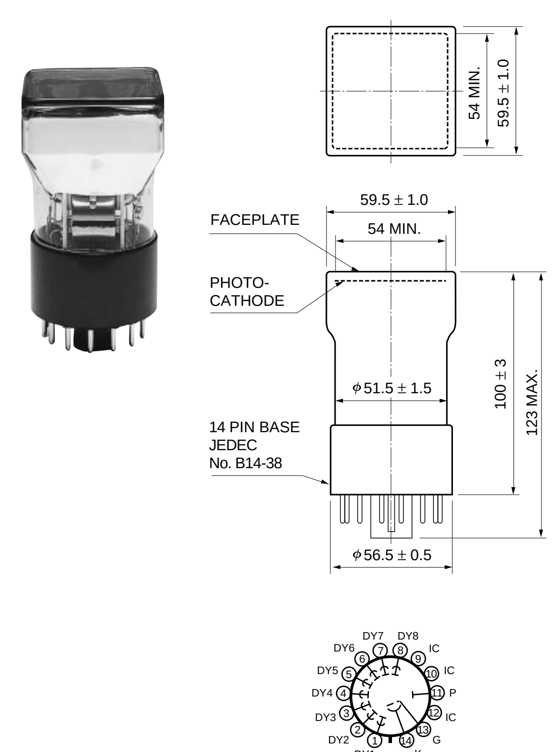
(Unit: mm)

1 R6234



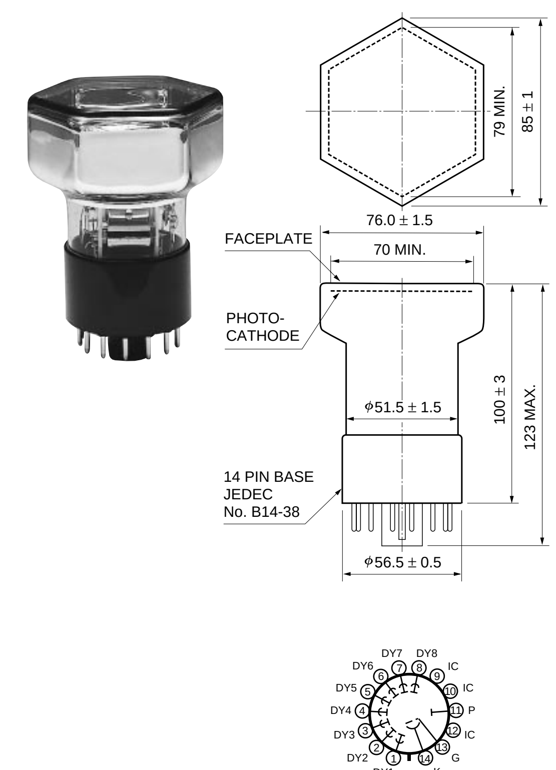
TPMHA0390EB

2 R6236



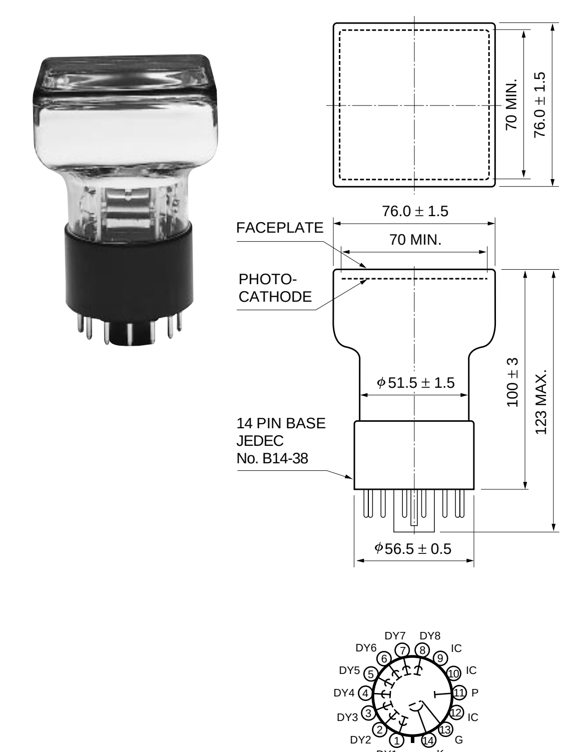
TPMHA0392EB

3 R6235



TPMHA0391EB

4 R6237



TPMHA0393EB

Special Envelope Photomultiplier Tubes

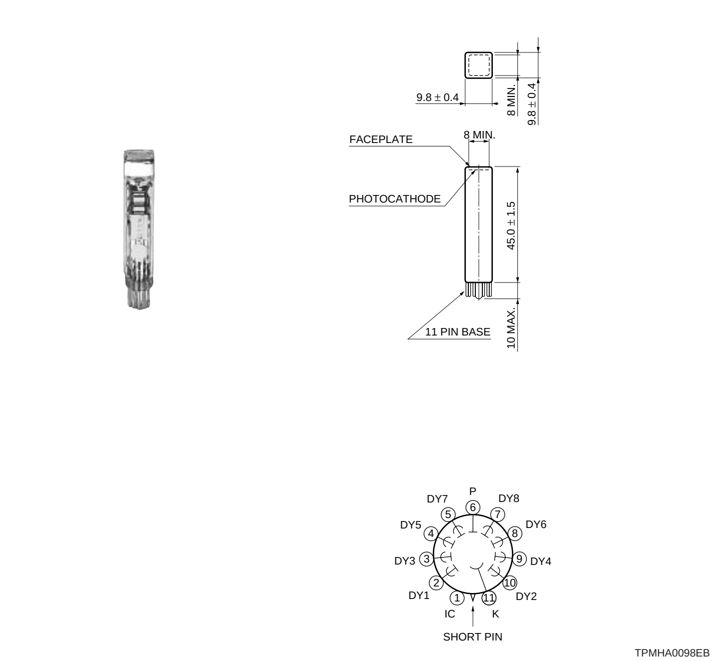
(at 25 °C)

Type No. (A)	Remarks	Spectral Response (B) Curve Code	Spectral Response Range (nm)	Spectral Response Peak Wavelength (nm)	(C) Photocathode Material	(D) Window Material	(E) Outline No.	(F) Dynode Structure / No. of Stages	(G) Socket / Socket Assembly	Maximum Ratings (H) Anode to Cathode Voltage (Vdc)	Maximum Ratings (J) Average Anode Current (mA)	Cathode Sensitivity Luminous Min. (µ A/lm)	Cathode Sensitivity Luminous Typ. (µ A/lm)
R2248	10 mm × 10 mm square envelope	400K	300 to 650	420	BA	K	1	L/8	E678-11N*/4	1500	0.03	60	95
R2102	13 mm × 13 mm square envelope	400K	300 to 650	420	BA	K	2	L/10	E678-13A*/7	1250	0.1	40	100
R2497	25 mm × 25 mm square envelope	400K	300 to 650	420	BA	K	3	L/10	E678-12A*	1800	0.1	70	115
R1548	Rectangular dual structure in single envelope	400K	300 to 650	420	BA	K	4	L/10	E678-17A*	1750	0.1	60	80

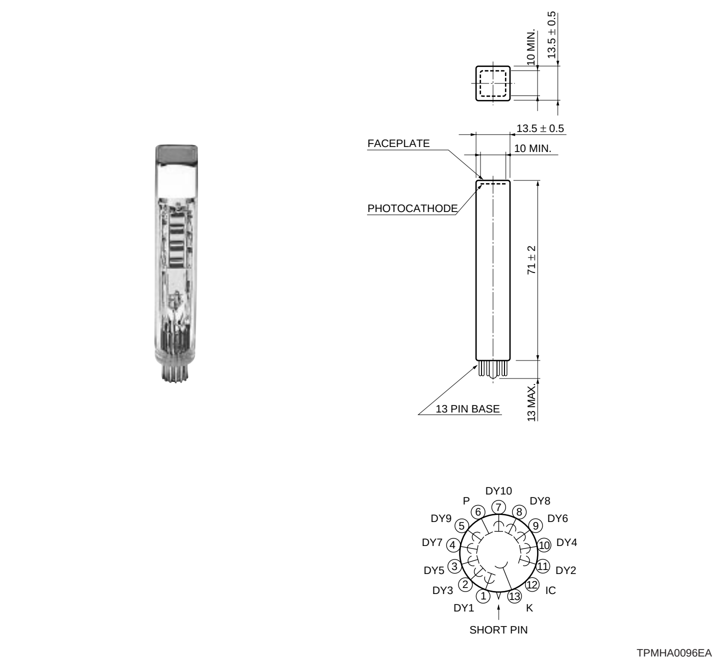
Type No. (A)	Cathode Sensitivity Blue Sensitivity Index (CS 5-58) Typ.	Cathode Sensitivity (K) Radiant Typ. (mA/W)	(L) Anode to Cathode Supply Voltage (Vdc)	Anode Characteristics (M) Anode Sensitivity Luminous Min. (A/lm)	Anode Sensitivity Luminous Typ. (A/lm)	Anode Sensitivity Radiant Typ. (A/W)	Gain Typ.	Anode Dark Current (After 30 min.) Typ. (nA)	Anode Dark Current (After 30 min.) Max. (nA)	Time Response Rise Time Typ. (ns)	Time Response Electron Transit Time Typ. (ns)	Notes
R2248	9.5	76	1250 (1)	30	100	8.0×10^4	1.1×10^6	1	50	0.9	9	
R2102	9.5	76	1000 (13)	30	100	7.6×10^4	1.0×10^6	1	15	2.5	24	
R2497	11.0	88	1500 (19)	50	300	2.3×10^5	2.6×10^6	10	100	2.4	22	
R1548	9.5	76	1250 (21)	50	200	1.9×10^5	2.5×10^6	20	250	1.8	20	Flying lead type: R1548-02

(Unit: mm)

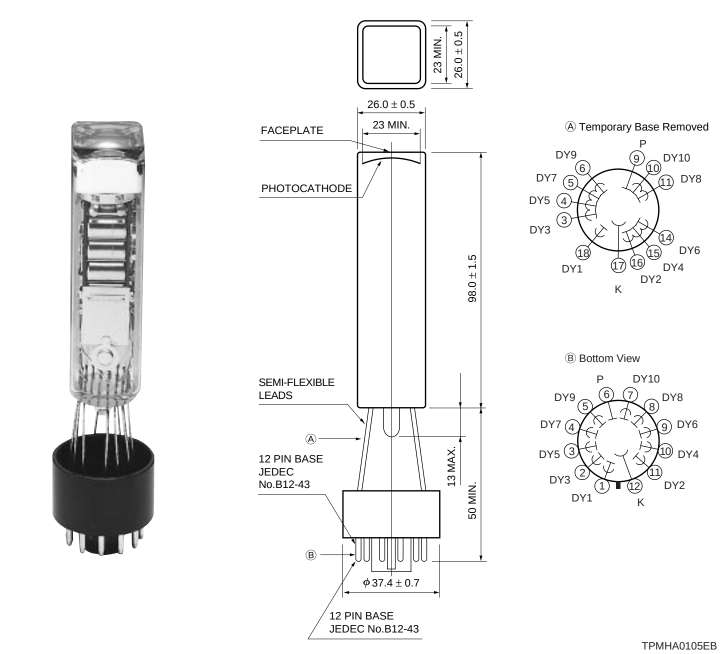
1 R2248



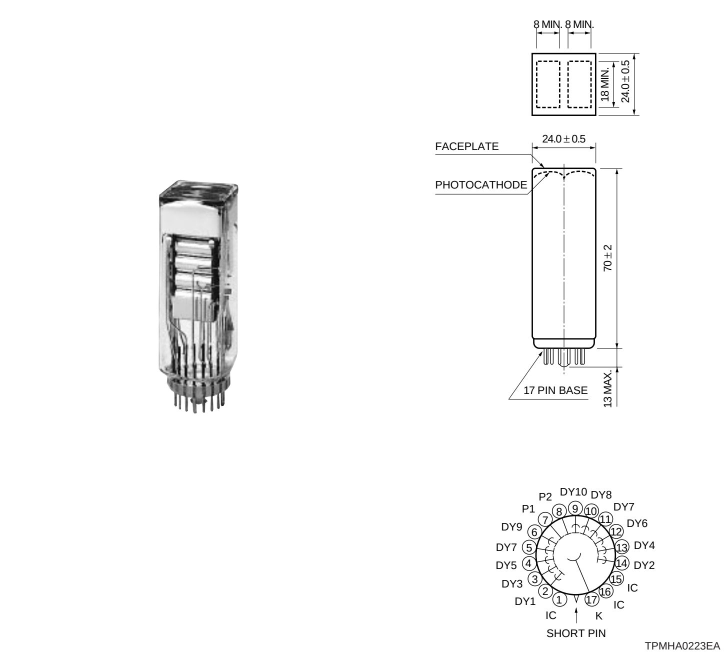
2 R2102



3 R2497



4 R1548



Tubes for Highly Magnetic Environments

(at 25 °C)

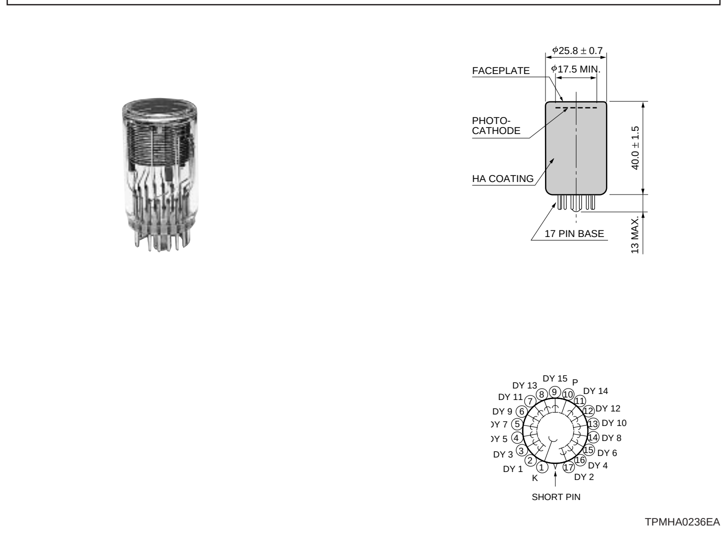
Type No. (A)	Tube Diameter mm (inch)	Outline No.	Spectral Response: Curve code (B)	Spectral Response: Range (nm)	Spectral Response: Peak Wavelength (nm)	Dynode Structure / No. of Stages (F)	Socket / Socket Assembly (G)	Maximum Ratings (H): Anode to Cathode Voltage (V)	Maximum Ratings (H): Average Anode Current (mA)	Cathode Sensitivity: Quantum Efficiency at 390nm Typ. (%) (J)	Cathode Sensitivity: Luminous Typ. (µ A/lm)
High Gain Types											
R5505	25/(1)	1				FM/15	E678-17A*/44	2300	0.01	23	80
R5946	38/(1.5)	2				FM/16	E678-19D	2300	0.01	23	80
R5924	51/(2)	3	400K	300 to 650	420	FM/19	–	2300	0.1	22	70
R6504	64/(2.5)	4				FM/19	–	2300	0.1	22	70
R5542	78/(3)	5				FM/19	–	2300	0.1	22	70

Cathode Sensitivity: Blue Sensitivity Index (CS 5-58) Typ.	Anode to Cathode Supply Voltage (V) (L)	Anode Characteristics (M): Anode Luminous Sensitivity Typ. (A/lm)	Gain at 0 tesla Typ.	Gain at 0.5 tesla Typ.	Gain at 1.0 tesla Typ.	Anode Dark Current (After 30 min.) Typ. (nA)	Anode Dark Current (After 30 min.) Max. (nA)	Time Response: Rise Time Typ. (ns)	Time Response: Electron Transit Time Typ. (ns)	Notes	Type No. (A)
9.5	2000 (41)	40	5×10^5	2.3×10^5	1.8×10^4	5	30	1.5	5.6	Assembly type :H6152-01	R5505
9.5	2000 (42)	80	1×10^6	4.3×10^5	2.9×10^4	5	30	1.9	7.2	Assembly type :H6153-01	R5946
9.0	2000 (43)	700	1×10^7	4.1×10^6	2.5×10^5	30	200	2.5	9.5	Assembly type :H6614-01	R5924
9.0	2000 (43)	700	1×10^7	4.1×10^6	2.0×10^5	50	300	2.7	11.0		R6504
9.0	2000 (43)	600	1×10^7	3.0×10^6	1.7×10^5	80	400	2.9	12.3	Assembly type :H6155-01	R5542

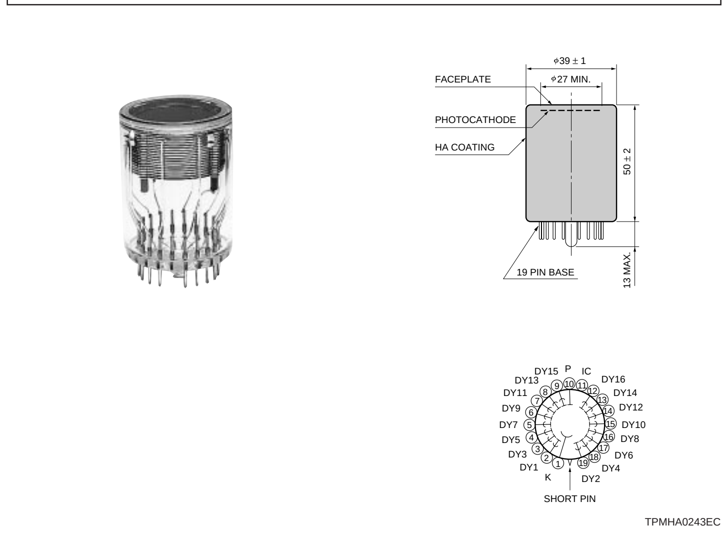
These tubes use fine mesh dynodes and offer excellent pulse linearity and TTS characteristics.
UV glass window type R5506 (1 "), R6148 (1.5 "), R6608 (2 "), R6505 (2.5 "), R5543 (3 ") are available.

(Unit: mm)

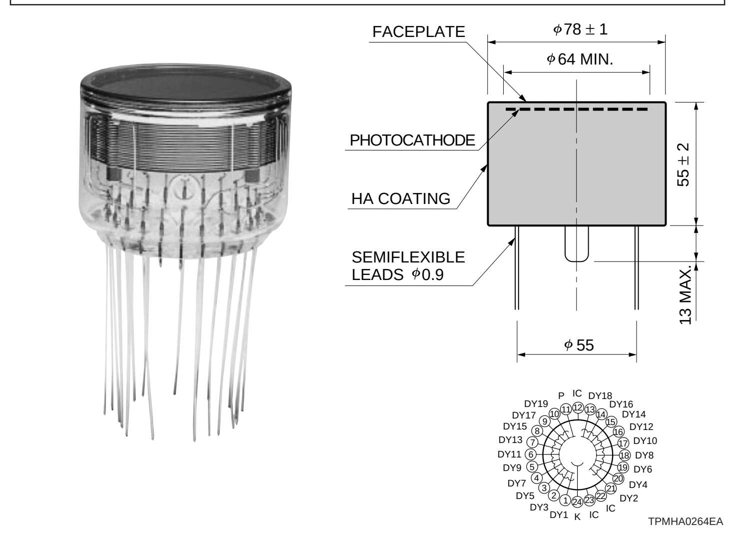
1 R5505



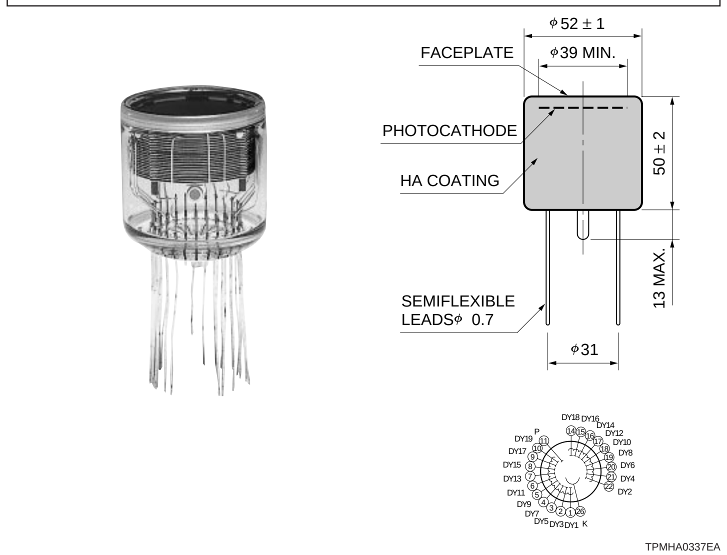
2 R5946



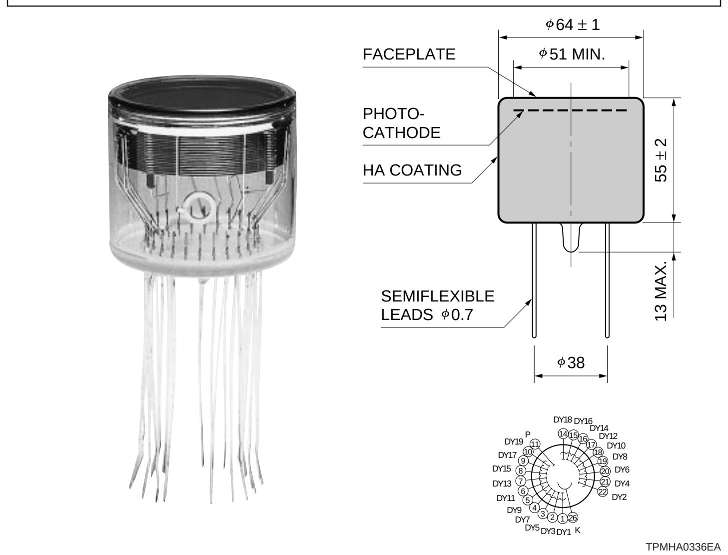
5 R5542



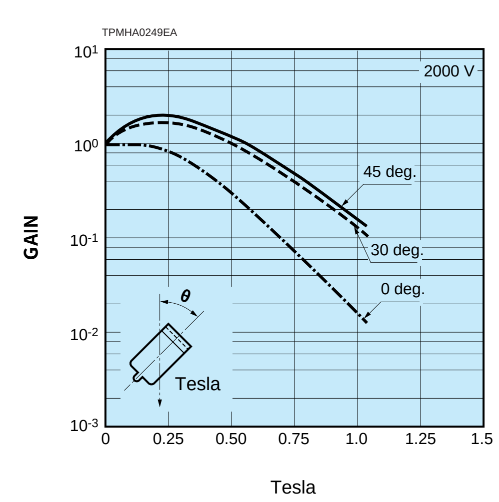
3 R5924



4 R6504



R5542 Typical Gain Magnetic Fields



Position-Sensitive Photomultiplier Tubes

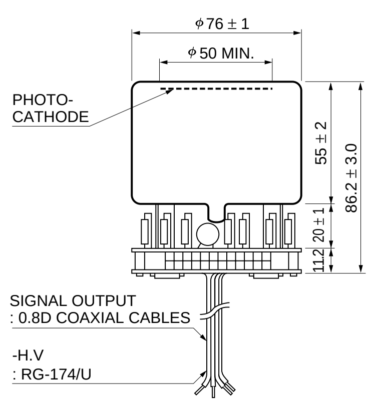
(at 25 °C)

Type No. (A)	Remarks	Spectral Response: Curve Code (B)	Spectral Response: Range (nm)	Spectral Response: Peak Wave-length (nm)	No. of Anode Wires or Anode Marixes	Effective Photocathode Area (mm)	Out-line No.	Dynode Structure / No. of Stages (F)	Maximum Ratings (H): Anode to Cathode Voltage (Vdc)	Maximum Ratings: Average Anode Current (J) (mA)	Cathode Sensitivity: Luminous Min. (µ A/lm)	Cathode Sensitivity: Luminous Typ. (µ A/lm)
Position-Sensitive Photomultiplier Tubes												
R2486-02	Cross-wire anode type, 76 mm dia. envelope	400K	300 to 650	420	16(X) + 16(Y)	ϕ50	1	CM/12	1300	0.1	50	80
R2487-02	Cross-wire anode type, 78 mm × 78 mm square envelope	400K	300 to 650	420	18(X) + 16(Y)	60(X) × 55(Y)	2	CM/12	1300	0.1	40	80
R3292-02	Cross-wire anode type, 130 mm dia. envelope	400K	300 to 650	420	28(X) + 28(Y)	ϕ100	3	CM/12	1300	0.1	50	80

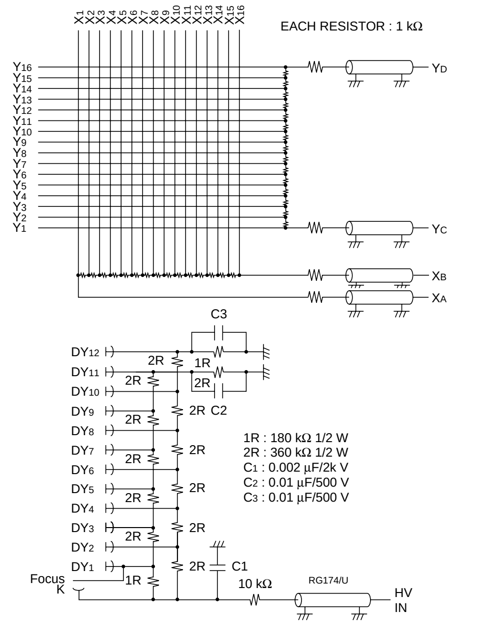
Type No. (A)	Cathode Sensitivity: Blue Sensitivity Index (CS 5-58) Typ.	Cathode Sensitivity: Red / White Ratio Typ.	Cathode Sensitivity: Radiant Typ. (K) (mA/W)	Anode to Cathode Supply Voltage (L) (Vdc)	Anode Characteristics (R): Anode Sensitivity Luminous Min. (A/ℓm)	Anode Sensitivity Luminous Typ. (A/ℓm)	Anode Sensitivity Radiant Typ. (A/W)	Gain Typ.	Anode Dark Current (After 30 min.) Typ. (nA)	Anode Dark Current Max. (nA)	Time Response: Rise Time Typ. (ns)	Time Response: Electron Transit Time Typ. (ns)	Notes
R2486-02	9.0	–	72	1250 (39)	5.0	8.0	7.2×10^3	1×10^5	20	50	5.5	17	
R2487-02	9.0	–	72	1250 (39)	3.0	8.0	7.2×10^3	1×10^5	20	80	5.5	17	
R3292-02	9.0	–	72	1250 (39)	5.0	8.0	7.2×10^3	1×10^5	40	150	6.0	20	

(Unit: mm)

1 R2486-02



TPMHA0160ED



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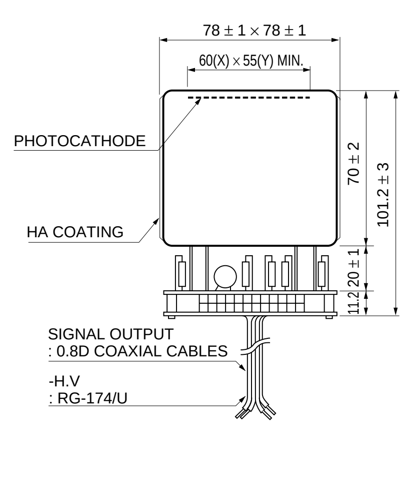
2 R2487-02



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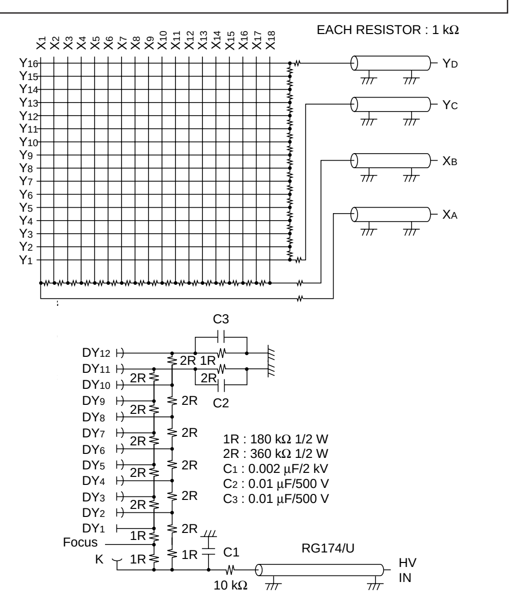

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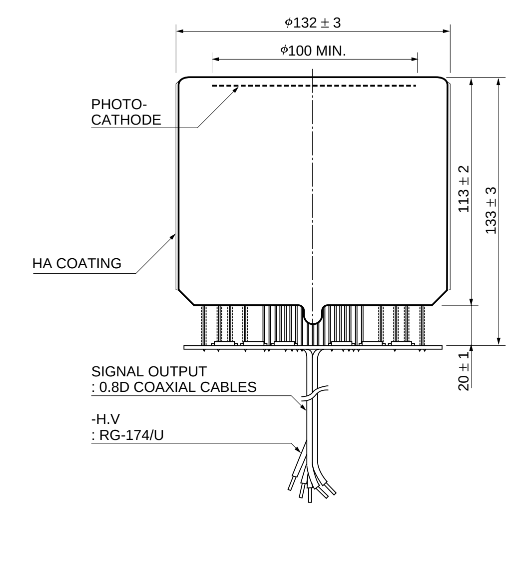
3 R3292-02



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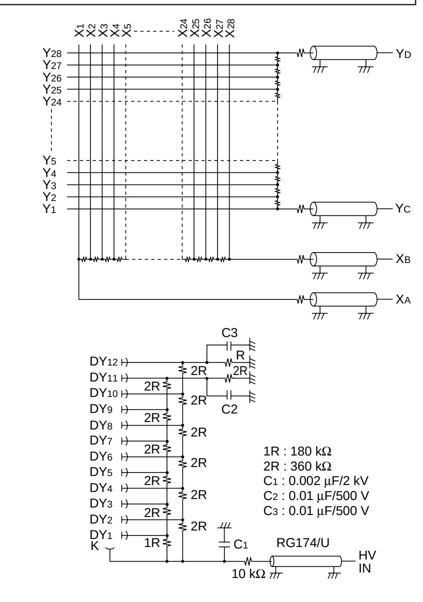
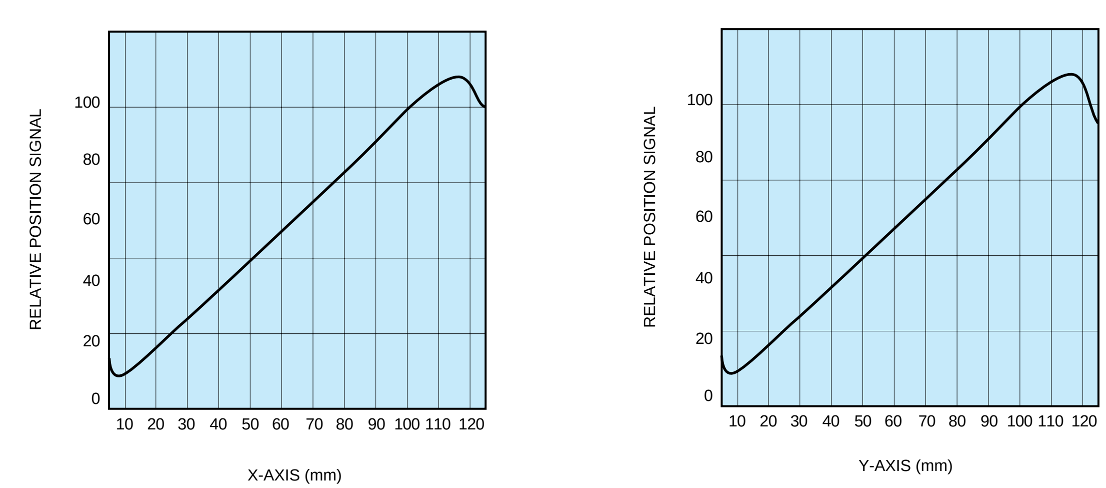


TPMHA0088ED

R3292-02 Position Signal Linearity

TPMHB0449EA



Microchannel Plate-Photomultiplier Tubes (MCP-PMTs)

(at 25 °C)

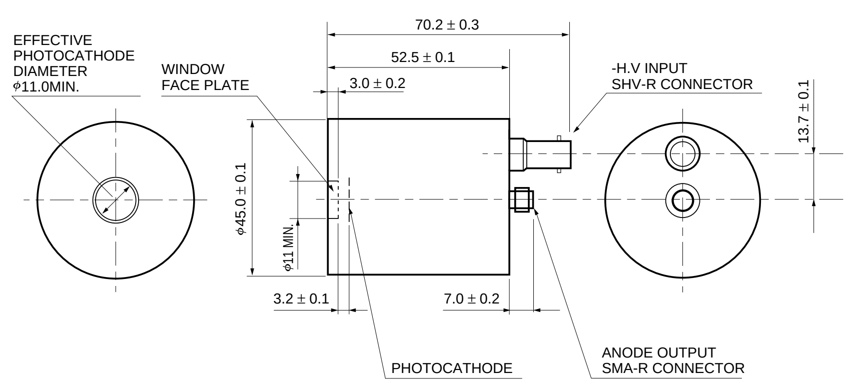
Type No. (A)	Remarks	Spectral Response (B) Curve Code	Spectral Response Range (nm)	Spectral Response Peak Wavelength (nm)	Photocathode Material (C)	Window Material (D)	Outline No. (E)	No. of MCP Stage	Maximum Ratings (H) Supply Voltage (Vdc)	Anode Current Continous (nA)	Anode Current Pulsed Peak (mA)	Terminals -HV Input	Terminals Signal Output
Standard Types (Effective Photocathode Area: 11 mm Dia.)													
R3809U-50	For UV to near IR range	500S	160 to 850	430	MA	Q	1	2	-3400	100	350	SHV-R	SMA-R
R3809U-51	For UV to near IR range (Extended red multialkali)	501S	160 to 910	600	EMA	Q	1						
R3809U-52	For UV to visible range	403K	160 to 650	400	BA	Q	1						
R3809U-57	For UV range	201M	115 to 320	230	Cs-Te	MgF_2	1						
R3809U-58	For UV to near IR range	500M	115 to 850	430	MA	MgF_2	1						
R3809U-59	For visible to IR range	700M	400 to 1200	800	Ag-O-Cs	K	1						
Gated Type (Effective Photocathode Area: 10 mm Dia.)													
R5916U-50	High-speed gate operation of less than 5 ns	500S	160 to 850	430	MA	Q	2	2	-3400	100	350	SHV-R	SMA-R
R5916U-51	High-speed gate operation of less than 5 ns	501S	160 to 910	600	EMA	Q	2						
R5916U-52	High-speed gate operation of less than 5 ns	403K	160 to 650	400	BA	Q	2						

Cathode Sensitivity Quantum Efficiency (K) (%)	Luminous Min. (µ A/lm)	Luminous Typ. (µ A/lm)	Anode to Cathode Supply Voltage (Vdc)	Anode Characteristics (N) Anode Sensitivity Luminous Typ. (A/lm)	Gain Typ.	Anode Dark Current Typ. (nA)	Anode Dark Current Max. (nA)	Time Response Rise Time Typ. (ns)	Electron Transit Time Typ. (ns)	TTS (ps)	Type No. (A)
20	100	150	-3000	30	2×10^5	–	10	0.15	0.55	25	R3809U-50
8.3	240	350		70		–	10				R3809U-51
20	20	50		10		–	0.5				R3809U-52
11	–	–		–		–	0.1				R3809U-57
20	100	150		30		–	10				R3809U-58
0.25	12	25		5		–	10				R3809U-59
15	100	150	-3000	30	2×10^5	–	10	0.18	1.0	90	R5916U-50
7.6	200	300		60		–	10				R5916U-51
15	20	45		9		–	0.5				R5916U-52

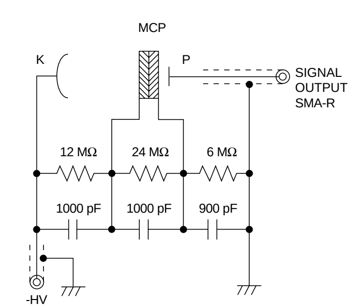
To improve the S/N ratio in low light level detection, an exclusive cooler unit (C4878/E3059-500) for R3809U MCP-PMT is available.
The R5916U has a series of types in the same suffixes as R3809U series. But an exclusive cooler unit shall be made upon custom order only.
High speed amplifier C5594 series (Gain: 36 dB Typ., Frequency Bandwidth: 50 kHz to 1.5 GHz) are avairable.

(Unit: mm)

1 R3809U-50 Series

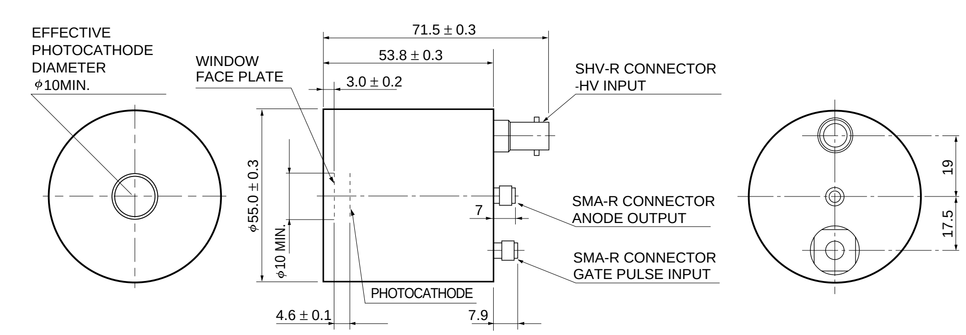


TPMHA0352EB



TPMHC0089EC

2 R5916U-50 Series



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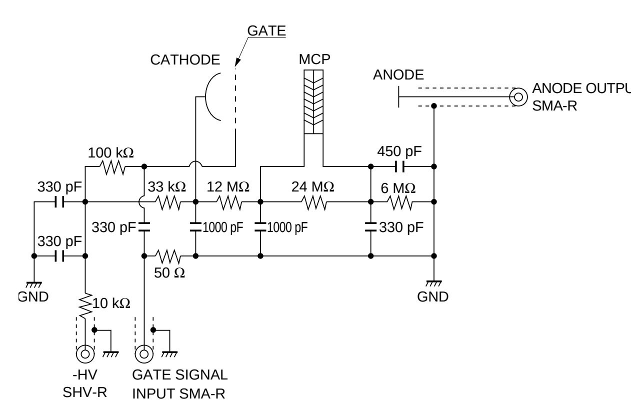


TPMHC0090ED

Metal Package Photomultiplier Tubes

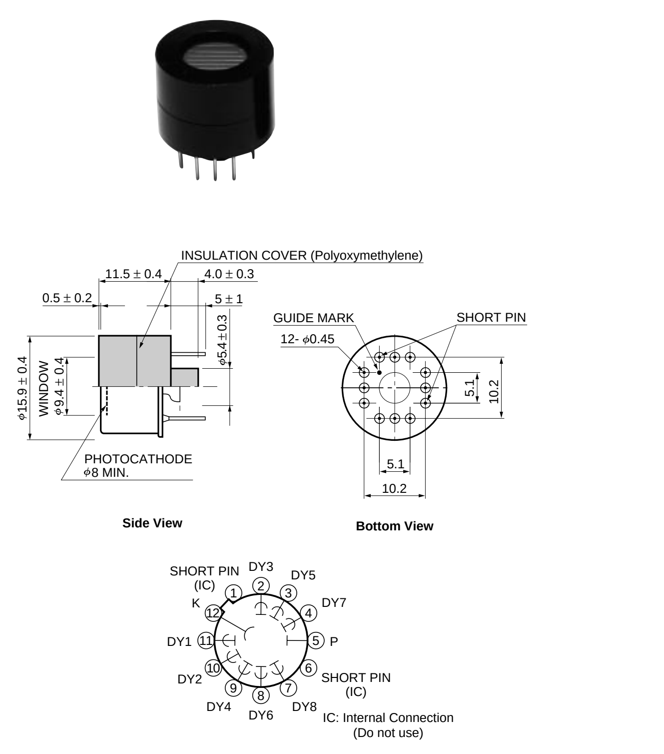
(at 25 °C)

(A) Type No.	Remarks	Spectral Response (B) Curve Code	Spectral Response Range (nm)	Spectral Response Peak Wave-length (nm)	(C) Photo-cathode Material	(D) Window Material	(E) Out-line No.	(F) Dynode Structure / No. of Stages	(G) Socket / Socket Assembly	Maximum Ratings (H) Anode to Cathode Voltage (Vdc)	Maximum Ratings (J) Average Anode Current (mA)	Cathode Sensitivity Luminous Min. (µ A/lm)	Cathode Sensitivity Luminous Typ. (µ A/lm)
R7400U Series													
R7400U	For visible range	400K	300 to 650	420	BA	K	1	MC/8	E678-12M■/46	1000	0.1	40	70
R7400U-01	Multialkali photocathode for visible to near IR range	–	300 to 850	400	MA	K	1	MC/8	E678-12M■/46	1000	0.1	80	150
R7400U-02	Multialkali photocathode for visible to near IR range	–	300 to 880	500	MA	K	1	MC/8	E678-12M■/46	1000	0.1	200	250
R7400U-03	For UV to visible range	400U	185 to 650	420	BA	U	1	MC/8	E678-12M■/46	1000	0.1	40	70
R7400U-04	Multialkali photocathode for UV to near IR range	–	185 to 850	400	MA	U	1	MC/8	E678-12M■/46	1000	0.1	80	150
R7400U-06	For UV to visible range	400S	160 to 650	420	BA	Q	2	MC/8	E678-12M■/46	1000	0.1	40	70
R7400U-09	Solar blind	–	160 to 320	240	Cs-Te	Q	2	MC/8	E678-12M■/46	1000	0.1	–	–
R7401	With lens	400K	300 to 650	420	BA	K	3	MC/8	E678-12M■/46	1000	0.1	40	70
R7402	With lens	–	300 to 850	400	MA	K	3	MC/8	E678-12M■/46	1000	0.1	80	150

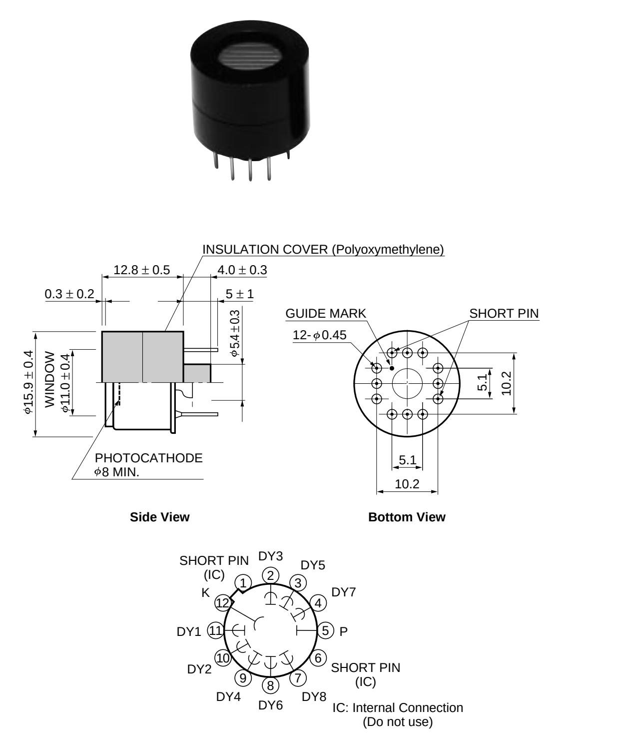
Cathode Sensitivity Blue Sensitivity Index (CS 5-58) Typ.	Cathode Sensitivity Red / White Ratio Typ.	Cathode Sensitivity (K) Radiant Typ. (mA/W)	(L) Anode to Cathode Supply Voltage (Vdc)	Anode Characteristics (M) Anode Sensitivity Luminous Min. (A/lm)	Anode Sensitivity Luminous Typ. (A/lm)	Anode Sensitivity Radiant Typ. (A/W)	Gain Typ.	Anode Dark Current (After 30 min.) Typ. (nA)	Anode Dark Current (After 30 min.) Max. (nA)	Time Response Rise Time Typ. (ns)	Time Response Electron Transit Time Typ. (ns)	Notes	(A) Type No.
8.0	–	62	800 (9)	10	50	4.3×10^4	7.0×10^5	0.2	2	0.78	5.4	Photon counting type : R7400P	R7400U
–	200	60	800 (9)	15	75	3.0×10^4	5.0×10^5	0.4	4	0.78	5.4	Photon counting type : R7400P-01	R7400U-01
–	250	58	800 (9)	25	125	2.9×10^4	5.0×10^5	2.0	20	0.78	5.4		R7400U-02
8.0	–	62	800 (9)	10	50	4.3×10^4	7.0×10^5	0.2	2	0.78	5.4	Photon counting type : R7400P-03	R7400U-03
–	200	60	800 (9)	15	75	3.0×10^4	5.0×10^5	0.4	4	0.78	5.4	Photon counting type : R7400P-04	R7400U-04
8.0	–	62	800 (9)	10	50	4.3×10^4	7.0×10^5	0.2	2	0.78	5.4	Photon counting type : R7400P-06	R7400U-06
–	–	22 (b)	800 (9)	–	–	1100 (b)	5.0×10^4	0.025	0.5	0.78	5.4		R7400U-09
8.0	–	62	800 (9)	10	50	4.3×10^4	7.0×10^5	0.2	2	0.78	5.4	Photon counting type : R7401P	R7401
–	200	60	800 (9)	15	75	3.0×10^4	5.0×10^5	0.4	4	0.78	5.4	Photon counting type : R7402P	R7402

(Unit: mm)

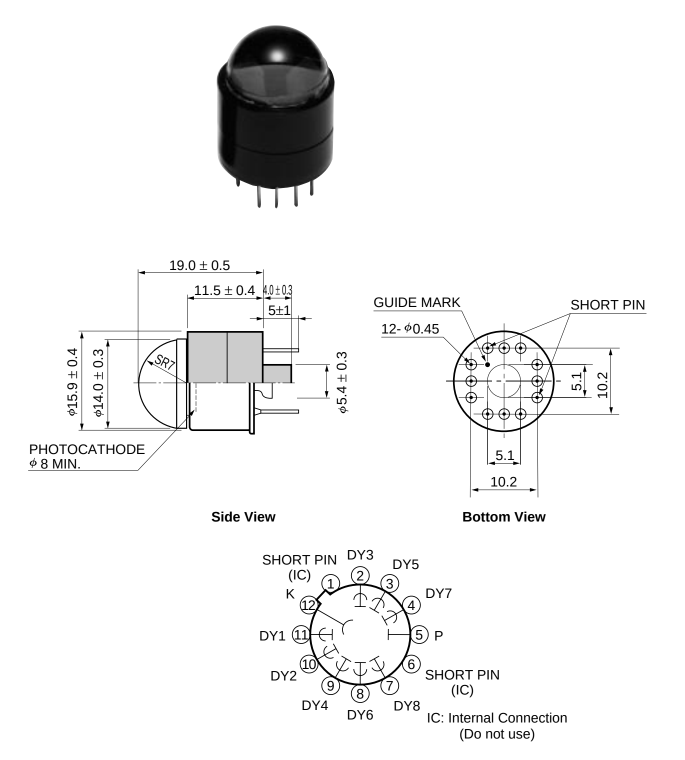
1 R7400U, -01, -02, -03, -04



2 R7400U-06, -09



3 R7401, R7402



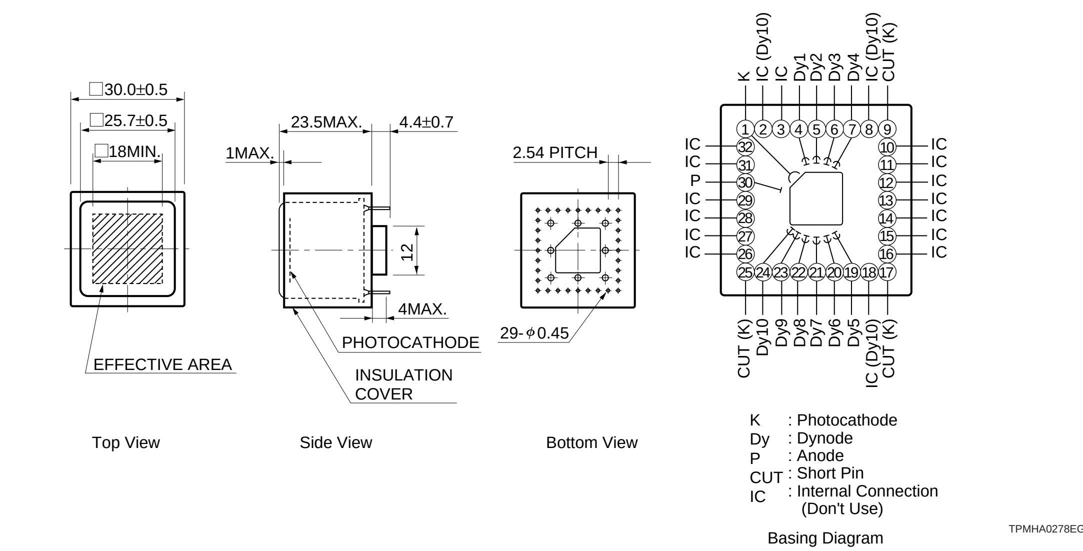
Metal Package Photomultiplier Tubes

(at 25 °C)

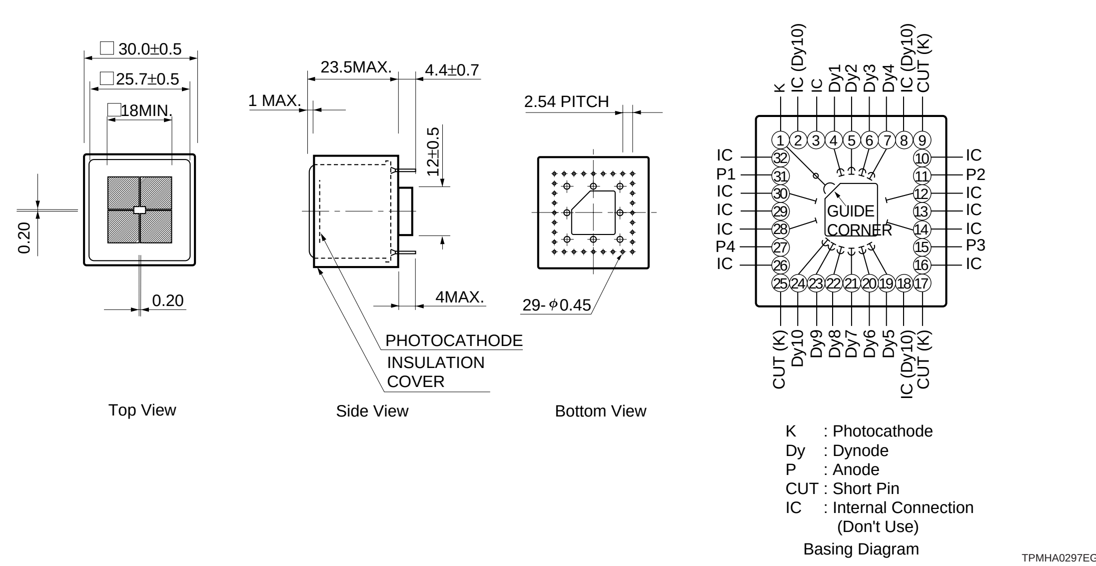
Type No. (A)	Remarks	Spectral Response: Curve Code (B)	Spectral Response: Range (nm)	Spectral Response: Peak Wave-length (nm)	Photo-cathode Material (C)	Window Material (D)	Out-line No. (E)	Dynode Structure / No. of Stages (F)	Socket / Socket Assembly (G)	Maximum Ratings (H): Anode to Cathode Voltage (Vdc)	Maximum Ratings: Average Anode Current (J) (mA)	Cathode Sensitivity: Luminous Min. (µ A/lm)	Cathode Sensitivity: Luminous Typ. (µ A/lm)
R5900U Series													
R5900U	For visible range Single anode	400K	300 to 650	420	BA	K	1	MC/10	E678-32B■/47	900	0.1	50	70
R5900U-00-M4	For visible range 2 × 2 Multianode				BA	K	2	MC/10	E678-32B■/48	900	0.1	50	70
H6568	For visible range 4 × 4 Multianode				BA	K	3	MC/12	–	1000	0.01	–	70

Cathode Sensitivity: Blue Sensitivity Index (CS 5-58) Typ.	Cathode Sensitivity: Red / White Ratio Typ.	Cathode Sensitivity: Radiant Typ. (K) (mA/W)	Anode to Cathode Supply Voltage (L) (Vdc)	Anode Characteristics (M): Anode Sensitivity Luminous Min. (A/lm)	Anode Sensitivity Luminous Typ. (A/lm)	Anode Sensitivity Radiant Typ. (A/W)	Gain Typ.	Anode Dark Current (After 30 min.) Typ. (nA)	Anode Dark Current (After 30 min.) Max. (nA)	Time Response: Rise Time Typ. (ns)	Time Response: Electron Transit Time Typ. (ns)	Notes	Type No. (A)
8.0	–	72	800 (23)	25	140	–	2.0×10^6	2	20	1.5	–		R5900U
8.0	–	72	800 (24)	25	140	–	2.0×10^6	0.5	–	1.2	–		R5900U-00-M4
8.0	–	72	800 (39)	–	230	–	3.3×10^6	1	–	0.83	–		H6568

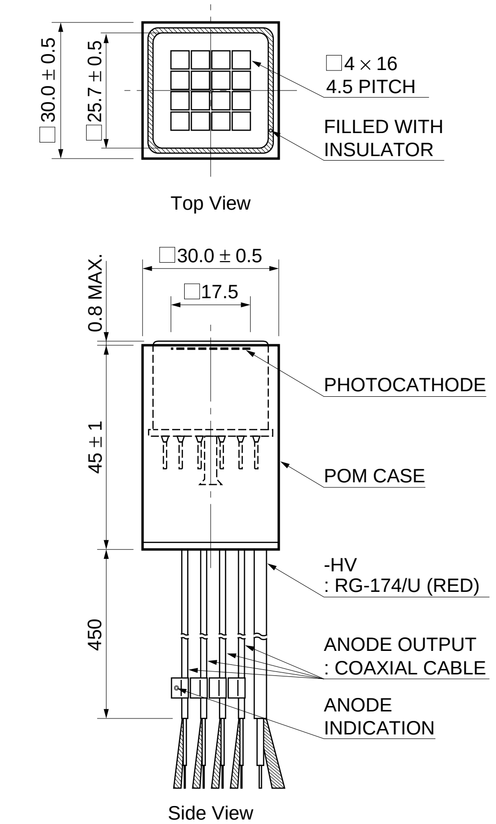
1 R5900U

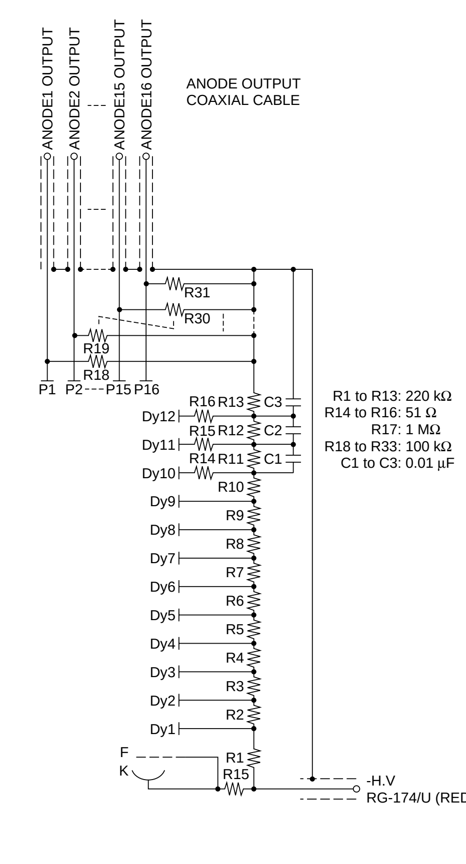


2 R5900U-00-M4



3 H6568





Metal Package Photomultiplier Tubes

(at 25 °C)

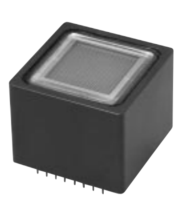
R5900U Series

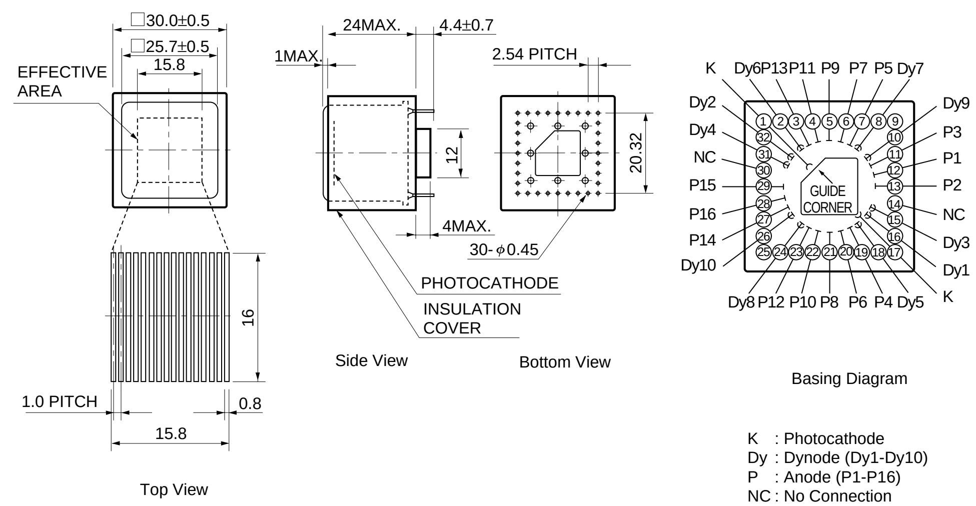
Type No. (A)	Remarks	Spectral Response: Curve Code (B)	Spectral Response: Range (nm)	Spectral Response: Peak Wavelength (nm)	Photocathode Material (C)	Window Material (D)	Outline No. (E)	Dynode Structure / No. of Stages (F)	Socket / Socket Assembly (G)	Maximum Ratings (H): Anode to Cathode Voltage (Vdc)	Maximum Ratings (H): Average Anode Current (J) (mA)	Cathode Sensitivity Luminous Min. (μ A/lm)	Cathode Sensitivity Luminous Typ. (μ A/lm)
R5900U-00-L16	For visible range 16 Linear Multianode	400K	300 to 650	420	BA	K	1	MC/10	E678-32B■/49	900	0.01	50	70
*R5900U-01-L16	For visible to near IR range 16 Linear Multianode	–	300 to 850	420	MA	K	1	MC/10	E678-32B■/49	900	0.01	100	150
R5900U-00-C8	For visible range 4 + 4 Cross plate anode	400K	300 to 650	420	BA	K	2	MC/11	E678-32B■/50	900	0.1	50	70

Type No. (A)	Cathode Sensitivity: Blue Sensitivity Index (CS 5-58) Typ.	Cathode Sensitivity: Red / White Ratio Typ.	Cathode Sensitivity: Radiant Typ. (K) (mA/W)	Anode to Cathode Supply Voltage (L) (Vdc)	Anode Sensitivity Luminous Min. (A/lm)	Anode Sensitivity Luminous Typ. (A/lm)	Anode Sensitivity Radiant Typ. (A/W)	Gain Typ.	Anode Dark Current (After 30 min.) Typ. (nA)	Anode Dark Current (After 30 min.) Max. (nA)	Time Response: Rise Time Typ. (ns)	Time Response: Electron Transit Time Typ. (ns)	Notes
R5900U-00-L16	8.0	–	72	800 (13)	50	280	–	4.0×10^6	0.2	2	0.6	–	
R5900U-01-L16*	–	0.15	–	800 (13)	50	150	–	1.0×10^6	1	10	0.6	–	
R5900U-00-C8	8.0	–	72	800 (28)	–	50	–	7.0×10^5	2	–	1.4	–	

Anode Characteristics (M)

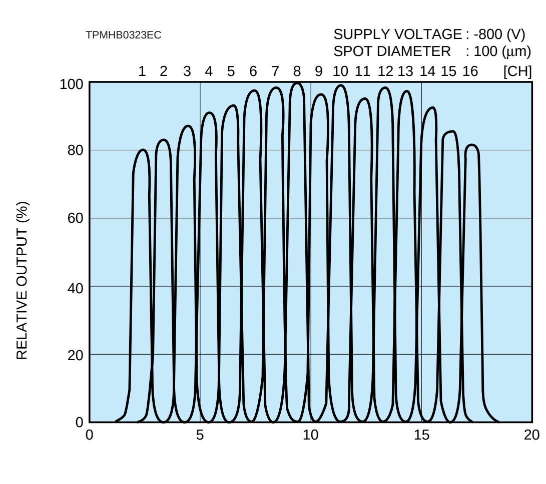
1 R5900U -00 -L16, R5900U -01 -L16



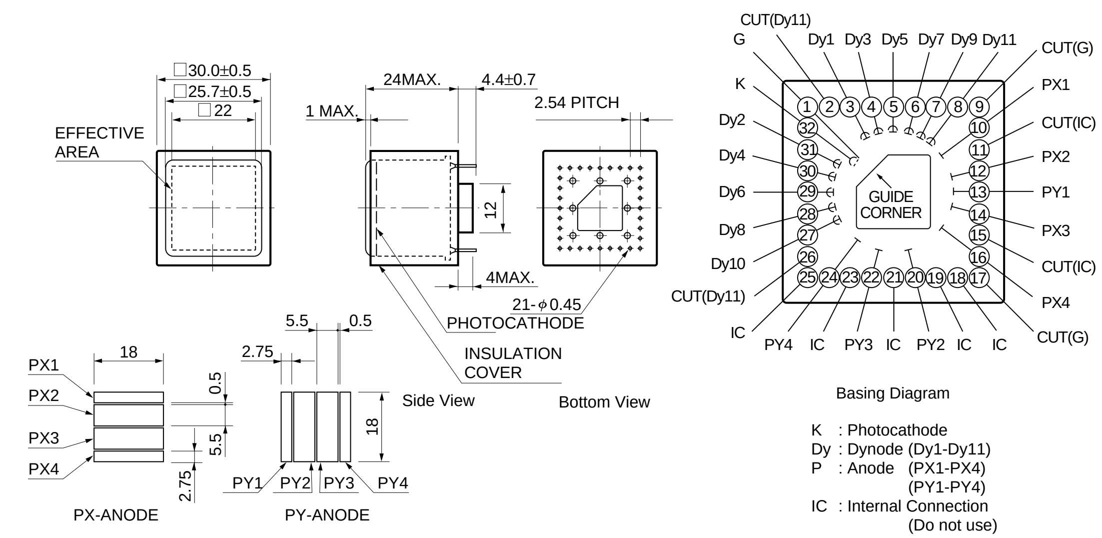


TPMHA0298EE

R5900U -00 -L16 Anode Uniformity

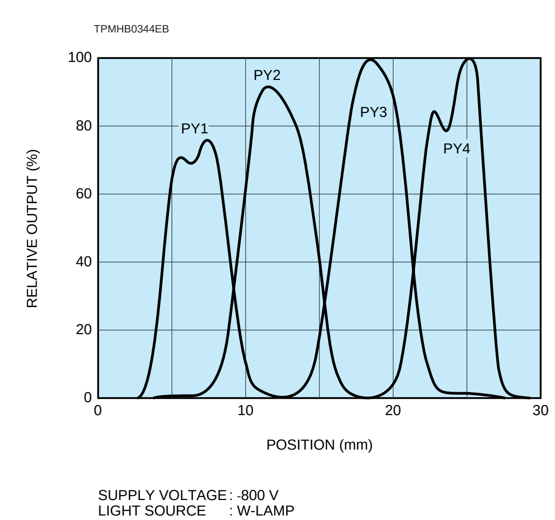


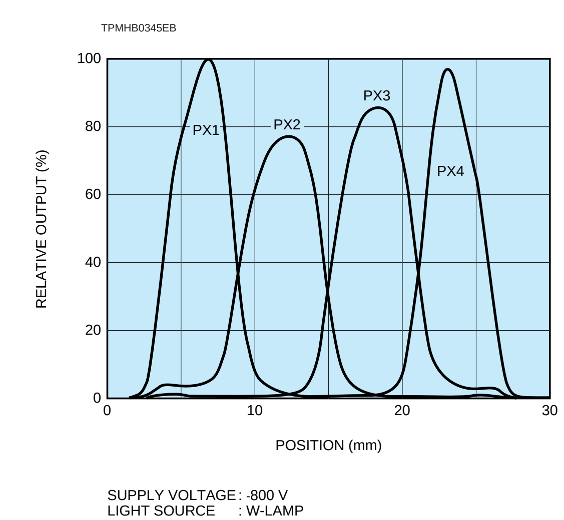
2 R5900U -00 -C8



TPMHA0356EC

R5900U -00 -C8 Uniformity





Photosensor Module

(at 25 °C)

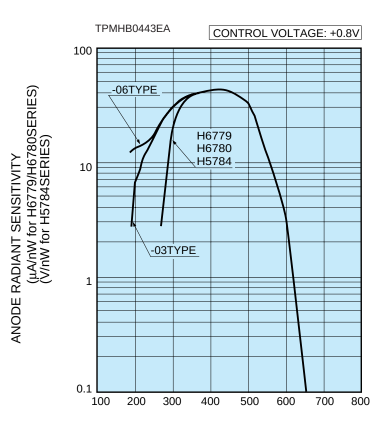
Type No.	Spectral Response Range (nm)	Spectral Response Peak Wavelength λp (nm)	Out-line No.	Radiant at 420nm (at +0.8 V) (Note1)	Anode Dark Current (at +0.8 V) (Note2)	Anode Pulse Rise Time (at +0.8 V) (ns)	Supply Voltage (Vdc)	Recommended Control Voltage Range (V)	Max. Supply Voltage (Vdc)	Max. Output (Note 3)	Configuration
H6779	300 to 650	420	1	43	0.2	0.78	+11.5 to +15.5	+0.25 to +0.95	+18	100	PC-board mounting type
H6779-01	300 to 820			30	0.4						
*H6779-02	300 to 880			17	2.0						
H6779-03	185 to 650			43	0.2						
H6779-04	185 to 820			30	0.4						
H6779-06	185 to 650			43	0.2						
H6780	300 to 650	420	2	43	0.2	0.78	+11.5 to +15.5	+0.25 to +0.95	+18	100	Cable output type
H6780-01	300 to 820			30	0.4						
*H6780-02	300 to 880			17	2.0						
H6780-03	185 to 650			43	0.2						
H6780-04	185 to 820			30	0.4						
H6780-06	185 to 650			43	0.2						
H5784	300 to 650	420	3	43	±3	–	±11.5 to ±15.5	±0.25 to ±0.95	±18	10	Cable output type DC to 20 kHz
H5784-01	300 to 820			30	±3						
*H5784-02	300 to 880			17	±3						
H5784-03	185 to 650			43	±3						
H5784-04	185 to 820			30	±3						
H5784-06	185 to 650			43	±3						

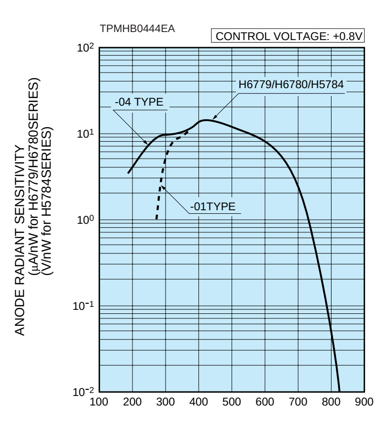
Note1: H6779/H6780 series ... (µA/nW) H5784 series ... (V/nW)
Note2: H6779/H6780 series ... (nA) H5784 series ... Output Offset (mV)
Note3: H6779/H6780 series ... (µA) H5784 series ... (V)

There are the other types of much lower current consumption modules which are H5773 and H5783 series.
When the system with the photosensor will require the current consumption low, H5773 and H5783 series are suitable modules, although these types have rather higher ripple noise (current) and longer settling time than new series.

The H6779 / H6780 / H5784 series are light sensor modules including a compact photomultiplier tube (Metal Package PMT) and operating power supply. The H6779 series are on-board types which facilitates mounting directly on a printed circuit board and H6780 series have a cable output. The H5784 series have a low noise amplifier with a cable output.
Optical Fiber Adapter E5776(FC type) and Exclusive Power Supply C7169 (±15 V, Vcont output and Vcont display) are available as options.

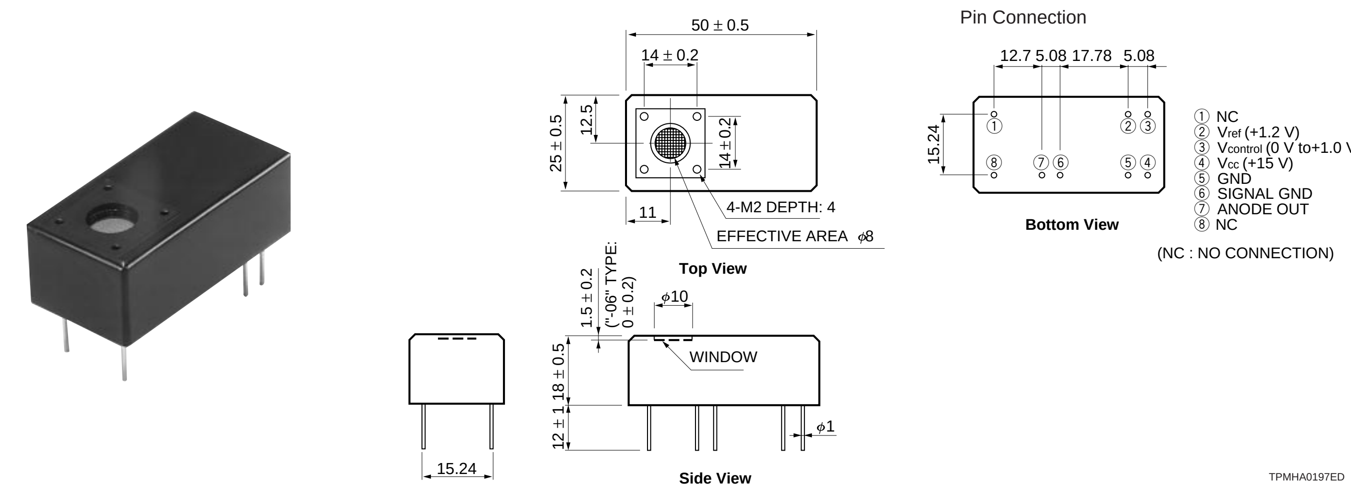
H6779/H6780/H5784 Series Typical Spectral Response



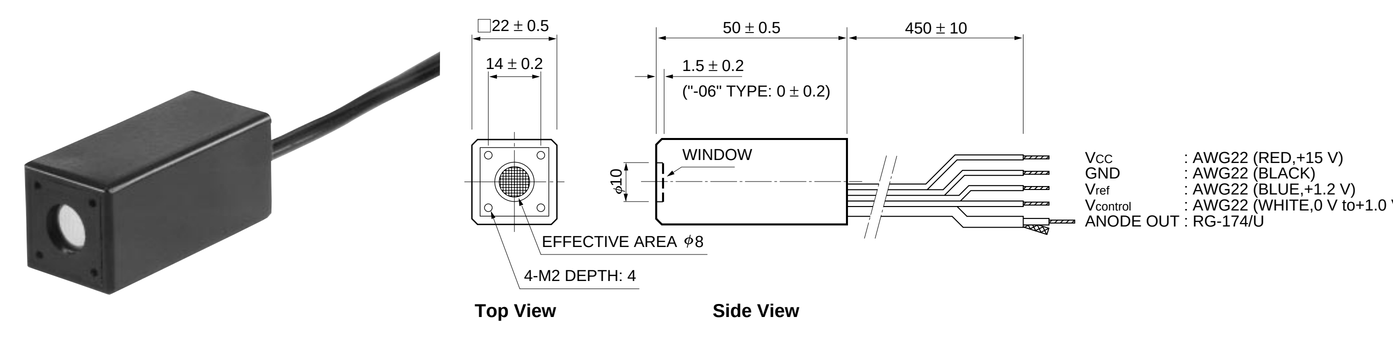


(Unit: mm)

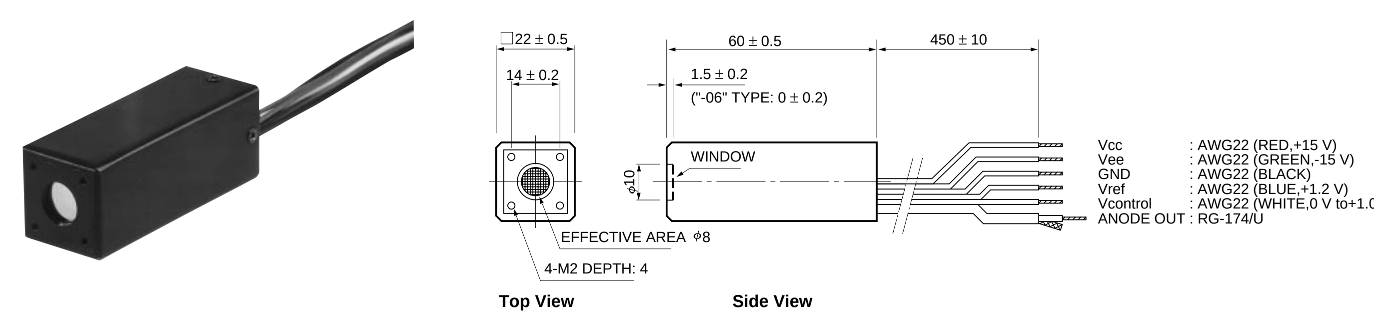
1 H6779 Series



2 H6780 Series



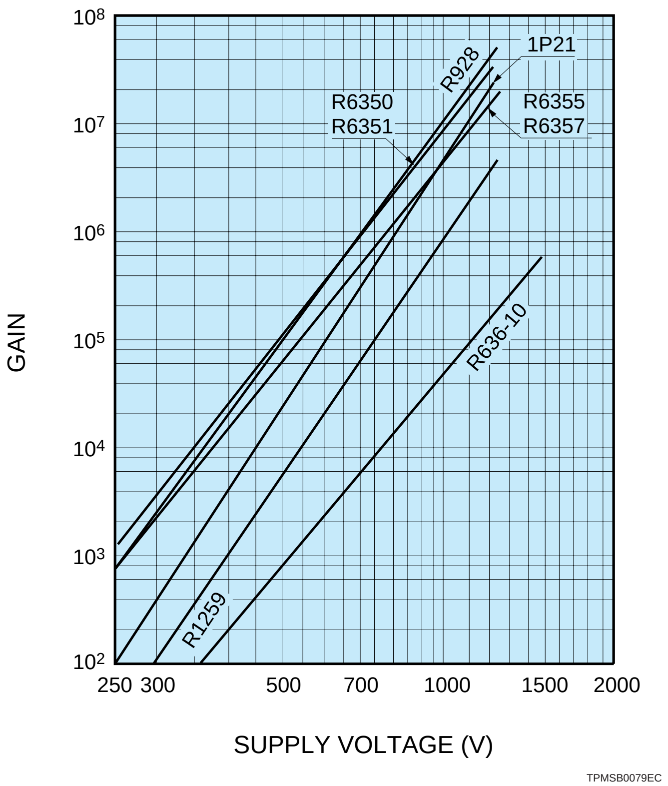
3 H5784 Series



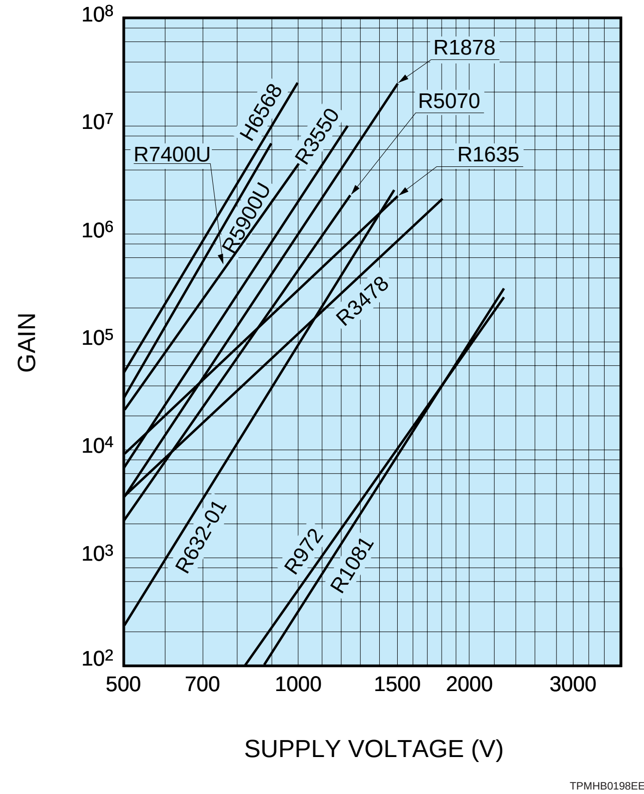
Gain

(For tubes not listed here, please consult our sales office)

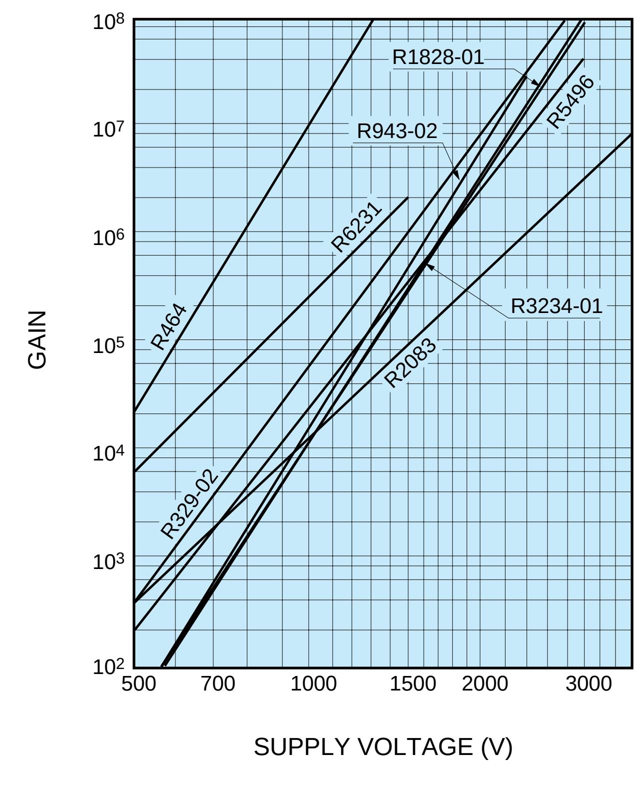
Side-On Types



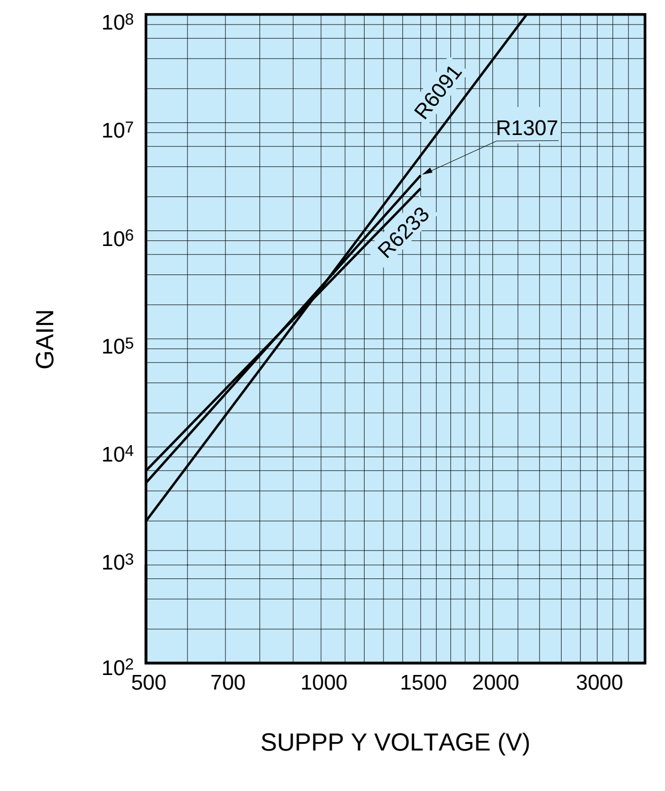
Head-On Types (10 mm - 25 mm Dia.) Metal Package PMT



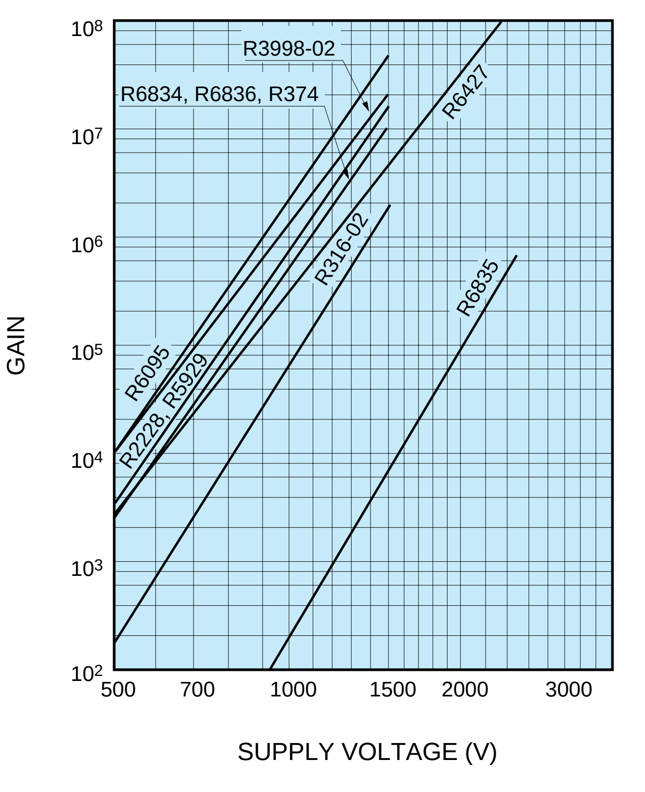
Head-On Types (51 mm Dia.)



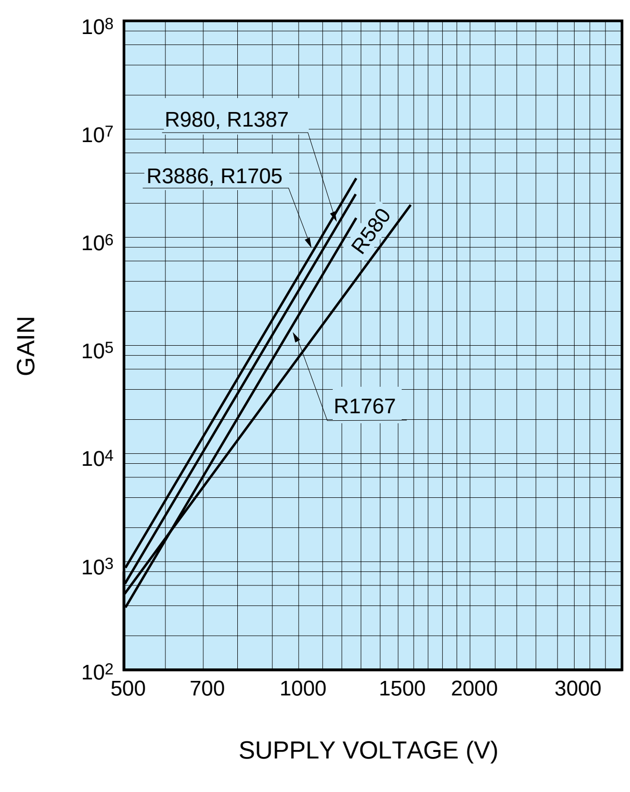
Head-On Types (76 mm Dia.)



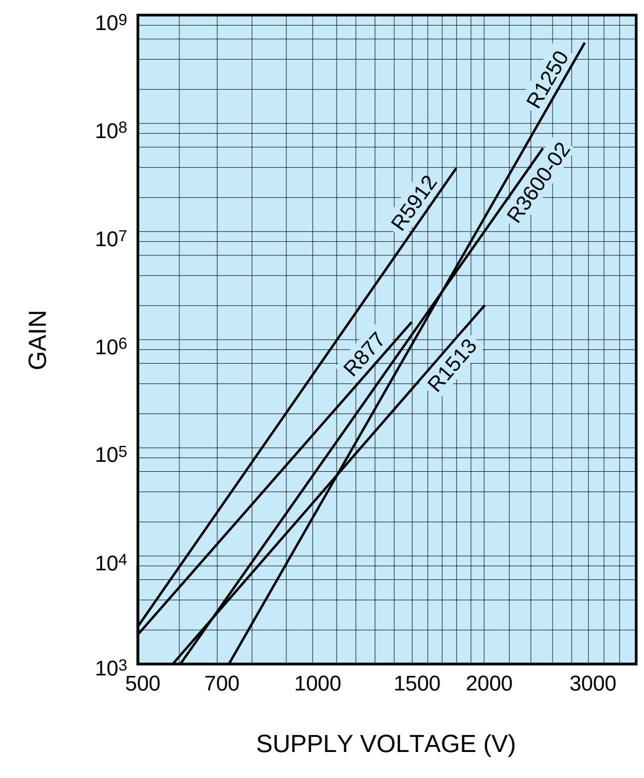
Head-On Types (28 mm Dia.)



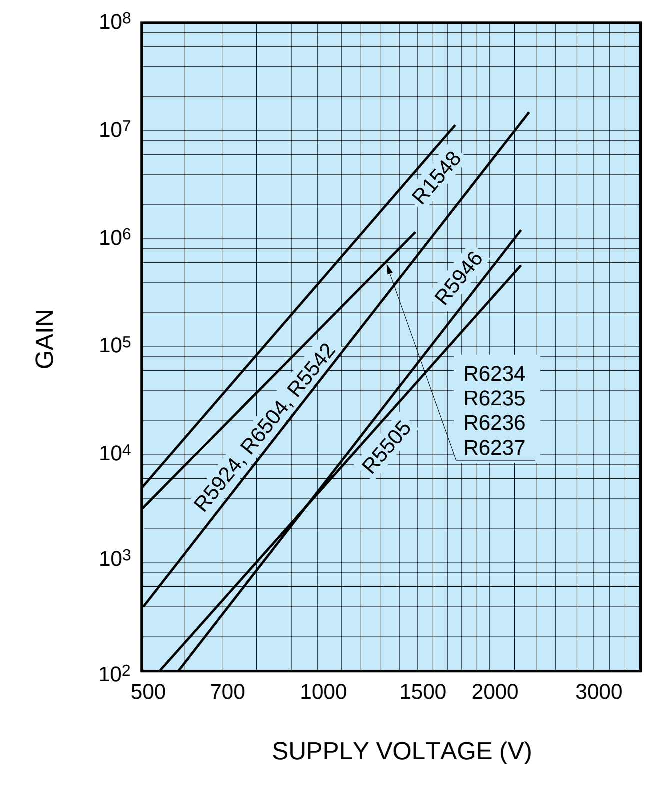
Head-On Types (38 mm Dia.)



Head-On Types (127 mm Dia.) Hemispherical Types



Special Types



Voltage Distribution Ratio

The characteristic values tabulated in the catalog for the individual tube types are measured with the voltage-divider networks having the voltage distribution ratio shown below.

Distribution Ratio Codes	Number of Stage	Voltage Distribution Ratio K : Photocathode Dy : Dynode P : Anode G : Grid F : Focus																	
	8	K	G	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Acc	Dy7	Dy8	P						
①		2	—	2	1	1	1	1	1	—	1	1							
②		1	1	1	1	1	1	1	1	—	1	1							
③		1.3	4.8	1.2	1.8	1	1	1	1	0.5	3	2.5							
④		3	—	1.5	1	1	1	1	1	—	1	1							
⑤		3	—	1.5	1.5	1	1	1	1	—	1	1							
⑥		7	—	1	1.5	1	1	1	1	—	1	1							
⑦		4	0	1	1.4	1	1	1	1	—	1	1							
⑧		2	2	1	1	1	1	1	1	—	1	1							
⑨		1	—	1	1	1	1	1	1	—	1	0.5							
	9	K	G_1	G_2	G_3	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	P				
⑩		1	—	—	—	1	1	1	1	1	1	1	1	1					
⑪		3	1	—	—	1	1	1	1	1.5	1	1	1	1					
⑫		5	0	3	0	1	1	1	1	1	1	1	1	1					
	10	K	G	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	P					
⑬		1	—	1	1	1	1	1	1	1	1	1	1						
⑭		1	1	1	1	1	1	1	1	1	1	1	1						
⑮		1.5	—	1	1	1	1	1	1	1	1	1	1						
⑯		2	—	1	1	1	1	1	1	1	1	1	1						
⑰		2	—	1	1.5	1	1	1	1	1	1	1	0.75						
⑱		3	—	1	1	1	1	1	1	1	1	1	1						
⑲		3	—	1	1.5	1	1	1	1	1	1	1	1						
⑳		3	—	1.5	1	1	1	1	1	1	1	1	1						
㉑		4	—	1	1.5	1	1	1	1	1	1	1	1						
㉒		1.3	4.8	1.2	1.8	1	1	1	1	1	1.5	3	2.5 (Note 2)						
㉓		1.5	—	1.5	1.5	1	1	1	1	1	1	1	0.5						
㉔		1.5	—	1.5	1.5	1	1	1	1	1	1	1	1						
		K	Dy1	F2	F1	F3	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	P			
㉕		11.3	0	0.6	0	3.4	5	3.33	1.67	1	1	1	1	1	1				
	11	K	G	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	Dy11	P				
㉖		1	—	1	1	1	1	1	1	1	1	1	1	1					
㉗		8	0.05	1	1	1	1	1	1	1	1	1	1	1					
㉘		0.5	1.5	2	1	1	1	1	1	1	1	1	1	0.5					
		K	F2	F1	F3	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	Dy11	P		
㉙		5	1	2	0.02	3	1	1	1	1	1	1	1	1	1	1			
	12	K	G	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	Dy11	Dy12	P			
㉚		3	—	3	3	1	1	1	1	1	1	1	1	2	5				
㉛		1	1	1	1	1	1	1	1	1	1	1	1	1	1				
㉜		1.2	2.8	1.2	1.8	1	1	1	1	1	1	1.5	1.5	3	2.5				
㉝		2	—	1	1	1	1	1	1	1	1	1	1	1	1				
㉞		4	0	1	1.4	1	1	1	1	1	1	1	1	1	1 (Note 1)				
㉟		4	0	2.5	1.5	1	1	1	1	1	1	1	1	1	1				
㊱		1	3	1.2	1.8	1	1	1	1	1	1	1.5	1.5	3	2.5				
㊲		4	0	1.2	1.8	1	1	1	1	1	1	1	1	1	1				
㊳		6	0	1	1.4	1	1	1	1	1	1	1	1	1	1				
㊴		1	—	1	1	1	1	1	1	1	1	1	1	1	1				
	14	K	G_1	G_2	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	Dy11	Dy12	Dy13	Dy14	P
㊵		2.5	7.5	0	1.2	1.8	1	1	1	1	1	1	1	1	1.5	1.5	3	2.5	
	15	K	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	Dy11	Dy12	Dy13	Dy14	Dy15	P	
㊶		2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
	16	K	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	Dy11	Dy12	Dy13	Dy14	Dy15	Dy16	P
㊷		2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
	19	K	Dy1	Dy2	Dy3	· · · · · · · · · · · · · · · · · ·										Dy17	Dy18	Dy19	P
㊸		2	1	1	1	· · · · · · · · · · · · · · · · · ·									1	1	1	1	

Note 1 : The shield pin should be connected to Dy5.
2 : Acc to be connected to Dy7 except R4998

Replacement Information

* : The same dimensional outline, base connection and electric characteristics.
** : The similar electric characteristics and the same dimensional outline and base connection.
*** : The similar electric but different dimensional outline and/or different base sonnection.

BURLE	Hamamatsu

Side-On Types

1P21	1P21* R105** R105UH**
1P28	1P28*
1P28/V1	R212* 1P28**
1P28A	1P28A*
1P28A/V1	R372**
1P28B	R1516*
4473	R372**
4526	R1923*
4832	R636-10***
4840	R446*
931A, 931VA	931A*
931B	931B* R105**
C31004, C31004A	R406*

Head-On Types

4501/V3	R331-05*
4516	R1166*** R1450*** R3478***
4856	R2154-02***
4900	R1307***
4903	R1387***
5819	R2154-02***
6199	R980***
6342A	R2154-02***
6342A/V1	R2154-02***
6655A	R2154-02***
8575	R329-02**
8644	R1617***
8850	R329***
C31000AJ[4]	R4607-01***
C31000AP[4]	R4607-01***
C31000AJ-175[5]	R4607-01***
C31000AP-175[5]	R4607-01***
C31000M	R2256***
C31016G[4]	R1288***
C31016H[5]	R1288***
C31034	R943-02***
C31034-02	R943-02***
C31034-06	R943-02***
C31034A	R943-02***
C31034A-02	R943-02***
C31034A-05	R943-02***
S83006E	R877***
S83010E	R980***
S83010EM1	R3886***
S83049F	R1307**
S83050E	R980***
S83050EM1	R3886***
S83054F	R1306**
S83068E	R6427***
9661B	1P28* 931A** 1P21**

ETL	Hamamatsu

Side-On Types

9780B	1P28** 931A** 1P21**
9781B	1P28** R212**
9781R	1P28A** R3788**
9783B	R106** R106UH** R4332**
9785B	R446*
9785QB	R456*

Head-On Types

9078B	R1166**
9082B	R1450**
9102KB, 9902KB 9903KB	R580**
9110BFL	R1288**
9111B, 9112B	R1924**
9113B	R1925**
9124B, 9125B, 9128B	R6095** R6094**
9135B	R5800***
9207B	R4607-01***
9214KB	R1828-01***
9250KB, 9257KB, 9266KB	R2154-02**
9330KB, 9390KB	R877**
9353B	R5912***
9524B, 9766B, 9924B	R6095**
9530KB, 9791KB	R877***
9558B	R375***
9659B	R669***
9734B	R6095***
9758KB	R1307***
9789B, 9844B	R464***
9792KB	R877***
9798B	R374**
9807KB, 9813KB	R1828-01***
9814B	R329-02***
9815B	R5496***
9820QB	R331***
9821B, 9921B	R6091***
9822B	R6091***
9823KB	R1250**
9826B	R1450*** R3478***
9828B	R5929**
9829B, 9849B	R331-05*
9829QB, 9849QB	R331*
9865B	R649***
9881B	R1450*** R3478***
9882B	R1617***
9884B, 9887B	R329-02***
9893KB/350	R3234-01***
9899B	R331-05***
9972KB, 9973KB	R1387**

PHOTONIS	Hamamatsu
XP1911	R1166** R1450* R3478***
XP1918	R2076*** R762**
XP2012B, XP2072B	R580**
XP2013B	R1387***
XP2015B	R1767***
XP2017B	R2066***
XP2020	R1828-01*
XP2020/Q	R2059*
XP2050	R877***
XP2052B	R980**
XP2202B	R2154-02**
XP2203B	R3256**
XP2206B	R4607-01***
XP2262B	R329-02***
XP2282B	R2083***
XP2312B	R6091***
XP2802	R1166***
XP2971, XP2972	R6427**
XP2978	R7057**
XP3462B	R6091***
XP4500B	R1584***
XP4512B	R1250***

Photomultiplier Tube Assemblies

Photomultiplier tube assemblies integrate a photomultiplier tube and a D-type or DP-type socket assemby (see page 78 for socket assemblies) into a matching magnetic shields. The D-type photomultiplier tube assemblies require a high-voltage power supply, while the DP-type includes a DC-DC converter high-voltage power supply and can be operated by simply supplying +15 V.

▲Photomultiplier Tube Assemblies

D-Type PMT Assemblies (with a Head-on Type PMT)

Type No.	Built-in PMT						Maximum Ratings		Dimensions (mm)
	Diameter (mm)	Type No.	Photo-Cathode (C)	Window Material (D)	Gain	Supply Voltage (V)	Supply Voltage (V)	Bleeder Current (mA)	
H3164-10	10	R1635	BA	K	1.1×10^6	1250	-1500	0.41	ϕ10.5 × 95
H3695-10	10	R2496	BA	Q	1.1×10^6	1250	-1500	0.37	ϕ11.3 × 95
H3165-10	13	R647	BA	K	1.0×10^6	1000	-1250	0.34	ϕ14.3 × 116
H6520	19	R1166	BA	K	9.5×10^5	1000	-1250	0.33	ϕ23.5 × 130
H6524	19	R1450	BA	K	1.7×10^6	1500	-1800	0.43	ϕ23.5 × 130
H6152-01	25	R5505	BA	K	5.0×10^5	2000	-2300	0.41	ϕ31.0 × 75
H6533	25	R4998	BA	K	5.7×10^6	2250	-2500	0.36	ϕ31.0 × 120
H7415	28	R6427	BA	K	5.0×10^6	1500	-2000	0.41	ϕ33.0 × 130
H7416	28	R7056	BA	U	5.0×10^6	1500	-2000	0.41	ϕ33.0 × 130
H7417	28	R7057	BA	Q	2.0×10^6	1500	-2000	0.37	ϕ33.0 × 130
H3178-51	38	R580	BA	K	1.1×10^6	1500	-1750	0.63	ϕ47.0 × 162
H6153-01	38	R5946	BA	K	1.1×10^6	2000	-2300	0.39	ϕ45.0 × 80

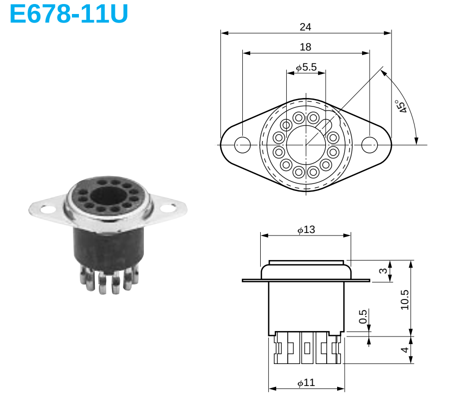
Type No.	Built-in PMT						Maximum Ratings		Dimensions (mm)
	Diameter (mm)	Type No.	Photo-Cathode (C)	Window Material (D)	Gain	Supply Voltage (V)	Supply Voltage (V)	Divider Current (mA)	
H6410	51	R329-02	BA	K	3.0×10^6	2000	-2700	0.67	ϕ60.0 × 200
H6521	51	R2256-02	BA	Q	3.0×10^6	2000	-2700	0.67	ϕ60.0 × 200
H6522	51	R5113-02	BA	U	3.0×10^6	2000	-2700	0.67	ϕ60.0 × 200
H1949-51	51	R1828-01	BA	K	2.0×10^7	2500	-3000	0.70	ϕ60.0 × 235
H3177-51	51	R2059	BA	Q	2.0×10^7	2500	-3000	0.70	ϕ60.0 × 235
H2431-50	51	R2083	BA	K	2.5×10^6	3000	-3500	0.61	ϕ60.0 × 200
H3378-50	51	R3377	BA	Q	2.5×10^6	3000	-3500	0.61	ϕ60.0 × 200
H6614-01	51	R5924	BA	K	1.0×10^7	2000	-2300	0.33	ϕ60.0 × 80
H6156-50	51	R5496	BA	K	1.3×10^7	2500	-3000	0.71	ϕ60.0 × 215
H6559	76	R6091	BA	K	1.0×10^7	2000	-2500	0.62	ϕ83.0 × 218
H6527	127	R1250	BA	K	1.4×10^7	2000	-3000	1.02	ϕ142.0 × 360
H6528	127	R1584	BA	U	1.4×10^7	2000	-3000	1.02	ϕ142.0 × 360
R3600-06	508	R3600-02	BA	K	1.0×10^7	2000	+2500	0.44	ϕ508.0 × 695

DP-Type PMT Assemblies (with a Side-on Type PMT and Built-in HV Power Supply)

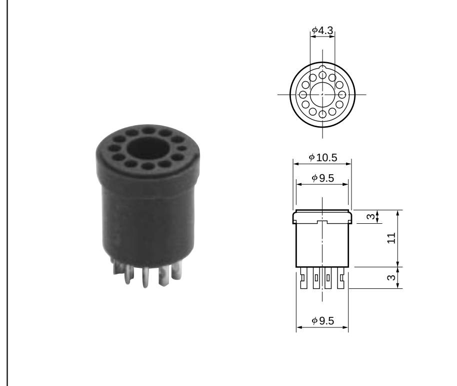
<table>
<tr><th>Type No.</th><th>Built-in PMT</th><th>Input Voltage Range (V)</th><th>Maximum Input Current (mA)</th><th>Power Supply Output Voltage Range (V)</th><th>Power Supply Output Voltage Programming</th><th>Dimensions (mm)</th></tr>
<tr><td>H957-01</td><td>R212</td><td rowspan="4">+15 ± 0.5</td><td rowspan="4">150</td><td rowspan="4">-400 to -900</td><td rowspan="4">Resistance (0 kΩ to 10 kΩ) or Voltage (0 V to 4V)</td><td rowspan="4">32.0 dia. × 100 L</td></tr>
<tr><td>H957-06</td><td>931B</td></tr>
<tr><td>H957-08</td><td>R928</td></tr>
<tr><td>H957-15</td><td rowspan="2">R3896</td></tr>
<tr><td>H7318</td><td>+15 ± 1</td><td>45</td><td>0 to -1250</td><td>50 kΩ Potentiometer or Voltage (0 V to 5 V)</td><td>35.4 dia. × 113 L</td></tr>
</table>

E678 Series Sockets

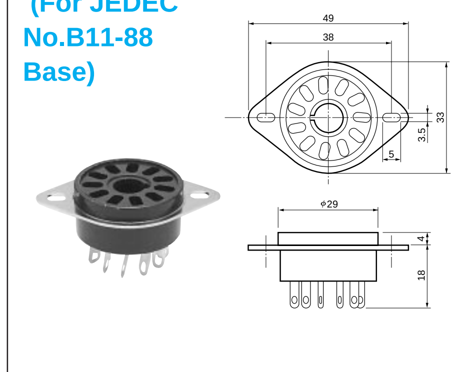
E678-11U



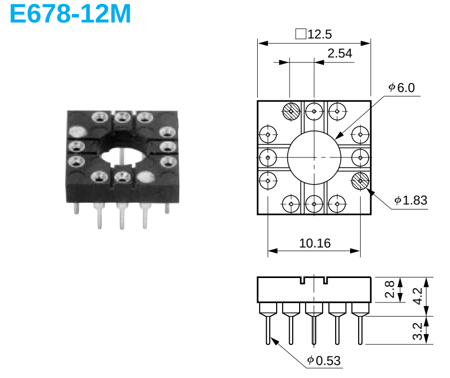
E678-11N



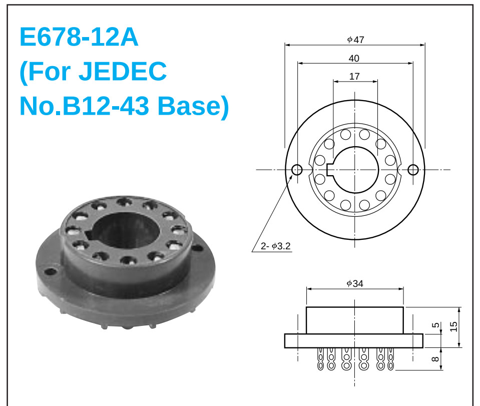
E678-11A (For JEDEC No.B11-88 Base)



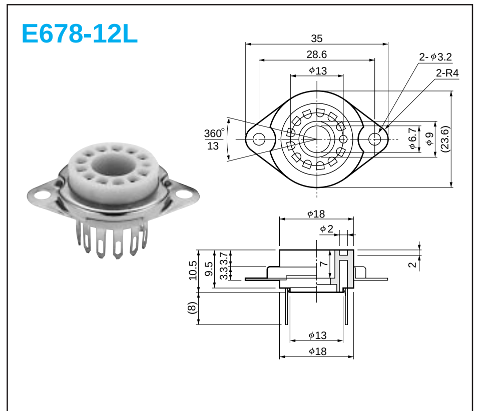
E678-12M



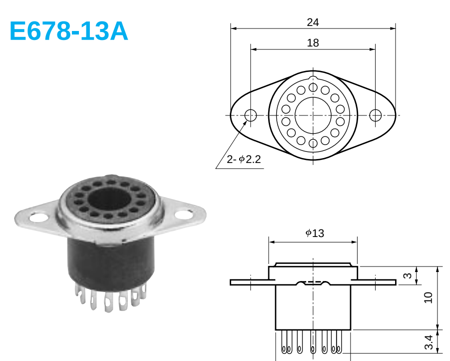
E678-12A (For JEDEC No.B12-43 Base)



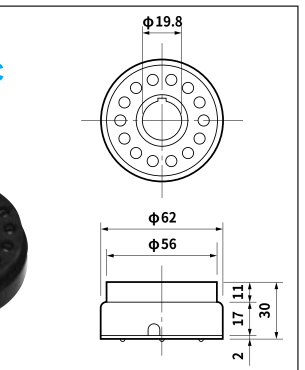
E678-12L



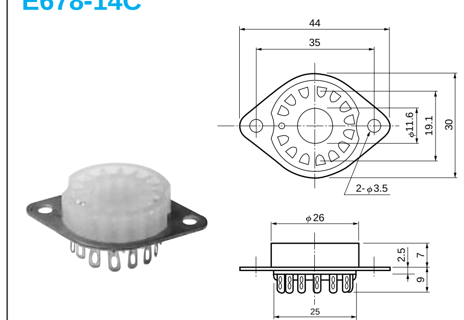
E678-13A



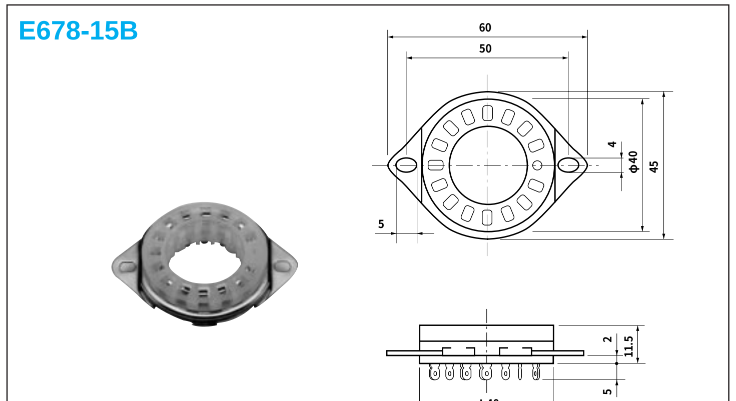
E678-14V (For JEDEC No.B14-38 Base)



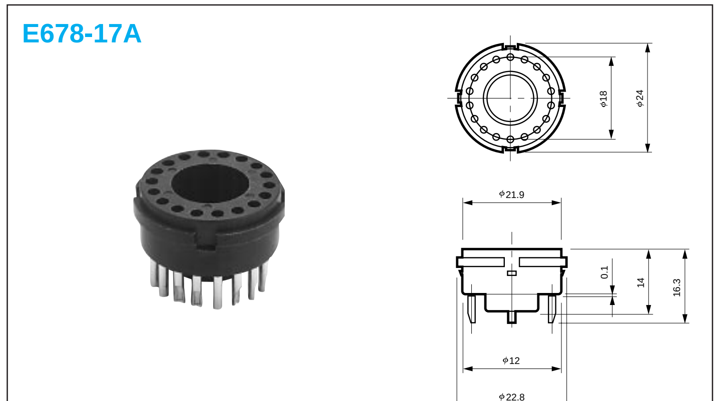
E678-14C



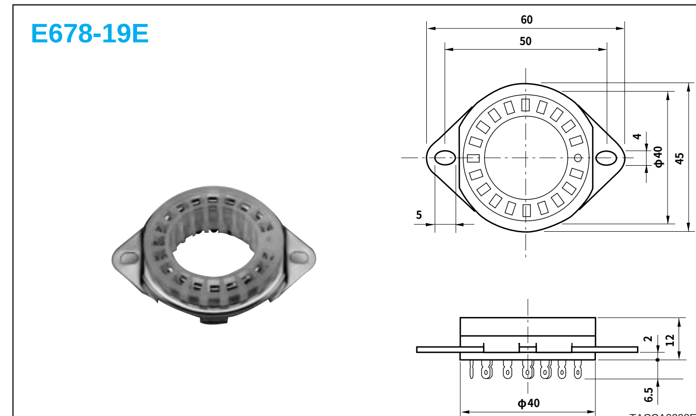
E678-15B



E678-17A



E678-19E



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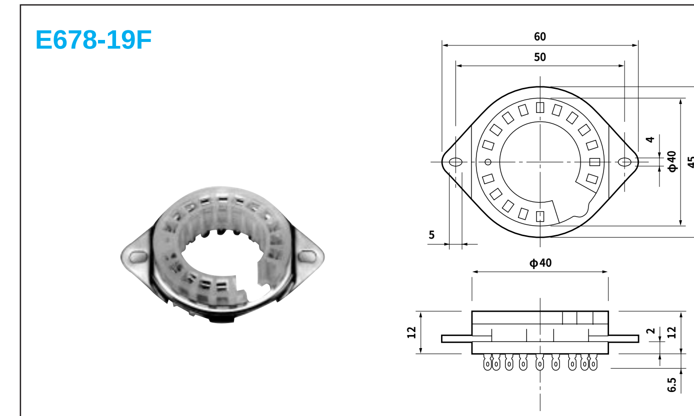
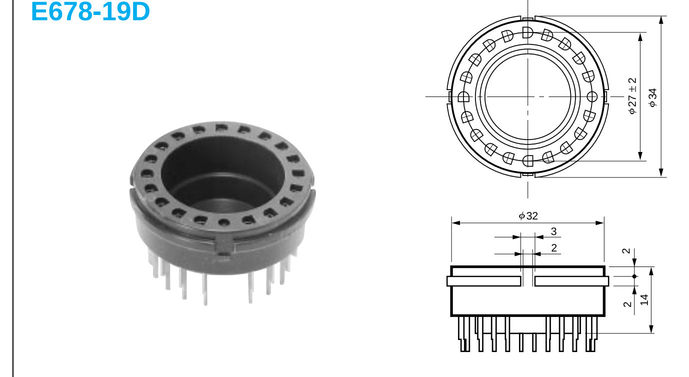
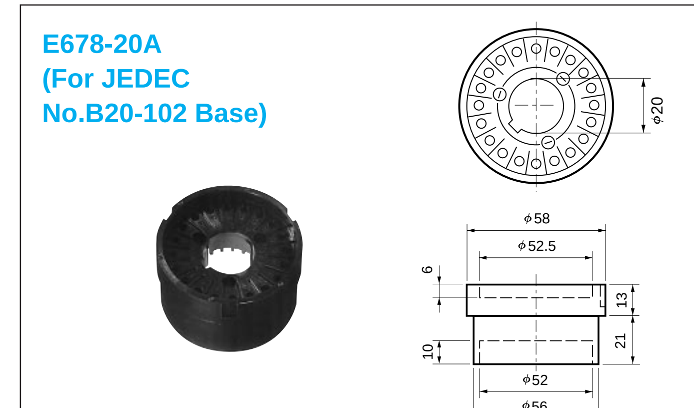


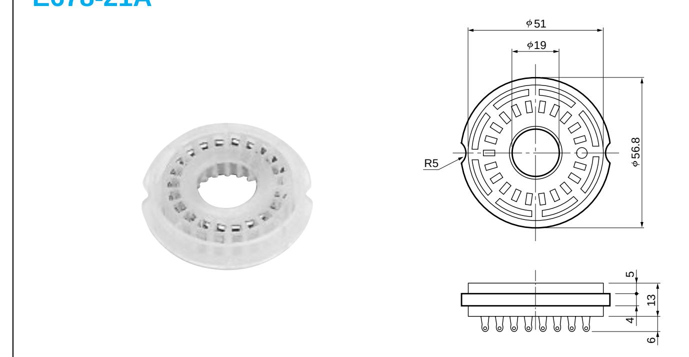
E678-19D



E678-20A (For JEDEC No.B20-102 Base)



E678-21A



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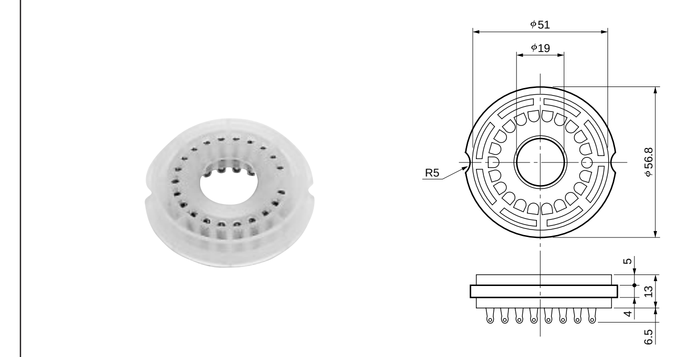

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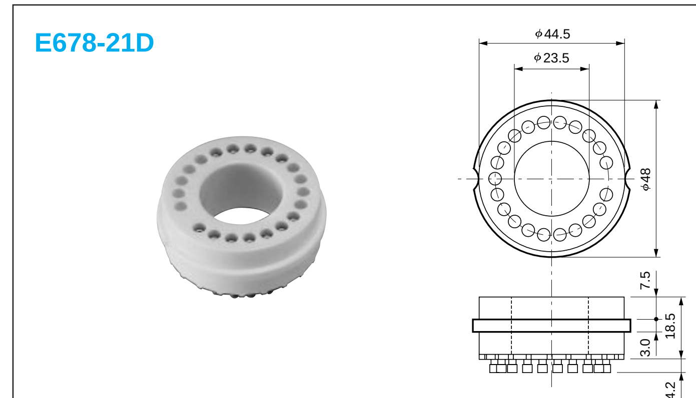
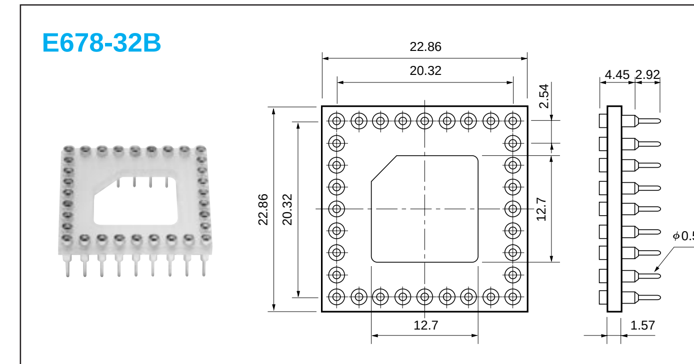


E678-32B



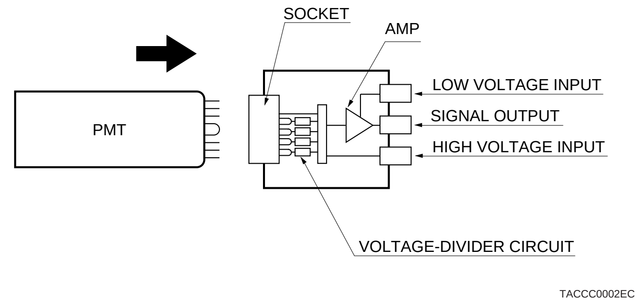
Socket Assemblies

(For further information, a detailed catalog is available.)

Operating a photomultiplier tube requires a voltage-divider circuit (divider circuit). For easier handling and operation of photomultiplier tubes, Hamamatsu provides a complete line of socket assemblies which are carefully engineered to integrate a socket and optimum voltage-divider circuit into a compact case. In addition, socket assemblies which further include a preamplifier or high-voltage power supply are available.

The socket assemblies are classified into three types by their functions as described below.

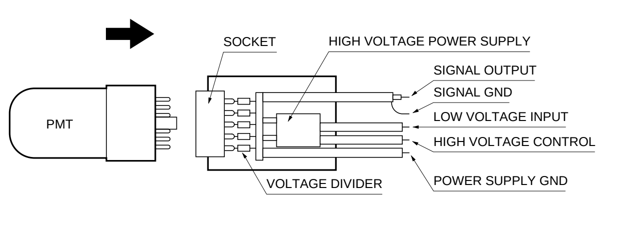
DA-Type Socket Assemblies (with built-in voltage divider and amplifier)



The DA-type socket assemblies incorporate a current-to-voltage conversion amplifier in addition to a voltage-divider circuit. High voltage (for PMT) and low voltage (for amplifier) power supplies are required. Since the high impedance output of the photomultiplier tube is connected to the amplifier at a minimum distance, the problem of external noise induced in connecting cables can be eliminated. Two families of DA-type socket assemblies are available: the C7246 series for a bandwidth from DC to 20 kHz and the C7247 series from DC up to 5 MHz. Both families are designed for use with 28 mm (1-1/8 inch)diameter side-on and head-on photomultiplier tubes.

Type No.		C7246	C7246-01	C7247	C7247-01
Applicable PMT		28 mm (1-1/8 ") dia. Head-on	28 mm (1-1/8 ") dia. Side-on	28 mm (1-1/8 ") dia. Head-on	28 mm (1-1/8 ") dia. Side-on
Max. Supply Voltage to Voltage Divider		-1500 V dc		-1500 V dc	
Supply Voltage to Amplifier		±12 V dc to 15 V dc		±12 V dc to 15 V dc	
Current-to-Voltage Conversion Factor		0.3 V / µA		0.3 V / µA	
Max. Input Signal Current (at -1000 V, 10 V output)	DC	33 µA		33 µA	
	Pulse	33 µA		33 µA	
Max. Output Voltage (Unterminated)		10 V peak (20 kHz)		10 V peak (5 MHz)	
Frequency Bandwidth		DC to 20 kHz		DC to 5 MHz	

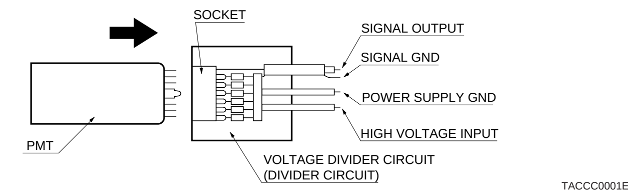
DP-Type Socket Assemblies (with built-in voltage divider and power supply)



The DP-type socket assemblies feature a built-in voltage divider and compact high-voltage power supply. By applying a +15 V supply to the power supply, easy operation of a photomultiplier tube is possible. As standard products, the C956 series assemblies are provided for use with 28 mm (1-1/8 inch) diameter side-on and head-on photomultiplier tubes.

Type No.	C6270	C956-07
Applicable PMT	28 mm (1-1/8 ") dia. side-on	28 mm (1-1/8 ") dia. head-on
Input Voltage	+(15 ± 1) V dc	
Input Current	45 mA Max.	140 mA Max.
Output Voltage Range	0 V dc to -1250 V dc Typ.	-200 V dc to -1250 V dc Typ.
Input Regulation	±0.01 % Typ. at + (15 ± 1) V dc	±0.05 % Max. at + (15 ± 1) V dc
Maximum PMT Signal Output at -1000 V	100 µA Typ.	15 µA Typ.

D-Type Socket Assemblies



The D-type socket assemblies incorporate a socket and voltage-divider circuit. A high voltage power supply and a current/electric charge signal processing circuit are required. The following four types are available according to the grounded electrode, supply voltage polarity and output signal form.

1. Anode ground, DC output
2. Anode ground, DC/pulse output
3. Cathode ground, pulse output
4. Anode or cathode ground, DC/pulse output

For Side-On Photomultiplier Tubes

Code	Socket Assembly Type No.	Applicable PMT Diameter	Grounded Electrode/ Supply Voltage Polarity	Output Signal
1	E850 -13	13 mm(1/2 ")	Anode/-	DC/Pulse
2	E717 -63	28 mm(1-1/8 ")	Anode/-	DC/Pulse
3	-35		Anode/- · Cathode/+	DC/Pulse

For Head-On Photomultiplier Tubes

Code	Socket Assembly Type No.	Applicable PMT Diameter	Grounded Electrode/ Supply Voltage Polarity	Output Signa
4	E1761 -04	10 mm(3/8 ")	Anode/-	DC/Pulse
5	-05		Anode/-	DC/Pulse
6	-21		Anode/-	DC/Pulse
7	E849 -35	13 mm(1/2 ")	Anode/-	DC/Pulse
8	-52		Anode/-	DC/Pulse
9	-68		Anode/-	DC/Pulse
10	-90		Anode/-	DC/Pulse
11	E2253 -08	19 mm(3/4 ")	Cathode/+	Pulse
12	-05		Anode/-	DC/Pulse
13	E974 -13		Anode/-	DC/Pulse
14	-14		Cathode/+	Pulse
15	-17		Anode/-	DC/Pulse
16	-18		Anode/-	DC/Pulse
17	-22		Anode/-	DC/Pulse
18	E2924	25 mm(1 ")	Anode/-	DC/Pulse
19	-500		Anode/-	DC/Pulse
20	-05		Cathode/+	Pulse
21	E2624 -500		Anode/-	DC/Pulse
22	E2624	28 mm(1-1/8 ")	Anode/-	DC/Pulse
23	-05		Cathode/+	Pulse
24	E990 -07		Anode/-	DC/Pulse
25	-08		Cathode/+	Pulse
26	-28		Anode/-	DC/Pulse
27	E2183 -502	38 mm(1-1/2 ")	Cathode/+	Pulse
28	-500		Anode/-	DC/Pulse

NOTE) Please consult our sales office when you use a photomultiplier tube in a vacuum.

Code	Socket Assembly Type No.	Applicable PMT Diameter	Grounded Electrode/ Supply Voltage Polarity	Output Signal
29	E1198 -23	51 mm(2 ") [76 mm(3 ")] [127 mm(5 ")]	Cathode/+	Pulse
20	-05		Anode/-	DC/Pulse
31	-07		Anode/-	DC/Pulse
32	-22		Anode/-	DC/Pulse
33	E4512 -502		Anode/-	DC/Pulse
34	E5859 -01		Anode/-	DC/Pulse
35	E5859 -05		Anode/-	DC/Pulse
36	E2979 -500		Anode/-	DC/Pulse
37	E4512 -503		Cathode/+	Pulse
38	-504		Cathode/+	Pulse
39	-505		Cathode/+	Pulse
40	E1435 -02		Anode/-	DC/Pulse
41	E4229 -501		Anode/-	DC/Pulse
42	E1458 -501		Anode/-	DC/Pulse
43	-502		Cathode/+	Pulse
44	E6133 -03	25 mm(1 ") For highly magnetic environments	Anode/-	DC/Pulse
45	E6132-02	51 mm(2 ") For highly magnetic environments	Anode/-	DC/Pulse

Metal Package Photomultiplier Tubes

Code	Socket Assembly Type No.	Applicable PMT	Grounded Electrode/ Supply Voltage Polarity	Output Signal
46	E5780	R7400U	Anode/-	DC/Pulse
47	E5996	R5900U	Anode/-	DC/Pulse
48	E7083	R5900U-00-M4	Anode/-	DC/Pulse
49	E6736	R5900U-00-L16	Anode/-	DC/Pulse
50	E6669-01	R5900U-00-C8	Anode/-	DC/Pulse

High-Voltage Power Supplies

The output of a photomultiplier tube is extremely sensitive to the applied voltage. Even small variations in applied voltage greatly affect measurement accuracy. Thus a highly stable source of high voltage is required. (See page 8.) Hamamatsu regulated high-voltage power supplies are designed for precision measurement using a photomultiplier tube and manufactured with careful consideration given to high stability and low ripple. To meet various needs, they are available in a wide range of configurations and performances, including unit types for PC board mounting, bench-top types and a 5 kV output type for MCP-PMTs.

▲C3830

Type No.	Output Voltage Range (Vdc)	Maximum Output Current (mA)	Input Voltage	Dimensions (W × H × D) (mm)	Weight
Unit Types					
C4710	-240 to -1500	1	+15 V dc	65 × 27.5 × 45	105 g
C4710-01	-240 to -1500	1	+12 V dc	65 × 27.5 × 45	105 g
C4710-02	-240 to -1500	1	+24 V dc	65 × 27.5 × 45	105 g
C4710-50	+240 to +1500	1	+15 V dc	65 × 27.5 × 45	105 g
C4710-51	+240 to +1500	1	+12 V dc	65 × 27.5 × 45	105 g
C4710-52	+240 to +1500	1	+24 V dc	65 × 27.5 × 45	105 g
C4900	0 to -1250	0.6	+15 V dc	46 × 24 × 12	31 g
C4900-01	0 to -1250	0.5	+12 V dc	46 × 24 × 12	31 g
C4900-50	0 to +1250	0.6	+15 V dc	46 × 24 × 12	31 g
C4900-51	0 to +1250	0.5	+12 V dc	46 × 24 × 12	31 g
Bench-Top Types					
C3350	0 to ±3000	10	100/115/220/230 V ac	220 × 120 × 350	8 kg
C3360	0 to -5000	1	100-120/220-240 V ac	210 × 99 × 273	3.5 kg
C3830	-200 to -1500/±5/±15	1/500/200	100/120/220/230 V ac	255 × 54 × 230	2.8 kg
C4720	+200 to +1500/±5/±15	1/500/200	100/115/220/240 V ac	255 × 54 × 230	2.8 kg

Thermoelectric Coolers

(For more information, a detailed catalog is available.)

The thermionic electron emission from a photocathode and dynodes is a major factor that determines the dark current of the photomultiplier tube. (See page 8.) Cooling the photomultiplier tube can efficiently reduce the dark current and improve the S/N ratio, resulting in an significant enhancement in the detection limit. Hamamatsu provides a variety of thermoelectric coolers specifically designed for photomultiplier tubes to meet various needs.


▲C4877

Type No.	Applicable PMT	Input Voltage (Vac)	Cooling Temperature (°C)*	Remarks
C659-70 Series	28 mm (1-1/8 ") Dia. Side-on	100/115/220	Approx. -15	
C659-50 Series	28 mm (1-1/8 "),38 mm (1-1/2 ") Dia. Head-on	100/115/220	Approx. -20	
C4877 Series	38 mm (1-1/2 ") ,51 mm (2 ") Dia. Head-on	100/120/230	Approx. -30	Temperature controllable
C4878 Series	MCP-PMT	100/120/230	Approx. -30	Temperature controllable

* With +20 °C coolant.
Socket assemblies and holders are sold separately.

Magnetic Shield Cases

Photomultiplier tubes are generally very susceptible to magnetic fields. Even terrestrial magnetism will have a detrimental effect on the photomultiplier tube output. (See page 9.) Hamamatsu E989 series magnetic shield cases are designed to protect photomultiplier tubes from magnetic field effects. Since the E989 series magnetic shield cases are made of permalloy which has high permeability (about 10^5), the magnetic field strength within the shield case with respect to the external magnetic field strength (the reciprocal of this is called shielding factor) can be greatly attenuated down to 1/1 000 to 1/10 000, thus ensuring stable output from photomultiplier tubes even operating in magnetic fields.


▲ Magnetic Shield Cases

Applicable PMT Diameter		Type No.	Internal Diameter (mm)	Thickness (mm)	Length (mm)	Weight (g)
Side-on	13 mm (1/2 ")	E989-10	14.5	0.5	47 ± 0.5	10
	28 mm (1-1/8 ")	E989	33.6 ± 0.8	0.8	80 ± 1	66
Head-on	10 mm (3/8 ")	E989-28*	12 ± 0.5	0.5	48 ± 0.5	9
	13 mm (1/2 ")	E989-09	16 ± 0.5	0.8	75 ± 0.5	28
	19 mm (3/4 ")	E989-02	23 ± 0.5	0.8	95 ± 1	50
	25 mm (1 ")	E989-39	29 ± 0.5	0.8	48 ± 0.5	32
	28 mm (1-1/8 ")	E989-03	32 ± 0.5	0.8	120 ± 1	90
	38 mm (1-1/2 ")	E989-04	44^{+1}_{-0}	0.8	100 ± 1	102
	51 mm (2 ")	E989-05	60^{+1}_{-0}	0.8	130 ± 1	180
	76 mm (3 ")	E989-15	$80^{+1.5}_{-0}$	0.8	120 ± 1	200
	127 mm (5 ")	E989-26*	138 ± 1.5	0.8	170 ± 1	600

* With mounting tabs.

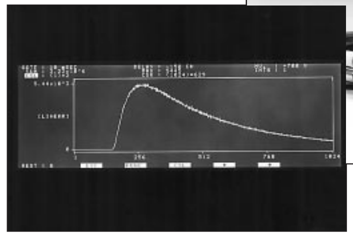
Photon Counters and Related Products

Recently, photon counting has become widely used as an effective technique for detecting very low light levels in various fields such as biology, chemistry and medicine. As a leading manufacturer of photomultiplier tubes, Hamamatsu provides a variety of photon counters and related products. Our product line includes Photon Counter that allows time-resolved photometry and Photon Counting Units that integrate only essential functions into a compact case. Please feel free to contact Hamamatsu sales offices for further information. Photon counting modules, photon counting head, photon counting unit and prescaler, are also available.

Photon Counter C5410 Series

The C5410 is a time-resolved photon counter with a large-screen liquid crystal display (640 dots × 200 dots) enabling an instantaneous display of the measured waveform as well as numerical count rates.
The C5410 also includes a high-voltage power supply, preamplifier and discriminator. High-precision photon counting can be performed by simply preparing a photomultiplier tube and D-type socket assembly (see page 79).

▲ C5410
PMT and socket assembly will be sold separately as an option.



▲ Instantaneous display of the measured waveform.

Photon Counting Modules
Photon Counting Heads

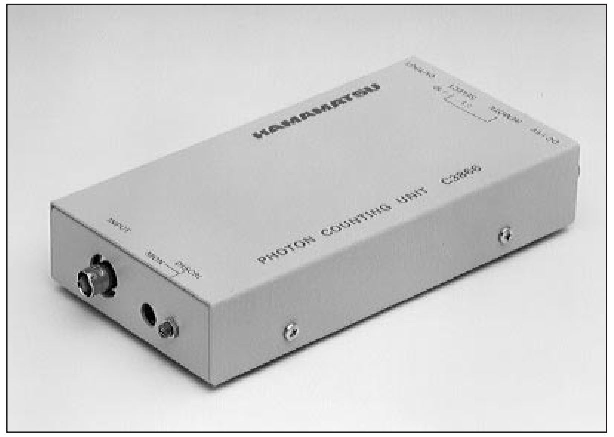
H6180 · H6240 Series

The H6180 and H6240 series are compact photon counting heads comprising a low noise PMT, a high speed photon counting circuit, and a high voltage power supply. The operation only requires connecting with a +5 Vdc power supply and a pulse counter. No discrimination level or high voltage adjustment are required of the user.

▲ LEFT: H6240
RIGHT: H6180-01 with optional mounting flange

Photon Counting Unit
C3866, C6465

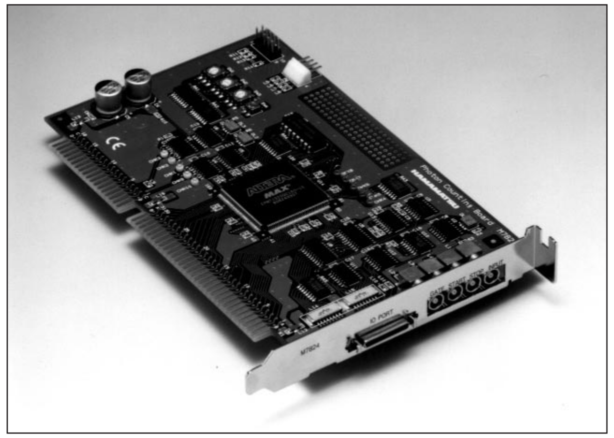
The C3866 and C6465 convert the photoelectron pulses of the photomultiplier tube into 5 V digital signals by the built-in amplifier/discriminator. Use of a high-speed electronic circuit permits light measurements with excellent linearity up to a maximum count rate of 10^7 s^{-1}(cps).



▲ C3866

Photon Counting Board M7824

The photon counting board M7824 is designed for direct plug-in to the ISA bus slot in a PC (Windouws 95/98).
Photon counting measurements over a wide dynamic range can be easily made by input of photoelectric pulses which are converted into a logic (TTL) signal.
The counter applies a double-count method that allows time-resolved photon counting of high-speed optical phenomena with no dead time between gates.
Simultaneous 2-channel measurements are also possible by using two M7824 boards.



▲ M7824

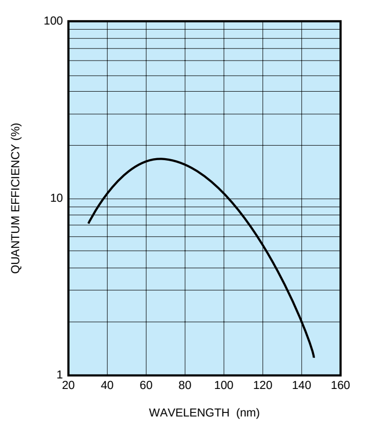
Electron multipliers (also called ion multipliers) are specially designed for the detection and measurement of electrons, charged particles such as ions, VUV radiations and soft X-rays. Hamamatsu electron multipliers have high gain and low noise, making them suitable for the detection of very small or low energy particles by using the counting method. They are well suited for mass spectroscopy, field ion microscopy, and electron or VUV spectroscopy such as Auger spectroscopy, AES and ESCA.

Each type has Cu-BeO dynodes connected by built-in divider resistors (1 MΩ per stage) and is supplied in an evacuated glass bulb. The first dynode can be replaced by a photocathode of Cs-I, K-Br, etc. for use in VUV photometry.

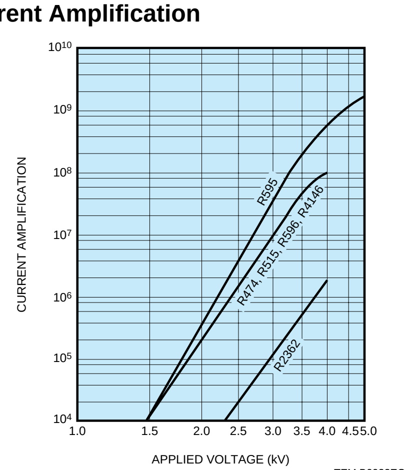
In such applications as ICP-MASS where electron multipliers are used in harsh atmosphere, use of the R5150 with superior environmental resistance is recommended. Also, for TOF-MASS applications, use of the R2362 with mesh dynodes is recommended.

Ⓐ Type. No.	Out - line	Dynode				Characteristics			Anode to all Other Electrode Capaci-tance (pF)	Maximum Ratings			
		Number of Stages	Structure	Material	Radiation Opening (mm)	Supply Voltage (Vdc)	Gain Typ.	Rise Time Typ. (ns)		Anode to First Dynode Voltage (Vdc)	Anode to Last Dynode Voltage (Vdc)	Ⓙ Average Anode Current (μ A)	Operating Vacuum Level (Pa)
Head-On Types													
R474	❶	16	Box-and-grid	Cu-BeO	8 × 6	2400	1×10^6	9.3	5.0	4000	350	10	133×10^{-4}
R515	❷	16	Box-and-grid	Cu-BeO	8 × 6	2400	1×10^6	9.3	4.0	4000	350	10	133×10^{-4}
R596	❸	16	Box-and-grid	Cu-BeO	12 × 10	2400	1×10^6	10	9.0	4000	400	10	133×10^{-4}
R595	❹	20	Box-and-grid	Cu-BeO	12 × 10	3000	4×10^7	12	9.0	5000	400	10	133×10^{-4}
R2362	❺	23	Mesh	Cu-BeO	20 dia.	3450	5×10^5	3.5	23	4000	350	10	133×10^{-4}
*R5150-10	❻	16	Box-and-line	Cu-BeO	8 dia.	2000	5×10^6	1.7	4.0	3500	300	10	133×10^{-4}

● **Typical Spectral Response of Cu-BeO Used for Dynodes**

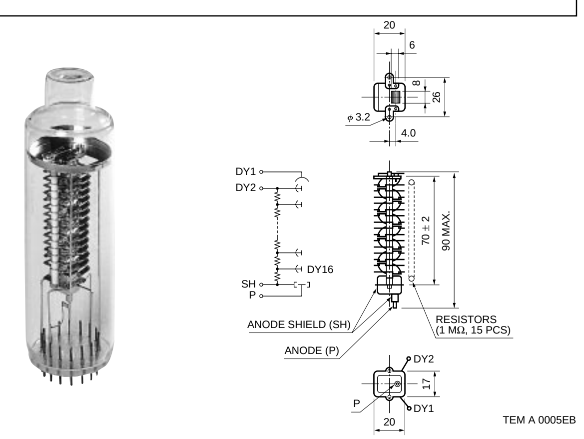


● **Typical Current Amplification**

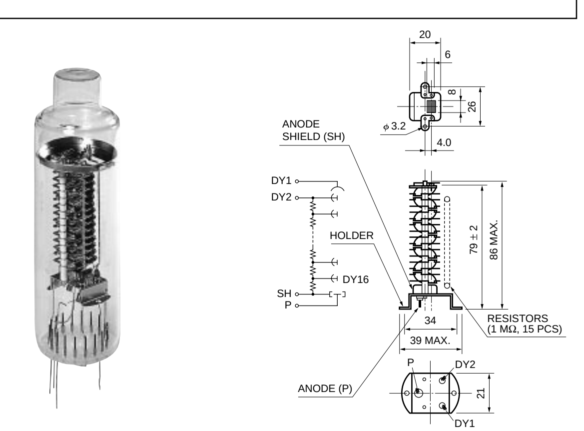


Unit : mm

❶ R474

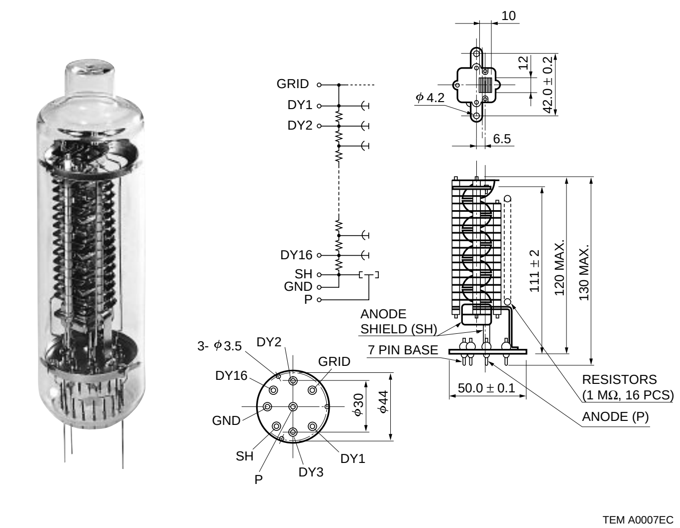


❷ R515

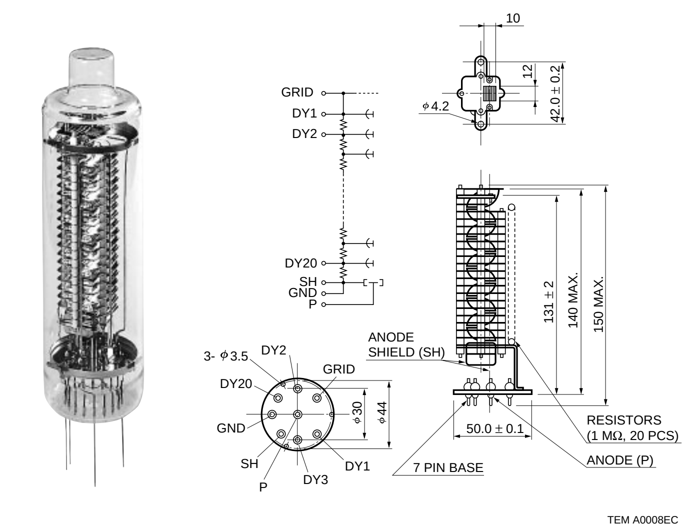


Unit : mm

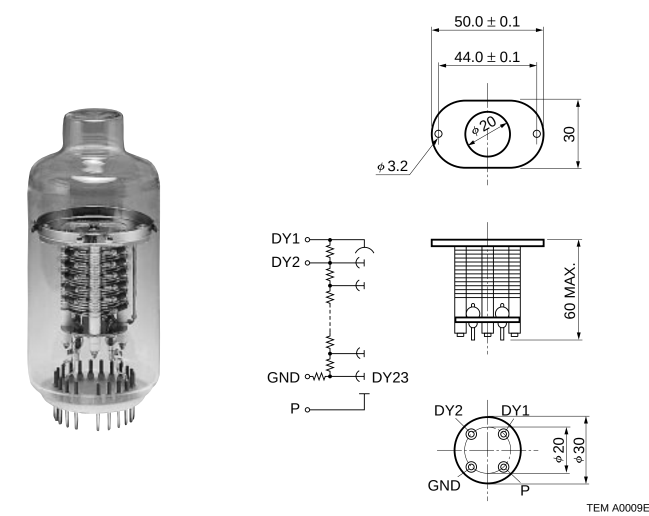
❸ R596



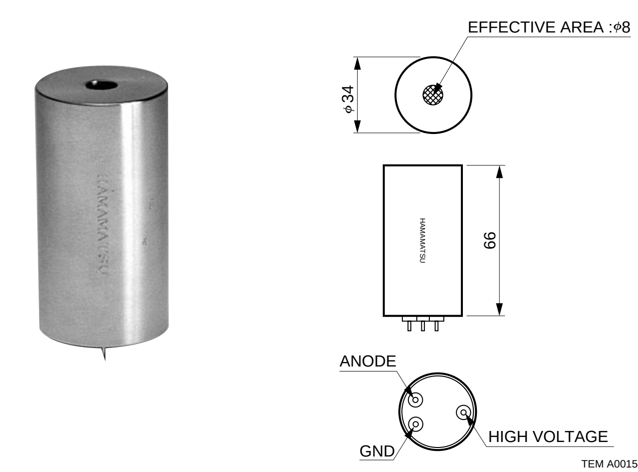
❹ R595



❺ R2362



❻ R5150-10



⚠ WARNING

HIGH VOLTAGE

Take sufficient care to avoid an electric shock hazard

A high voltage used in photomultiplier tube operation may present a shock hazard. Photomultiplier tubes should be installed and handled only by qualified personnel that have been instructed in handling of high voltages. Designs of equipment utilizing these devices should incorporate appropriate interlocks to protect the operator and service personnel.

The metal housing of the Metal Package PMT R5600 series is connected to the photocathode (potential) so that it becomes a high voltage potential when the product is operated at a negative high voltage (anode grounded).

PRECAUTIONS FOR USE

- **Handle tubes with extreme care**

Photomultiplier tubes have evacuated glass envelopes. Allowing the glass to be scratched or to be subjected to shock can cause cracks. Extreme care should be taken in handling, especially for tubes with graded sealing of synthetic silica.

- **Keep faceplate and base clean**

Do not touch the faceplate and base with bare hands. Dirt and fingerprints on the faceplate cause loss of transmittance and dirt on the base may cause ohmic leakage. Should they become soiled, wipe it clean using alcohol.

- **Do not expose to strong light**

Direct sunlight and other strong illumination may cause damage to the photocathode. They must not be allowed to strike the photocathode, even when the tube is not operated.

- **Handling of tubes with a glass base**

A glass base (also called button stem) is less rugged than a plastic base, so care should be taken in handling this type of tube. For example, when fabricating the voltage-divider circuit, solder the divider resistors to socket lugs while the tube is inserted in the socket.

- **Cooling of tubes**

When cooling a photomultiplier tube, the photocathode section is usually cooled. However, if you suppose that the base is also cooled down to -30 °C or below, please consult our sales office in advance.

- **Helium permeation through silica bulb**

Helium will permeate through the silica bulb, leading to an increase in noise. Avoid operating or storing tubes in an environment where helium is present.

Data and specifications listed in this catalog are subject to change due to product improvement and other factors. Before specifying any of the types in your production equipment, please consult our sales office.

WARRANTY

All Hamamatsu photomultiplier tubes and related products are warranted to the original purchaser for a period of 12 months following the date of shipment. The warranty is limited to repair or replacement of any defective material due to defects in workmanship or materials used in manufacture.

A: Any claim for damage of shipment must be made directly to the delivering carrier within five days.

B: Customers must inspect and test all detectors within 30 days after shipment. Failure to accomplish said incoming inspection shall limit all claims to 75 % of invoice value.

C: No credit will be issued for broken detectors unless in the opinion of Hamamatsu the damage is due to a bulb crack or a crack in a graded seal traceable to a manufacturing defect.

D: No credit will be issued for any detector which in the judgment of Hamamatsu has been damaged, abused, modified or whose serial number or type number have been obliterated or defaced.

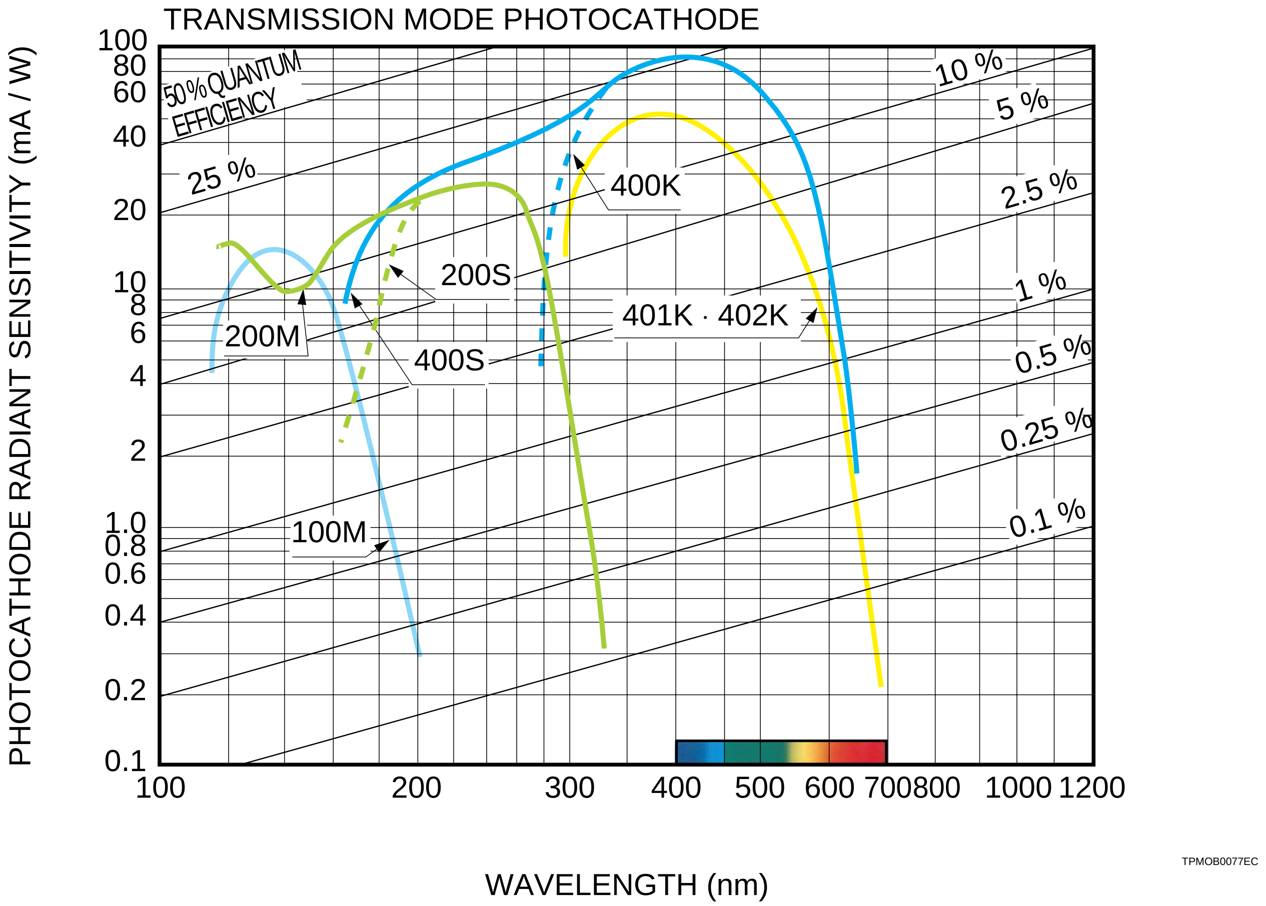
E: No detectors will be accepted for return unless permission has been obtained from Hamamatsu in writing, the shipment has been returned prepaid and insured, the detectors are packed in their original box and accompanied by the original data sheet furnished to the customer with the tube, and a full written explanation of the reason for rejection of each detector.

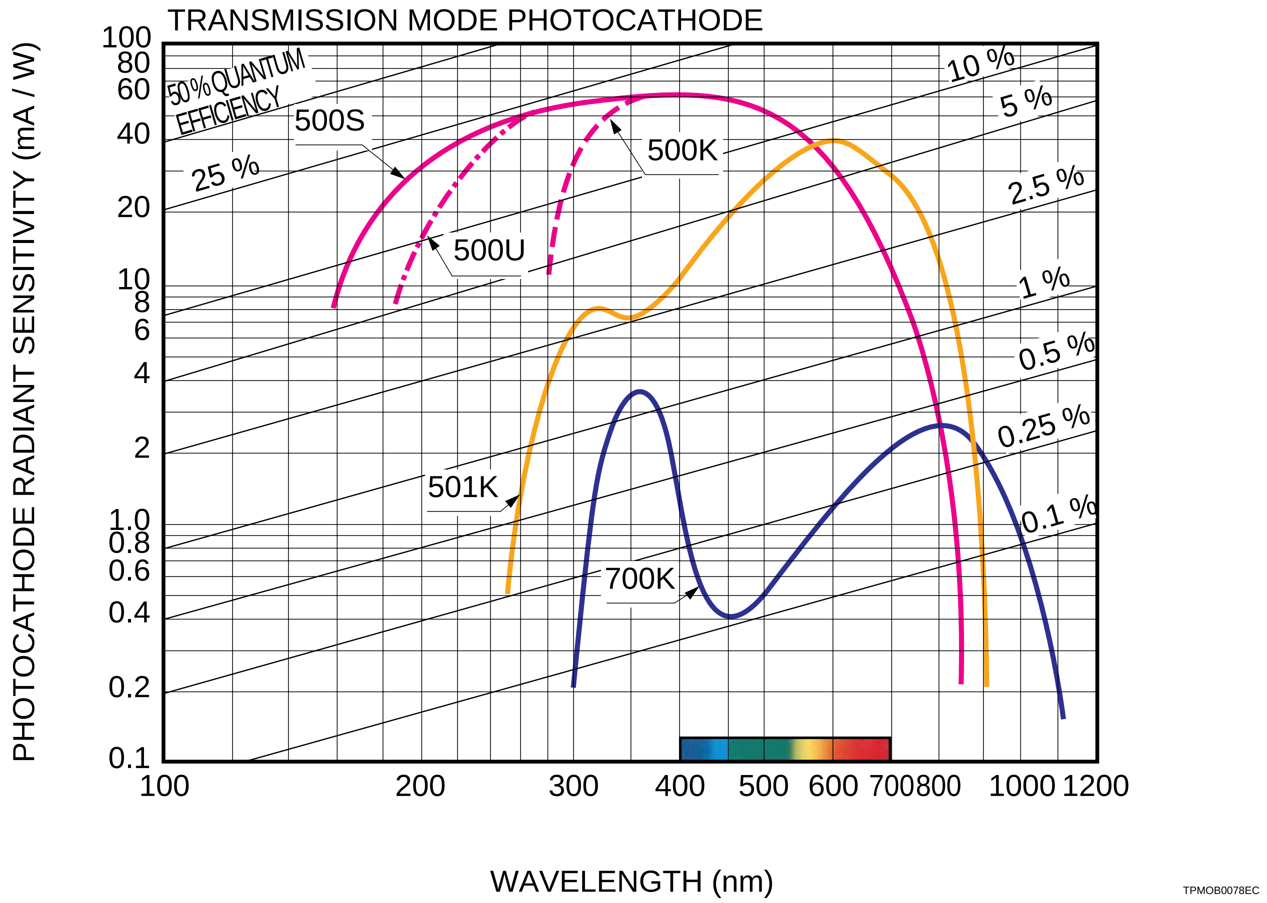
F: When products are used at a condition which exceeds the specified maximum ratings or which could hardly be anticipated, Hamamatsu will not be the guarantor of the products.

Curve Codes		Photocathode Materials	Window Materials	Spectral Response			PMT Examples
				Range	Peak Wavelength		
					Radiant Sensitivity	Q.E.	
				(nm)	(nm)	(nm)	
Semitransparent Photocathode							
○	100M	Cs-I	MgF_2	115 to 200	140	130	R972, R1081, R6835
○	200M	Cs-Te	MgF_2	115 to 320	240	240	R1080, R6836
	201M	Cs-Te	MgF_2	115 to 320	220	220	R3809U-57
○	200S	Cs-Te	Synthetic silica	160 to 320	240	240	R759, R821, R1893, R6834
	201S	Cs-Te	Synthetic silica	160 to 320	240	220	R2078
○	400K	Bialkali	Borosilicate	300 to 650	420	390	R329-02, R331-05, R464, R5496, R1635, R647, R1166, R2486-02, R2154-02, R3998-02, R5800, R6427, R6091, R5924, R5946, R6095, R580, R1828-01, R5611-01, R4998, R1924, R3234-01, R7400U, R5900U
	400U	Bialkali	UV	185 to 650	420	390	R7400U-03,R1584
○	400S	Bialkali	Synthetic silica	160 to 650	420	390	R2496, R7400U-06
○	401K	High temp. bialkali	Borosilicate	300 to 650	375	360	R1281, R1288, R1705, R3991, R4177-01, R4607-01
○	402K	Low noise bialkali	Borosilicate	300 to 650	375	360	R2557, R2801, R3550
	403K	Bialkali	Synthetic Silica	160 to 650	400	420	R3809U-52, R5916U-52
	430U	Bialkali	UV	185 to 650	375	300	R2693
	500M	Multialkali	MgF_2	115 to 850	430	360	R3809U-58
○	500K(S-20)	Multialkali	Borosilicate	300 to 850	420	360	R550, R649, R1387, R1513, R1617, R1878, R1894, R1925
○	500S	Multialkali	Synthetic silica	160 to 850	420	280	R375, R3809U-50, R5916U-50
○	500U	Multialkali	UV	185 to 850	420	290	R374, R1463, R1464, R2368
	502K (Super S20)	Multialkali	Borosilicate	300 to 900	420	400	R5070, R5929
	501S	Multialkali	Synthetic silica	160 to 910	600	590	R3809U-51, R5916U-51
○	501K	Multialkali	Borosilicate	300 to 900	600	580	R669, R2066, R2228, R2257
○	700K(S-1)	Ag-O-Cs	Borosilicate	400 to 1200	800	780	R316-02, R632-01, R1767, R5108
	700M	Ag-O-Cs	Borosilicate	400 to 1200	800	780	R3809U-59
Reflection mode Photocathode							
○	150M	Cs-I	MgF_2	115 to 195	130	120	R1259, R7511
○	250S	Cs-Te	Fused silica	160 to 320	230	190	R6354,R7154
○	250M	Cs-Te	MgF_2	115 to 320	200	190	R1220, R7311
○	350K(S-4)	Sb-Cs	Borosilicate	300 to 650	400	350	R105, 1P21, 931A
○	350U(S-5)	Sb-Cs	UV	185 to 650	340	270	R212, R3810, R6350, 1P28
○	350S(S-19)	Sb-Cs	Fused silica	160 to 650	340	210	R6351
	453K	Bialkali	Borosilicate	300 to 650	400	360	931B
	456U	Low noise bialkali	UV	185 to 680	400	300	R1527, R4220, R6353
	452U	Bialkali	UV	185 to 750	420	220	R3788, R6352
	558K	Multialkali	Borosilicate	300 to 800	530	510	R1923
	561U	Multialkali	UV	185 to 830	530	300	R6358
	556U	Multialkali	UV	185 to 850	430	280	R4632
	550U	Multialkali	UV	185 to 850	530	250	R3811, R6355
○	555U	Multialkali	UV	185 to 850	430	280	R3896
	552U	Multialkali	UV	185 to 900	400	260	R2949
○	562U	Multialkali	UV	185 to 900	400	260	R928
	554U	Multialkali	UV	185 to 900	450	370	R1477-06
○	650U	GaAs(Cs)	UV	185 to 930	300 to 800	300	R636-10
○	650S	GaAs (Cs)	Synthetic silica	160 to 930	300 to 800	280	R943-02
○	850U	InGaAs(Cs)	UV	185 to 1010	400	330	R2658
○	851K	InGaAs(Cs)	Borosilicate	300 to 1040	400	350	R3310-02

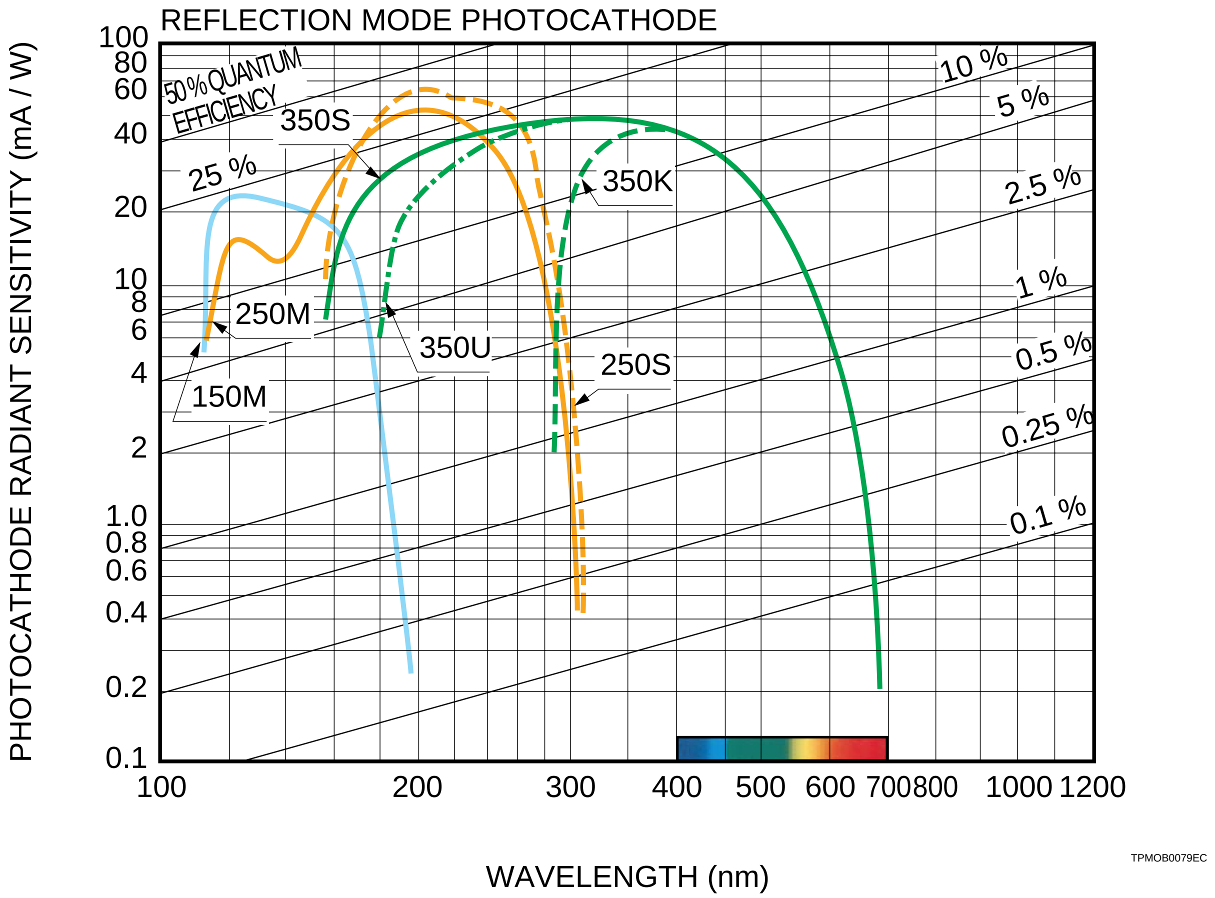
○ : Spectral response curves are shown on page 88, 89

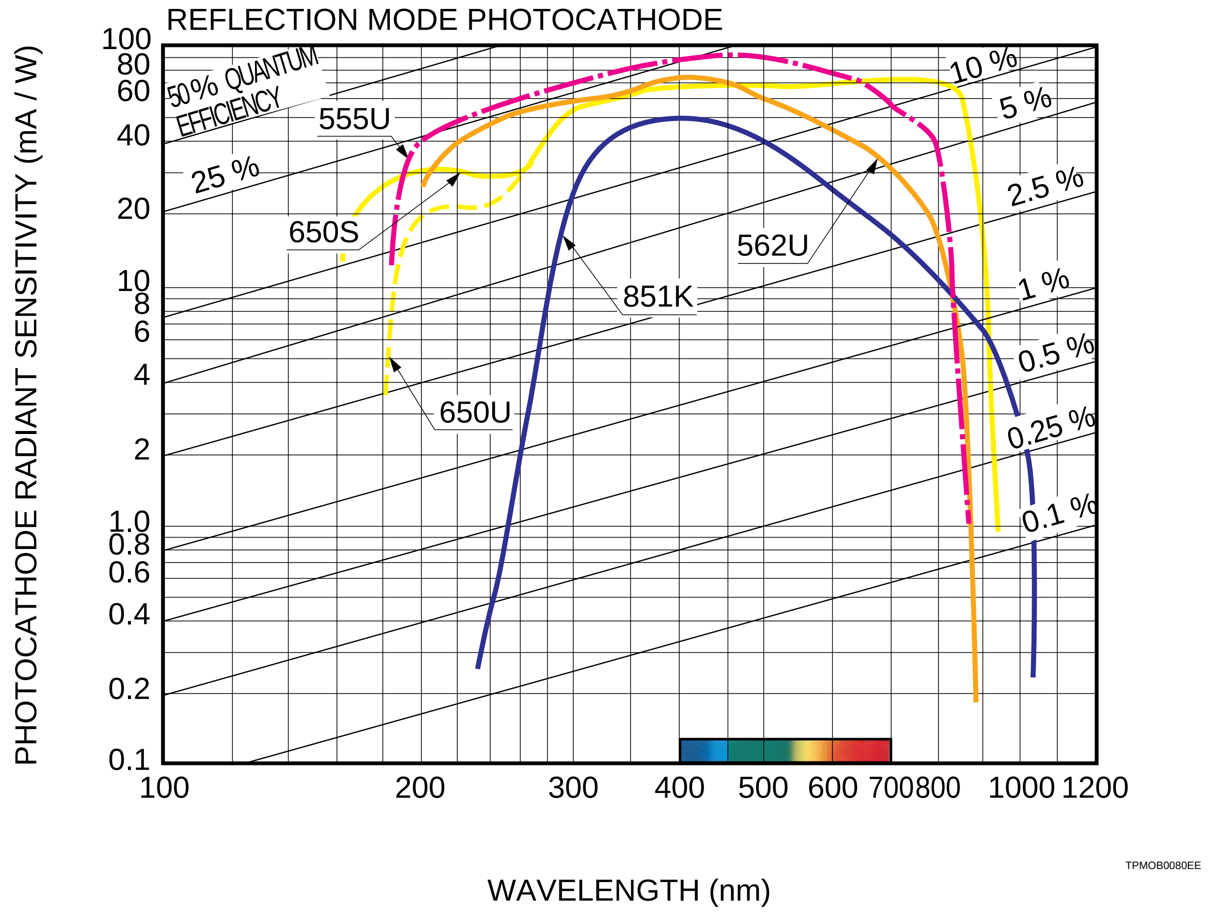
SEMITRANSPARENT PHOTOCATHODE SPECTRAL RESPONSE CHARACTERISTICS





OPAQUE PHOTOCATHODE SPECTRAL RESPONSE CHARACTERISTICS





NOTES

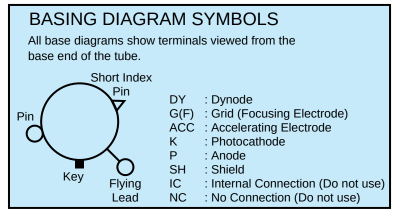
Ⓐ ∗ : Newly listed in this catalog.

Ⓑ Refer to pages 88 and 89 for typical spectral response charts.

Ⓒ Photocathode materials
- BA : Bialkali
- LBA : Low dark current bialkali
- HBA : High temperature bialkali
- MA : Multialkali
- EMA : Extended red multialkali

Ⓓ Window materials
- MF : MgF_2
- Q : Quartz (Fused Silica or Synthetic Silica)
- K : Borosilicate glass
- U : UV glass

Ⓔ Basing diagram



Ⓕ Dynode structure
- B : Box-and-grid
- VB : Venetian blind
- CC : Circular-cage
- L : Linear-focused
- B+L : Box and linear focused
- FM : Fine Mesh
- CM : Coarse Mesh
- MC : Metal Channel

Ⓖ ★ : A socket will be supplied with the tube.
■ : Sockets may be available from electronics supply houses or our sales office. (See pages 76 and 77.)

Ⓗ The maximum ambient temperature range is -80 °C to +50 °C except the following tubes using a high temperature bialkali photocathode which withstands from -80 °C up to +175 °C. When a tube is operated below -30 °C see page 86, "PRECAUTIONS FOR USE".

Diameter	Type No.	Diameter	Type No.
13 mm (1/2 ")	R4177-01	38 mm (1-1/2 ")	R1705
19 mm (3/4 ")	R1281,R3991	51 mm (2 ")	R4607-01
25 mm (1 ")	R1288	—	—

Ⓙ Averaged over any interval of 30 seconds maximum.

Ⓚ Measured at the peak wavelength.

Ⓛ Refer to page 72 for voltage distribution ratios.

Ⓜ Anode characteristics are measured with the supply voltage and voltage distribution ratio specified by Note L.

Ⓝ Anode characteristics are measured at the specified supply voltage on page 61.

Ⓡ Anode characteristics are measured with the specified anode-to-cathode supply voltage.

ⓐ at 122 nm
ⓑ at 254 nm
ⓒ at 852 nm
ⓓ Measured using a red filter Toshiba IR-D80A.
ⓔ at 4 A/lm
ⓕ at 10 A/lm
ⓖ at 1000 A/lm
ⓗ Dark counts per second s^{-1}(cps)
ⓙ Dark counts per second s^{-1}(cps) after one hour storage at -20 °C.
ⓚ Background noise per minute m^{-1}(cpm)

HAMAMATSU

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http://www.hamamatsu.com/

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X-Ray Image Intensifiers
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Si PIN Photodiodes
Si APDs
GaAsP Photodiodes
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Solid State Emitters

Imaging and Processing Systems
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Streak Cameras
Optical Measurement Systems
Imaging and Analysis Systems

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Quality, technology, and service are part of every product.

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