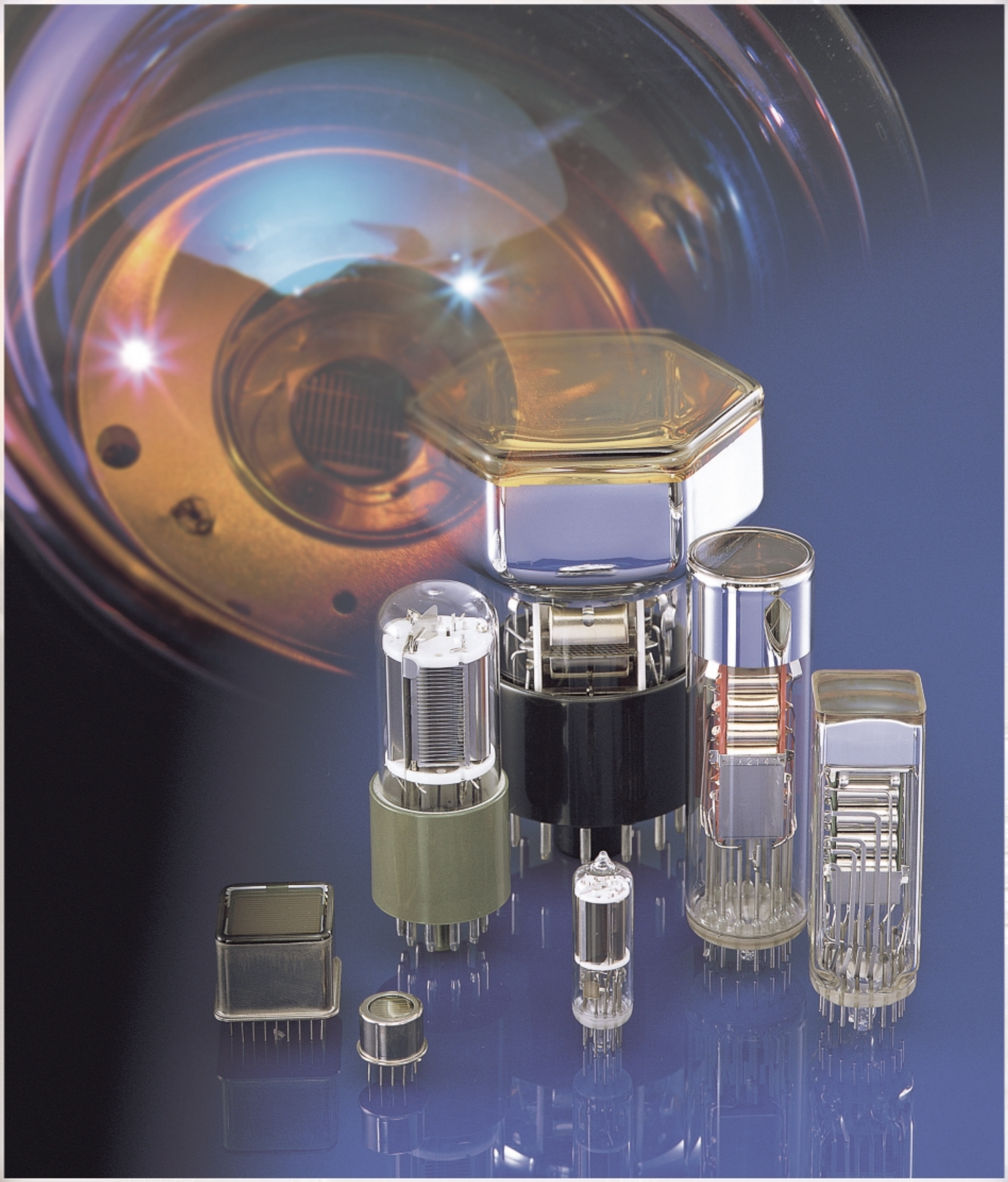
Photomultiplier Tubes

PHOTOMULTIPLIER TUBES AND RELATED PRODUCTS



HAMAMATSU

Opening The Future with Photonics

Human beings obtain more than 70 percent of the information visually by using their eyes. However, there are vast sums of information and unknown possibilities hidden within light not visible to the naked eye. This kind of light includes ultraviolet, infrared, X-ray and ultra-low level light impossible for human eyes to detect.

Since its founding over 50 years ago, Hamamatsu Photonics has been investigating not only light seen by the human eye but also light that far exceeds this level. As a leading manufacturer specializing in the field of photonics, Hamamatsu Photonics has marketed dozens of photosensitive devices, light sources and related products. Through these state-of-the-art products, Hamamatsu Photonics has committed itself to pioneering industrial and academic research work in still unexplored areas in many fields.

Hamamatsu Photonics will continue to deliver innovative breakthroughs in a diverse range of fields, always striving to make human life fuller and richer by "researching the many ways to use light".

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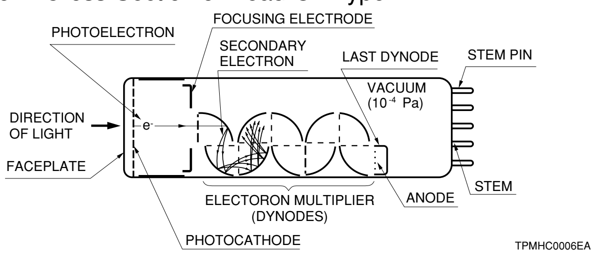
INTRODUCTION

Among photosensitive devices in use today, the photomultiplier tube (or PMT) is a versatile device providing ultra-fast response and extremely high sensitivity. 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 a secondary emission process. The multiplied electrons then are collected by the anode as an output signal.
Because of secondary-emission multiplication, photomultiplier tubes provide extremely high sensitivity and exceptionally low noise compared to other photosensitive devices currently used to detect radiant energy in the ultraviolet, visible, and near infrared regions. The photomultiplier tube also features fast time response and a choice of large photosensitive areas.
This section describes the prime features of photomultiplier tube construction and basic operating characteristics.

Figure 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 the head-on type receives light 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 side-on types employ an opaque photocathode (reflection-mode photocathode) and a circular-cage structure electron multiplier (see description of "ELECTRON MULTIPLIER") which has good sensitivity and high amplification 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 uniformity (see page 9) than the side-on type having a reflection-mode photocathode. Other features of head-on types include a choice of photosensitive areas ranging from tens 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 reception is important.

Figure 2: External Appearance

a) Side-On Type

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b) Head-On Type

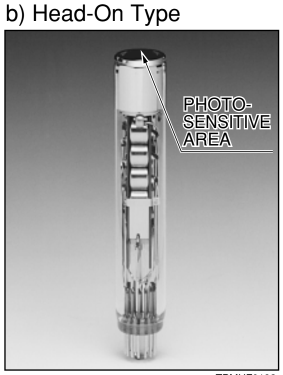

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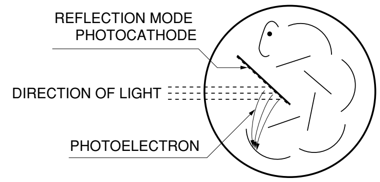
Figure 3: Types of Photocathode

a) Reflection Mode



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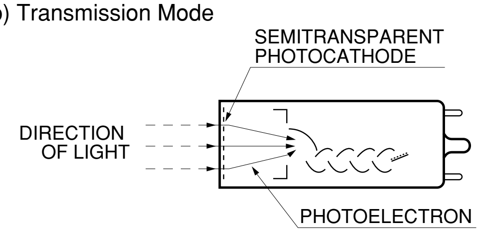
b) Transmission Mode



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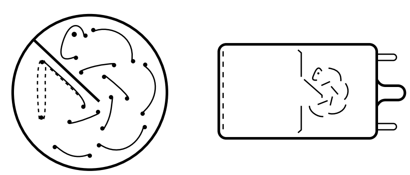
ELECTRON MULTIPLIER

The superior sensitivity (high current amplification 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 emission process. The electron multiplier consists of 8 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, fast response and high gain obtained at a relatively low supply voltage.



Side-On Type　Head-On Type

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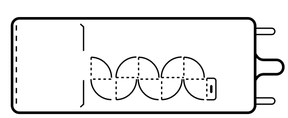
2) Box-and-grid type

This type consists of a train of quarter cylindrical dynodes and is widely used in head-on type photomultiplier tubes because of good electron collection efficiency and excellent uniformity.



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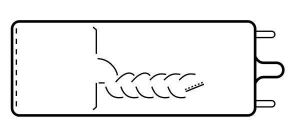
3) Linear-focused type

The linear-focused type features extremely fast response time and is widely used in applications where time resolution and pulse linearity are important. This type also has the advantage of providing a large output current.



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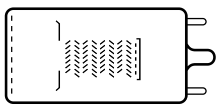
4) Venetian blind type

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 output current. This structure is usually used when time response is not a prime consideration.



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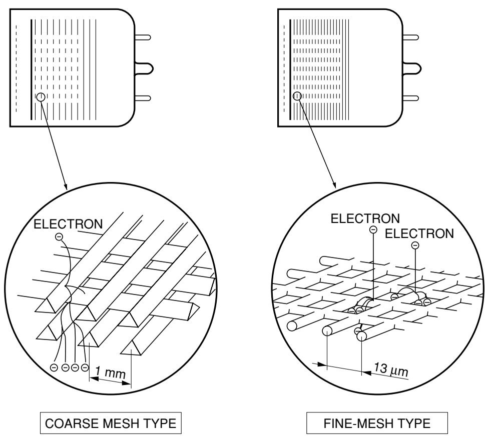
5) Mesh type

The mesh type has a structure of fine mesh electrodes stacked in close proximity. There are two mesh types of dynode: a coarse mesh type and a fine mesh type. Both types provide improved pulse linearity and high resistance to magnetic fields. The mesh type also has position-sensitive capability when used with cross-wire anodes or multiple anodes. The fine mesh type is particularly suited for use in applications where high magnetic fields are present.



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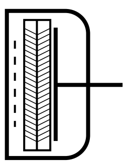
6) Microchannel plate (MCP) (see page 58)

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



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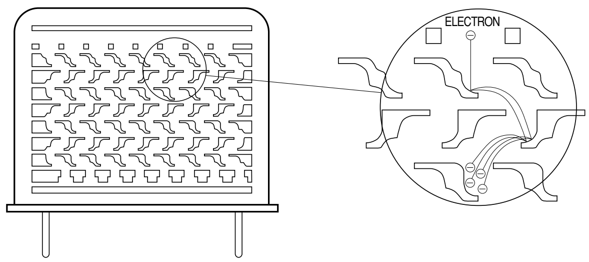
7) Metal Channel type

The metal channel dynode has a compact dynode construction manufactured by our unique fine machining techniques. It delivers high-speed response due to a space between each dynode stage that is much smaller than other types of conventional dynodes. The metal channel dynode is also ideal for position sensitive measurement.



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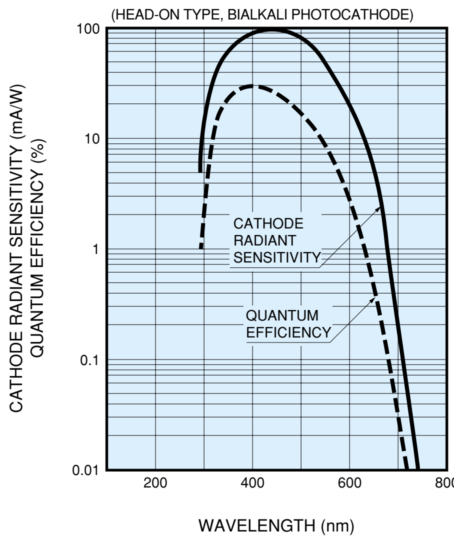
Hybrid dynodes combining two of the above dynodes are also available. These hybrid dynodes combine the best features of each dynode type.

SPECTRAL RESPONSE

The photocathode of a photomultiplier tube converts energy from incident light into electrons. 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 on long wavelengths is determined by the photocathode material and on short wavelengths by the window material. Typical spectral response characteristics for various types of photomultiplier tubes are shown on pages 114 and 115. In this catalog, the long-wavelength cutoff of the spectral response characteristic is defined as the wavelength at which the cathode radiant sensitivity is 1 % of the maximum sensitivity in bialkali and Ag-O-Cs photocathodes, and 0.1 % of the maximum sensitivity in 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 tube to tube.

Figure 4: Typical Spectral Response of Bialkali Photocathode



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Construction and Operating Characteristics

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 range of visible light to infrared radiation (300 mm to 1000 nm). The reflection mode covers a slightly narrower range from 300 mm to 1100 nm. Since Ag-O-Cs has comparatively high thermionic dark emission (refer to "ANODE DARK CURRENT" on page 8), photomultiplier tubes of this photocathode material are chiefly used for detection in the infrared region with the photocathode cooled.

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

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

4) Sb-Cs
Sb-Cs has a spectral response in the ultraviolet to visible range and is mainly used in reflection-mode photocathodes.

5) Bialkali (Sb-Rb-Cs, Sb-K-Cs)
These materials have a spectral response range similar to the Sb-Cs photocathode, but have higher sensitivity and lower dark current than Sb-Cs. They also have a blue sensitivity index matching the scintillation flashes of NaI scintillators, and so 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. One 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 and photon counting applications. The long wavelength response can be extended to 930 nm by special photocathode activation processing.

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

WINDOW MATERIALS

Window materials commonly used in photomultiplier tubes are described below. The window material must carefully be selected according to the application because the window material determines the spectral response short wavelength cutoff.

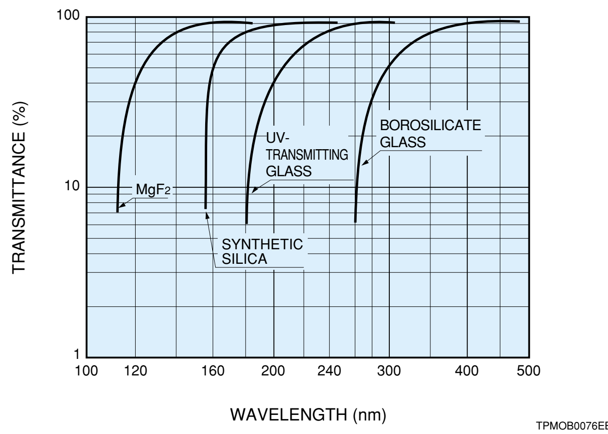
1) Borosilicate glass
This is the most frequently used window material. Borosilicate glass transmits radiation from the infrared to approximately 300 nm. It is not suitable for detection in the ultraviolet region. For some applications, a combination of a bialkali photocathode and a low-noise borosilicate glass (so called K-free glass) is used. The K-free glass contains very low potassium (^{40}K) which can cause unwanted background counts. 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 as the name implies is ideal for transmitting ultraviolet radiation and is used as widely as a borosilicate glass. The UV cutoff 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 the synthetic silica has a different thermal expansion coefficient than Kovar, which is used for the tube leads, it is not suitable as the tube stem material (see Figure 1 on page 4). Borosilicate glass is used for the stem, and a graded seal using glass with gradually different thermal expansion coefficients is connected to the synthetic silica window. The graded seal structure is vulnerable to shock so the tube should be handled carefully.

4) MgF2 (magnesium fluoride)
Crystals of alkali halide are superior in transmitting ultraviolet radiation, but have the disadvantage of deliquescence. Among these crystals, 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



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 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. Quantum efficiency is usually expressed as a percent. 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).

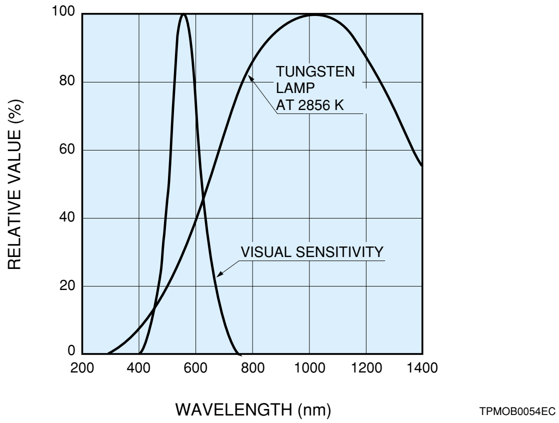
LUMINOUS SENSITIVITY

Since measuring the spectral response characteristic of photomultiplier tubes requires a sophisticated system and a great deal of time, we instead provide figures for anode or cathode luminous sensitivity and only provide spectral response characteristics when specially required by the customer.
Cathode luminous sensitivity is the photoelectric current from the photocathode per incident light flux (10^{-5} to 10^{-2} lumens) from a tungsten filament lamp operated at a distribution temperature of 2856K. Anode luminous sensitivity is the anode output current (amplified by the secondary emission process) per incident light flux (10^{-10} 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 insensitive to tungsten lamp light. (Radiant sensitivity at a specific wavelength is listed for those tubes using CsI or Cs-Te.)

The cathode luminous sensitivity is expressed in uA/lm (microamperes per lumen) and anode luminous sensitivity is expressed in 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 that are sensitive beyond the visible light region.

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



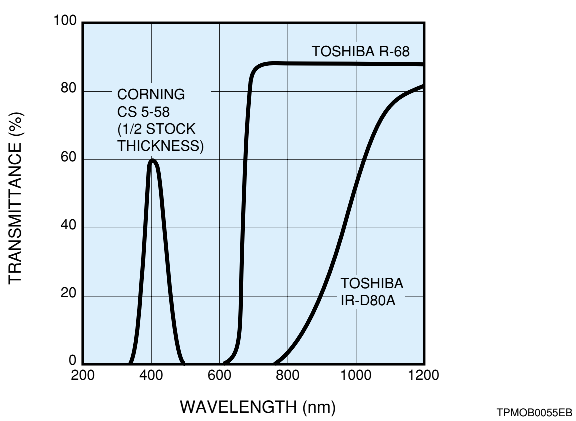
BLUE SENSITIVITY INDEX AND RED/WHITE RATIO

The cathode blue sensitivity index and the red/white ratio are often used as a simple comparison of photomultiplier tube spectral response.

The cathode blue sensitivity index is the photoelectric current from the photocathode produced by a light flux of a tungsten lamp at 2856K passing through a blue filter (Corning CS 5-58 polished to half stock thickness), measured under the same conditions as the cathode luminous sensitivity measurement. The light flux, once transmitted through the blue filter cannot be expressed in lumens. The blue sensitivity index is an important parameter in scintillation counting using an NaI scintillator since the NaI 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 2856K passing through a red filter (Toshiba IR-D80A for the S-1 photocathode or R-68 for others) divided by the cathode luminous sensitivity measured without filters under the same conditions as in cathode luminous sensitivity measurement.

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 achieves a high current amplification. A very small photoelectric current from the photocathode can therefore 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 stages 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 the constant, E is the interstage voltage, and α is a coefficient determined by the dynode material and geometric structure. This usually has a value of 0.7 to 0.8.

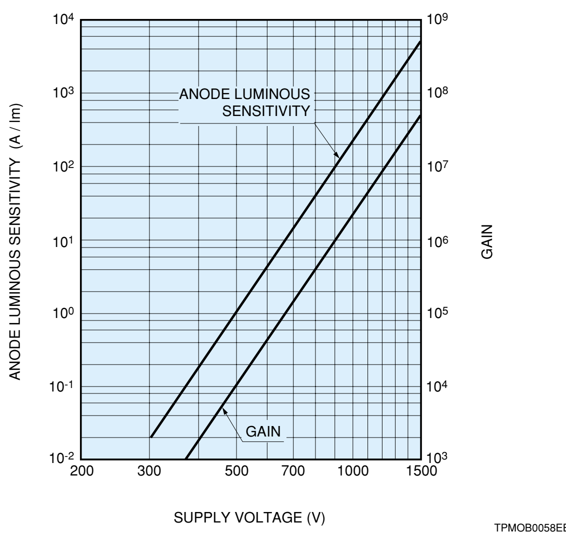
When a voltage V is applied between the cathode and the anode of a photomultiplier tube having n dynode stages, the gain μ, becomes

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

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

Since photomultiplier tubes generally have 9 to 12 dynode stages, the anode output has a 6th to 10th power gain proportional to the input voltage. So just a slight fluctuation in the applied voltage will appear as magnified 6 to 10 times in the photomultiplier tube output. This means the photomultiplier tube is extremely susceptible to fluctuations in the power supply voltage, so the power supply must be extremely stable and provide a minimum ripple, drift and temperature coefficient. Various types of well-regulated high-voltage power supplies designed for these requirements are available from Hamamatsu (see page 96).

Figure 8: Typical Gain vs. Supply Voltage

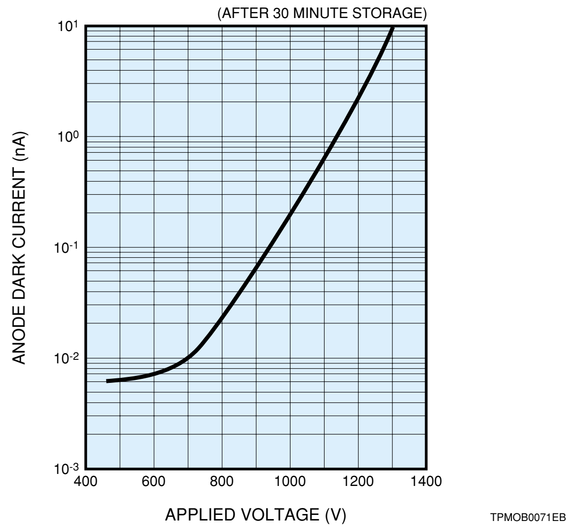


Construction and Operating Characteristics

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 is called the anode dark current, and the resulting noise is a critical factor in determining the lower limit of light detection. 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:

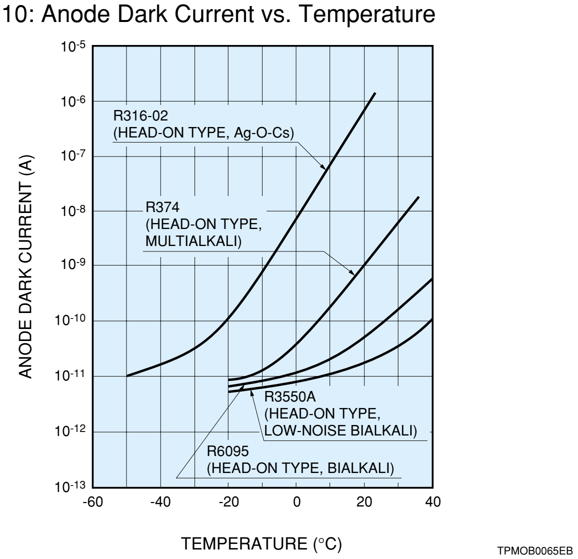
1) Thermionic emission of electrons

The materials of the photocathode emit tiny quantities of thermionic electrons even at room temperature. Most dark currents originate from the thermionic emissions, especially those from the photocathode since they are successively multiplied by the dynodes. Cooling the photocathode is most effective in reducing thermionic emission and is particularly useful in applications where low dark current is 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. Photomultiplier tubes using these photocathodes are usually cooled during operation.

Hamamatsu provides thermoelectric coolers (C9143, C9144, C4877, C4878) designed for various sizes of photomultiplier tubes (see page 102).

Figure 10: Anode Dark Current vs. Temperature



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. These secondary electrons result 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 short 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 a dark pulse may result. To eliminate this type of dark pulse, photomultiplier tubes may be operated with the anode at a high voltage and the cathode at ground potential. But this is not always possible during tube operation. To obtain the same effect without difficulty, Hamamatsu developed an "HA coating" in which the glass bulb is coated with a conductive paint making the same electrical potential as the cathode (see "GROUND POLARITY AND HA COATING" on page 11).

4) Leakage current (ohmic leakage)

Leakage current resulting from imperfect insulation of 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 Figure 9 and 10 are mainly due to leakage current.

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

5) Field emissions

When a photomultiplier tube is operated at a voltage near the maximum rated value, electrons might be emitted from electrodes by the strong electric field and cause dark pulses. So operating the photomultiplier tube at a voltage 20 to 30% lower than the maximum rating is recommended.

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 minutes of storage in a dark state.

ENI (EQUIVALENT NOISE INPUT)

ENI indicates the photon-limited signal-to-noise ratio. ENI refers to the amount of light in watts necessary to produce a signal-to-noise ratio of unity in the output of a photomultiplier tube. The value of ENI is given by:

$$\mathrm{ENI} = \frac{\sqrt{2q \cdot Idb \cdot g \cdot \Delta f}}{S} \text{ (watts)}$$

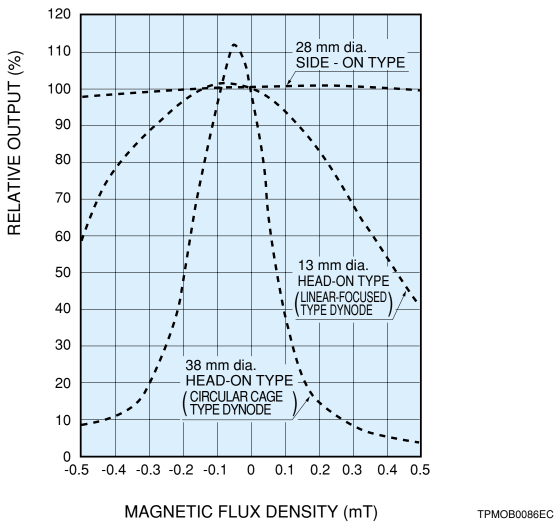
where q = electronic charge (1.60×10^{-19} coul.)
Idb = anode dark current in amperes after 30minute storage in darkness
g = gain
Δf = bandwidth of the system in hertz (usually 1 hertz)
S = anode radiant sensitivity in amperes per watt at the wavelength of interest

For 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 (at the peak sensitivity wavelength).

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 gain loss 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 (such as large diameter tubes) tend to be more adversely affected by magnetic fields.

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

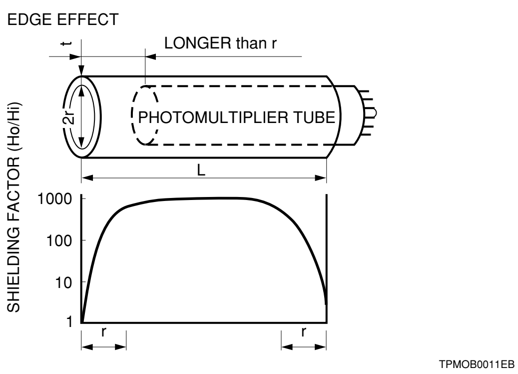


When a photomultiplier tube has to be operated in magnetic fields, it may be necessary to shield the tube with a magnetic shield case. (Hamamatsu provides a variety of magnetic shield cases. See page 106). The magnetic shielding factor is used to express the effect of a magnetic shield case. This is the ratio of the strength of the magnetic field outside the shield case or Hout, to that inside the shield case or Hin. The magnetic shielding factor is determined by the permeability μ, the thickness t (mm) and inner diameter r (mm) of the shield case as follows.

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

Note that the magnetic shielding effect decreases towards the edge of the shield case as shown in Figure 12. Covering the tube with a shield case longer than the tube length by at least half the tube diameter is recommended.

Figure 12: Edge Effect of Magnetic Shield Case



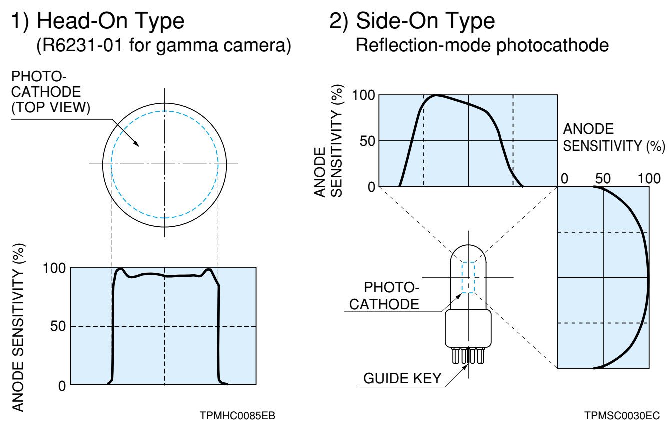
Hamamatsu provides photomultiplier tubes using fine-mesh type dynodes (see page 54). These photomultiplier tubes exhibit much higher resistance to external magnetic fields than the photomultiplier tubes with other dynodes. When the light level to be measured is high, "triode" and "tetrode" type tubes can be used even in highly magnetic fields.

SPATIAL UNIFORMITY

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 causing lower collection efficiency. The 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

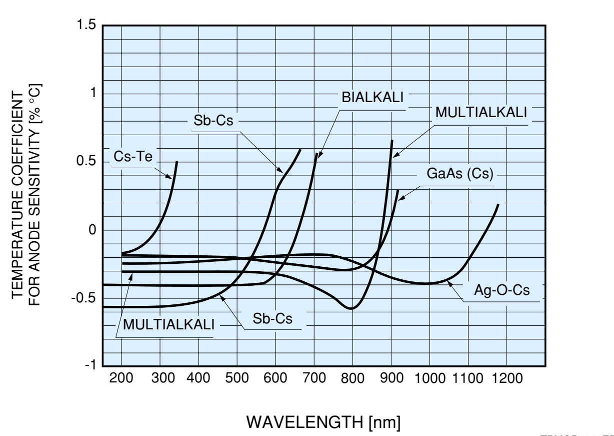


TEMPERATURE CHARACTERISTICS

Dark current originating from thermionic emissions can be reduced by decreasing the ambient temperature of a photomultiplier tube. The photomultiplier tube sensitivity also varies with the temperature, but these changes are smaller than temperature-induced changes in dark current, so cooling a photomultiplier tube will significantly improve the S/N ratio.

In the ultraviolet to visible region, the sensitivity temperature coefficient has a negative value, while near the long wavelength cutoff it has a positive value. Figure 14 shows typical temperature coefficients for various photocathodes versus wavelength, measured at room temperatures. Since the change in temperature coefficient change is large near the long wavelength cutoff, temperature control may be needed in some applications.

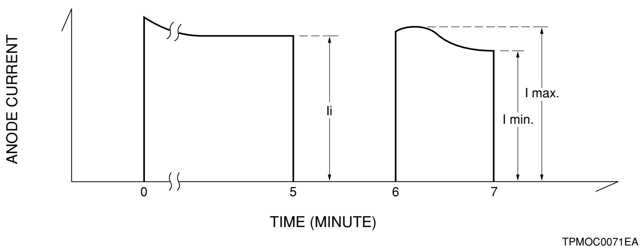
Figure 14: Temperature Coefficient for Anode Sensitivity (Typ.)



HYSTERESIS

Photomultiplier tubes exhibit a slightly unstable output for several seconds to nearly 1 minute after a voltage is applied or light is input, and the output may overshoot or undershoot before reaching a stable level (Figure 15). This unstable condition is called hysteresis and may be a problem in spectrophotometry and other applications.
Hysteresis is mainly caused by electrons deviating from their planned trajectories and electrostatically charging the dynode support section and glass bulb. When the applied voltage changes along with a change in the input light, noticeable hysteresis can occur.
As a countermeasure, many Hamamatsu side-on photomultiplier tubes employ an "anti-hysteresis design" which virtually eliminates hysteresis.

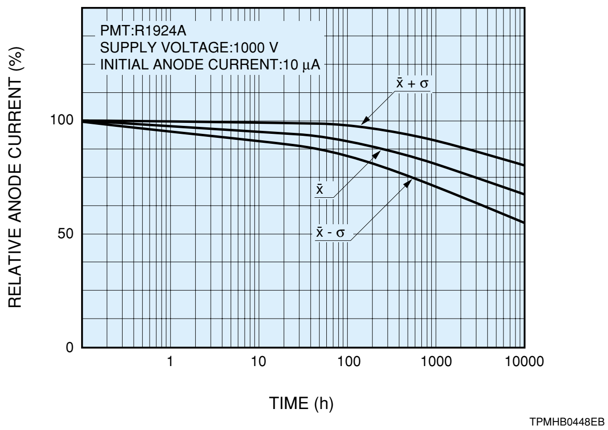
Figure 15: Hysteresis



DRIFT AND LIFE CHARACTERISTIC

While operating a photomultiplier tube continuously over a long period, the anode output current of the photomultiplier tube may vary slightly over time, even though operating conditions have not changed. Among the anode current fluctuations, changes over a relatively short time are called "drift", while changes over long periods such as 10^3 to 10^4 hours or more are called the life characteristic. Figure 16 shows typical drift curves.
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, keeping the average anode current within 1 µA or less is recommended.

Figure 16: Typical Life Characteristics



TIME RESPONSE

In the measurement of pulsed light, the anode output signal should faithfully reproduce a waveform resembling the incident pulse waveform. This reproducibility is greatly affected by the electron transit time, anode pulse rise time, and electron transit time spread (T.T.S.).
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 ps) 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 needed to rise from 10 % to 90 % of peak amplitude when the entire photocathode is illuminated by a delta function light pulse (pulse width less than 50 ps).
The electron transit time fluctuates between individual light pulses. This fluctuation is called transit time spread (T.T.S.) and defined as the FWHM of the frequency distribution of electron transit times (Figure 18). The T.T.S. is an important factor in time-resolved measurement.
The time response characteristics depend on the dynode structure and applied voltage. In general, photomultiplier tubes using a linear-focused or circular-cage structure exhibit better time response than tubes using a box-and-grid or venetian blind structure. Photomultiplier tubes for high-speed photometry use a spherical window or plano-concave window (flat on one side and concave on the other) and electrodes specifically designed to shorten the electron transit time. MCP-PMTs, which employ an MCP in place of conventional dynodes, offer better time response than tubes using other dynodes. For example, these have a significantly better T.T.S. compared to normal photomultiplier tubes because a nearly parallel electric field is applied between the photocathode, the MCP and the anode. Figure 19 shows typical time response characteristics vs. applied voltage for Hamamatsu R2059 (51 mm diameter head-on, 12-stage, linear-focused type).

Figure 17: Anode Pulse Rise Time and Electron Transit Time

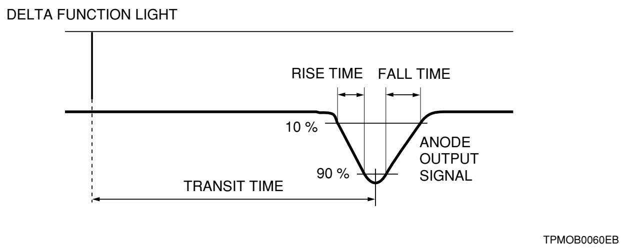


Figure 18: Electron Transit Time Spread (T.T.S.)

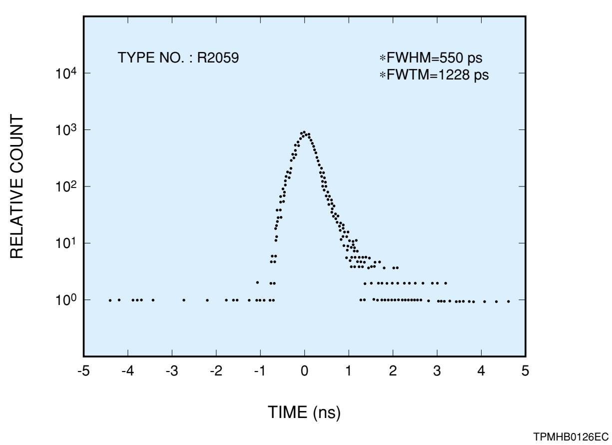
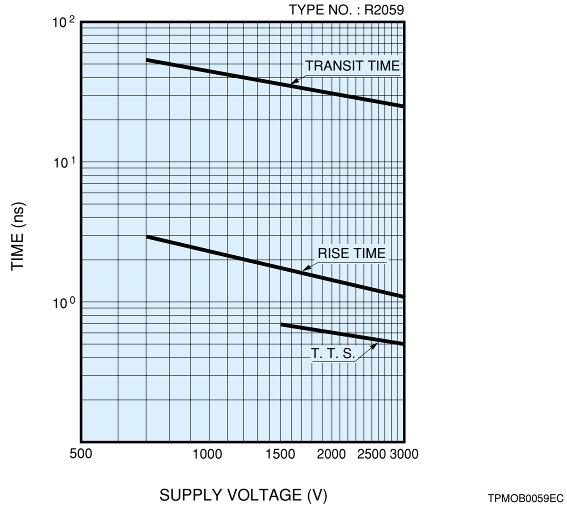


Figure 19: Time Response Characteristics vs. Supply Voltage

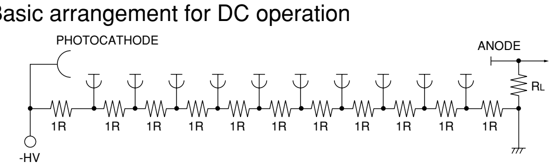


VOLTAGE-DIVIDER CIRCUITS

Interstage voltages for the dynodes of a photomultiplier tube are usually supplied by 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 relation between the incident light level and the output current of a photomultiplier tube using the voltage-divider circuit of figure 20. Deviation from 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). To prevent this problem, 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

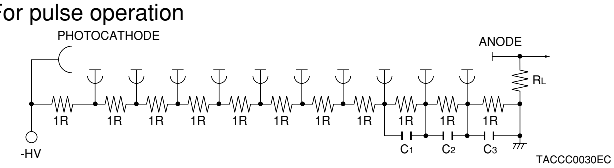
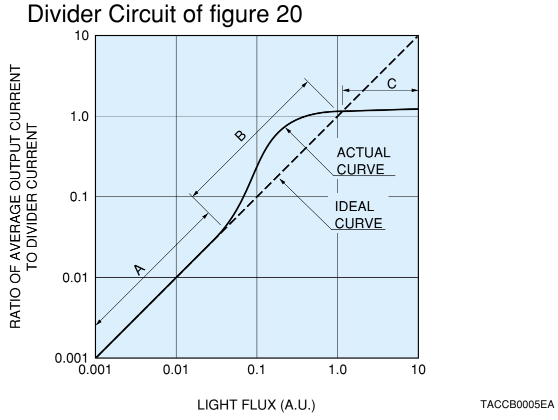


Figure 21: Output Characteristics of PMT Using Voltage-Divider Circuit of figure 20

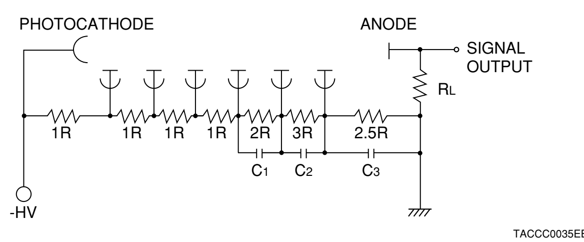


Generally high output current is required in pulsed light applications. In order to maintain dynode potentials at a constant value during pulse durations and obtain high peak currents, capacitors are placed in parallel with the divider resistors as shown in Figure 20 (b). The capacitor values depend on the output charge. When the output linearity versus input pulsed light needs to be better than 1 %, the capacitor value should be at least 100 times the photomultiplier output charge per pulse. If the peak output current (amperes) is I, the pulse width (seconds) t, and the voltage across the capacitor (volts) V, then the capacitor value C should be as follows:

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

In high energy physics applications where a high pulse output is required, output saturation will occur at a certain level as the incident light is increased while the interstage voltage is kept fixed,. This is caused by an increase in electron density between the electrodes, causing space charge effects which disturb the electron current flow. As a corrective measure to overcome these space charge effects, the voltage applied to the last few stages, where the electron density becomes high, should be set to 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 in normal divider circuits.
Hamamatsu provides a variety of socket assemblies incorporating voltage-divider circuits. They are compact, rugged, lightweight and carefully engineered to obtain the maximum performance of a photomultiplier tube with just a simple connection.

Figure 22: Typical 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, in 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, extreme care is required when designing housings for photomultiplier tubes and when using electrostatic or magnetic shield cases.
.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 coat around the bulb, connecting it to the cathode potential and covering the bulb with a protective film. This is called an "HA Coating" (see Figure 23).

Construction and Operating Characteristics

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 occurring in the faceplate, has adverse noise effects and also causes deterioration of the photocathode sensitivity. To solve these problems, it is recommended that the photomultiplier tube be operated in the cathode grounding scheme, as shown in Figure 24, with the anode at a high positive voltage. For example in scintillation counting, since the grounded scintillator is directly coupled to the faceplate of a photomultiplier tube, grounding the cathode and maintaining the anode at a high positive voltage is recommended. In this case, a coupling capacitor Cc must be used to isolate the high positive voltage applied to the anode from the signal, and DC signals cannot be output.

Figure 23: HA Coating

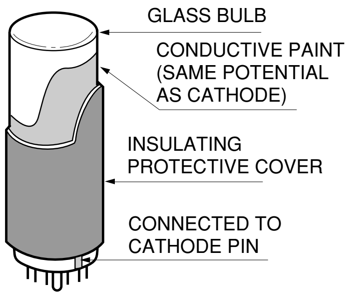
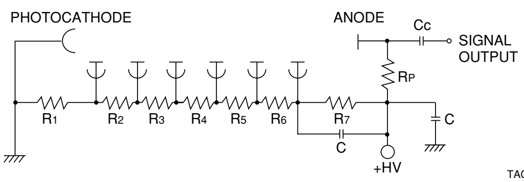


Figure 24: Cathode Ground Scheme



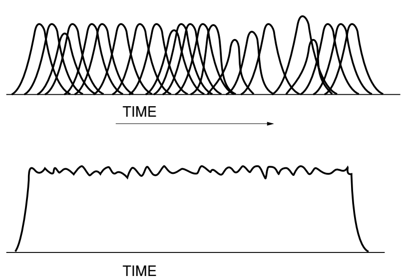
PHOTON COUNTING

Photon counting is one effective way to use a photomultiplier tube for measuring extremely low light levels and is widely used in astronomical photometry and for making chemiluminescence and bioluminescence measurements. In its usual application, a number of photons enter the photomultiplier tube and create an output pulse train like that in (a) of 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

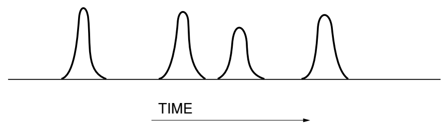
a)

b)



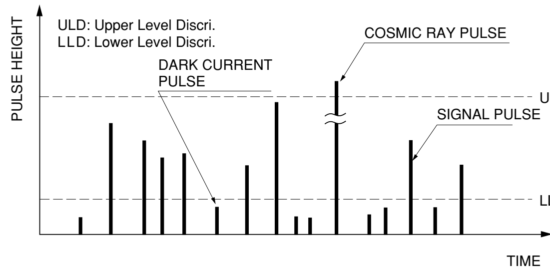
When the light intensity becomes so low that the incident photons are separated as shown in Figure 26. This condition is called a single photon event. The number of output pulses is in direct proportion to the amount of incident light and this pulse counting method has the advantages of better S/N ratio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

Figure 26: Discrete Output Pulses (Single Photon Event)



Simply counting the photomultiplier tube output pulses will not result in an accurate measurement, since the output contains noise pulses such as dark pulses and cosmic ray pulses extraneous to the signal pulses representing photoelectrons as shown in Figure 27. The most effective method for eliminating the noise is to discriminate the output pulses according to their amplitude. (Dark current pulese by thermal electrons emitted from the photocathode cannot be eliminated.)

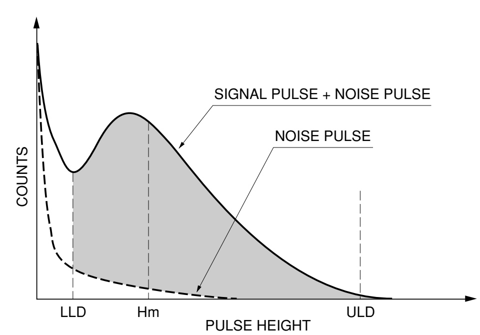
Figure 27: Output Pulse and Discrimination Level



A typical pulse height distribution (PHD) for a photomultiplier tube output 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 there are very few output pulses. Most pulses smaller than the LLD are noise and pulses larger than the ULD result from cosmic rays, etc. Therefore, by counting the pulses remaining between the LLD and ULD, accurate light measurements can be made. In the PHD, Hm is the mean height of the pulses. The LLD should be set at 1/3 of Hm and the ULD at triple Hm. The ULD may be omitted in most cases.

Considering the above, a clearly defined peak and valley in the PHD is a very significant characteristic required of photomultiplier tubes for photon counting. Figure 28 shows the typical PHD of a photomultiplier tube selected for photon counting.

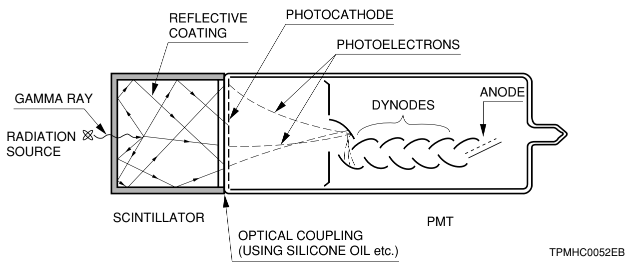
Figure 28: Typical Single Photon Pulse Height Distribution



SCINTILLATION COUNTING

Scintillation counting is one of the most sensitive and effective methods for detecting radiation. It uses a photomultiplier tube coupled to a scintillator that produces light when struck by radiation.

Figure 29: Scintillation Detector Using PMT and Scintillator



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

When radiation particles enter the scintillator, they produce light flashes in response to each particle. The amount of flash is extremely low, but is proportional to the energy of the incident particle. Since individual light flashes are detected by the photomultiplier tube, the output pulses obtained from the photomultiplier tube 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 radiation (^{55}Fe, ^{137}Cs, ^{60}Co) is detected by the combination of an NaI(Tl) scintillator and a photomultiplier tube. The PHD must show distinct peaks at each energy level. These peaks are evaluated as pulse height resolution which is the most significant characteristic in the radiation measurements. As Figure 32 shows, the pulse height resolution is defined as the FWHM (a) divided by the peak value (b) when pulse height distribution is measured using a single radiation source such as ^{137}Cs and ^{55}Fe.

Figure 30: Incident Radiation Particles and PMT Output

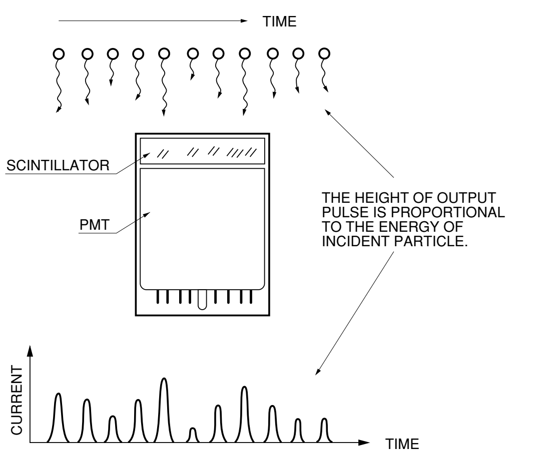
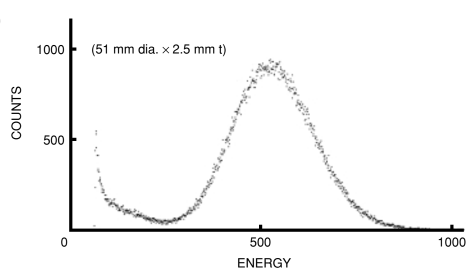
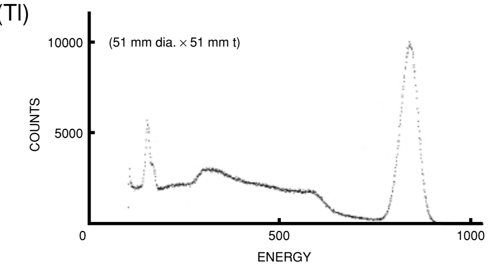


Figure 31: Typical Pulse Height Distributions (Energy Spectra)

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



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



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

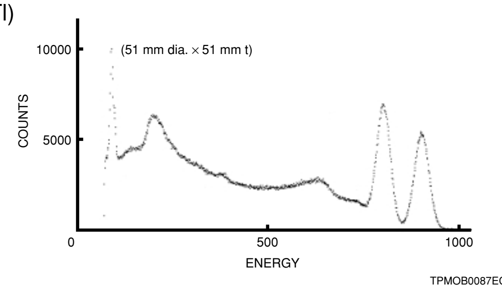
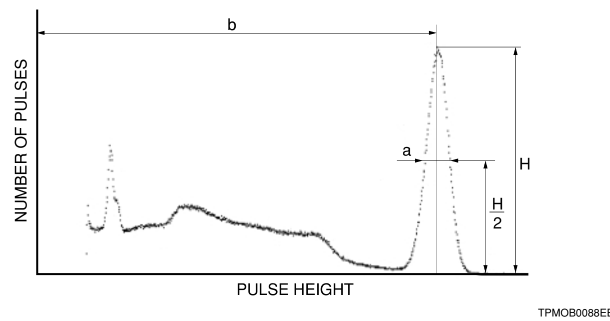
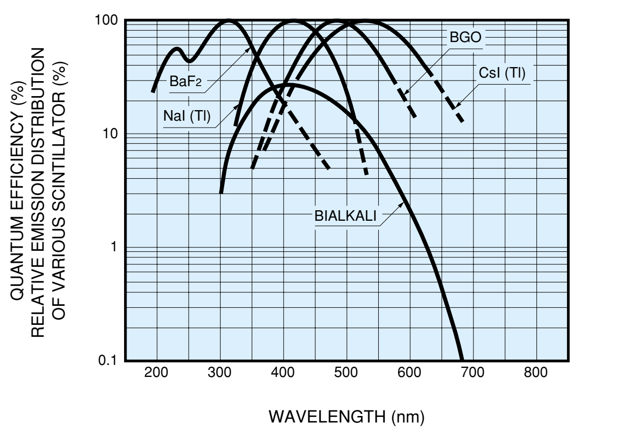


Figure 32: Definition of Pulse Height Resolution



$$\text{Energy resolution} = \frac{a}{b} \times 100\ \%$$

Figure 33: PMT Spectral Response and Spectral Emission of Scintillators



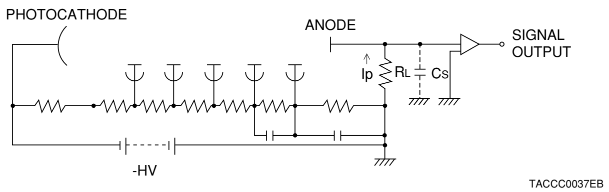
Pulse height resolution is mainly determined by the quantum efficiency of the photomultiplier tube that detects the scintillator emission. In the case of thallium-activated sodium iodide or NaI(Tl), which is one of the most popular scintillators, a head-on type photomultiplier tube with a bialkali photocathode is widely used since its spectral response matches the NaI(Tl) scintillator spectrum.

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 resistor is used for current-voltage conversion. This section describes factors to consider when selecting this load resistor.
Since for low output current levels, the photomultiplier may be assumed to act as virtually an ideal constant-current source, the load resistance can be made arbitrarily large, when converting a low-level current output to a high-level voltage output. In practice, however, using a very large load resistance causes poor frequency response and output linearity as described below.

Figure 34: Photomultiplier Tube Output Circuit

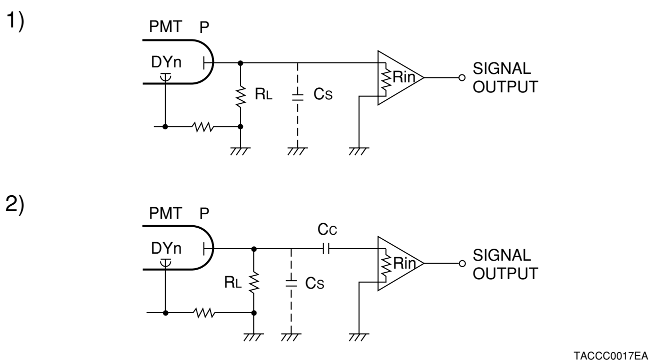


In the circuit of Figure 34, if we let the load resistance be R_L and the total capacitance of the photomultiplier tube anode to all other electrodes including stray capacitance such as wiring capacitance be Cs, then the cutoff frequency fc is expressed by the following relationship.

$$fc = \frac{1}{2\pi Cs \cdot R_L}$$

This relationship indicates that even if the photomultiplier tube and amplifier have very fast response, the response will be limited to the cutoff frequency fc of the output circuit. If the load resistance is made large, then the voltage drop across R_L becomes large at high current levels, affecting the voltage differential between the last dynode stage and the anode. This increases the effect of the space charge and lowers the efficiency of the anode in collecting electrons. In effect, the output becomes saturated above a certain current, causing poor output linearity (output current linearity versus incident light level) especially when the circuit is operated at low voltages.

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.

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

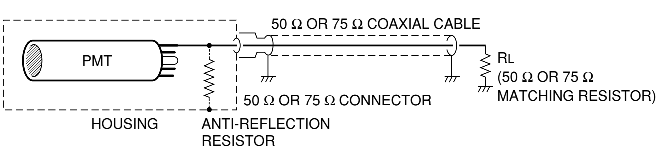
This value of R_o, which is less than the value of R_L, is then the effective load resistance of the photomultiplier tube. If, for example, $R_L=R_{in}$, then the effective load resistance is 1/2 that of R_L alone. From this we see that the upper limit of the load resistance is actually the input resistance of the amplifier and that making the load resistance much greater than this value does not have a significant effect.
While the above description assumed the load and input impedances to be purely resistive, stray capacitances, input capacitance and stray inductances affect the phase relationships during actual operation. Therefore, as the 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 selecting the load resistance:

1) When frequency response is important, the load resistance should be made as small as possible.
2) When output linearity is important, the load resistance should be chosen to keep the output voltage within a few volts.
3) The load resistance should be less than the input impedance of the external amplifier.

HIGH-SPEED OUTPUT CIRCUITS

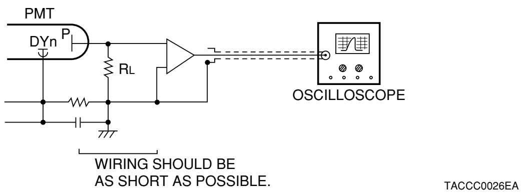
When detecting high-speed and pulsed light signals, a coaxial cable is used to make the connection between the photomultiplier tube and the electronic circuit. Since commonly used cables have characteristic impedances of 50 Ω or 75 Ω, this cable must be terminated in a pure resistance equal to the characteristic impedance to match the impedance and ensure distortion-free transmission of 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 actual cable length so no distortion will occur in the signal waveform.
If the impedance is not properly matched when the signal is received, the impedance seen at the photomultiplier tube output will differ depending on both frequency and cable length, causing significant waveform distortion. Impedance mismatches might also be due to the connectors being used. So these connectors should be chosen according to the frequency range to be used, to provide a good match with the coaxial cable.
When a mismatch at the signal receiving end occurs, not all of the pulse energy from the photomultiplier tube is dissipated at the receiving end and is instead partially reflected back to the photomultiplier tube via the cable. However if an impedance match has been achieved at the cable end on the photomultiplier tube side, then this reflected energy will be fully dissipated there. . If this is a mismatch, however, the energy will be reflected and returned to the signal-receiving end because the photomultiplier tube itself acts as an open circuit. 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 matching the impedance at the receiving end, a resistor is needed for matching the cable impedance at the photomultiplier tube end as well (Figure 36). If this is provided, it is possible to eliminate virtually all 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: Connection to Prevent Ringing



Next, let us consider waveform observation of high-speed pulses using an oscilloscope. This type of operation requires a low load resistance. However, the oscilloscope sensitivity is limited so an amplifier may be required.
Cables with a matching resistor have the advantage that the cable length will not affect the electrical 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 a high gain amplifier, the inherent noise of such an amplifier can itself hurt measurement performance. In such cases, the photomultiplier tube should be brought as close as possible to the amplifier to reduce stray capacitance and a larger load resistance should be used (while still maintaining the frequency response), to achieve the desired input voltage. (See Figure 37.)

Figure 37: Measurement with Ringing Suppression Measures



It is relatively simple to implement a high-speed amplifier using a wide-band video amplifier or operational amplifier. However, as a trade-off for design convenience, these ICs tend to create performance problems (such as noise). This makes it necessary to know their performance limits and take corrective action if necessary.
As the pulse repetition frequency increases, baseline shift becomes one reason for concern. This occurs because the DC signal component has been eliminated from the signal circuit by coupling with a capacitor which blocks the DC components. If this occurs, the reference zero level observed at the last stage is not the actual zero level. Instead, the apparent zero level is a time-average of the positive and negative fluctuations of the signal waveform. This is known as baseline shift. Since the height of the pulses above this baseline level is affected by the repetition frequency, this phenomenon can be a problem when observing waveforms or discriminating pulse levels.

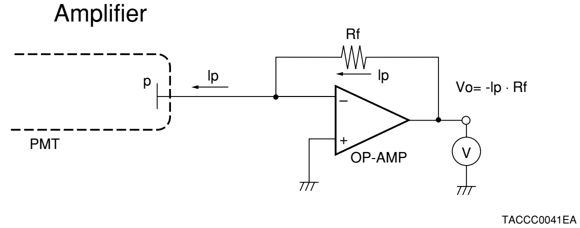
OPERATIONAL AMPLIFIERS

When a high-sensitivity ammeter is not available, using an operational amplifier allows making measurements with an inexpensive voltmeter. This section explains the technique for converting the output current of a 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.

$$V_o = -Rf \cdot Ip$$

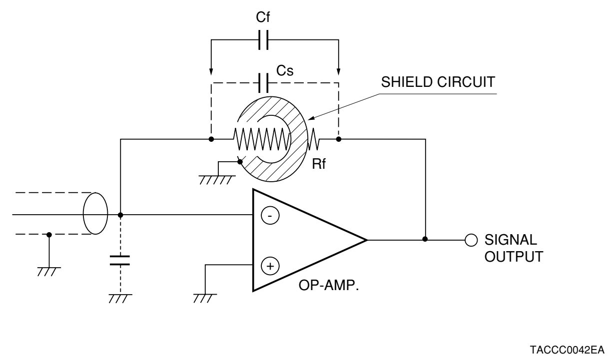
This relationship is derived for the following reason. If the input impedance of the operational amplifier is extremely large, and the output current of the photomultiplier tube is allowed to flow into the inverted (–) input terminal of the amplifier, most of the current will flow through Rf and subsequently to the operational amplifier output circuit. The output voltage V_o is therefore given by the expression $-R_f \times Ip$. When using such an operational amplifier, it is not of course possible to make unlimited increases in the output voltage because the actual maximum output is roughly equal to the operational amplifier supply voltage. At the other end of the scale, for extremely small currents, there are limits due to 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 Conversion Using Operational Amplifier



If the operational amplifier has an offset current (I_{os}), the above-described output voltage becomes $V_o = -R_f\,(Ip+I_{os})$, with the offset current component being superimposed on the output. Furthermore, the magnitude of the 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 with a low leakage current is used. Carbon resistors with their highly temperature-dependent resistance characteristics are not suitable for this application.
In addition to the above factors, when measuring extremely low level currents such as 100 pA and below, the materials used to fabricate the circuit also require careful selection. For example, materials such as bakelite are not suitable. More suitable materials include teflon, polystyrol or steatite. Low-noise cables should also be used, since general-purpose coaxial cables exhibit noise due to physical factors. An FET input operational amplifier is recommended for measuring low-level current.

Figure 39: Frequency Compensation by Operational Amplifier



In Figure 39, if a capacitance C_f (including any stray capacitance) is in parallel with the resistance Rf, the circuit exhibits a time constant of ($R_f \times C_f$), and the response speed is limited to this time constant. This is a particular problem if the 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, oscillations may occur and noise might be amplified since the cable capacitance C_c and R_f are in a feedback loop. While one method to avoid this is to connect C_f in parallel with R_f, to reduce high frequency gain as described above, this method creates a time constant of $R_f \times C_f$ which limits the response speed.

Selection Guide by Applications

<table>
<tr><th>Applications</th><th>Required Major Characteristics</th><th>Applicable PMT</th></tr>
<tr><td colspan="3"><h2>Spectroscopy</h2>●Equipment Utilizing Absorption</td></tr>
<tr><td>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 can be used to yield analytical data. In order to determine the quantity of a sample substance, it is irradiated while its light wavelength is scanned continuously. The spectral intensities of the light before and after passing through the sample are then detected by a photomultiplier tube and the amount of absorption in this way measured.</td><td rowspan="2">1) Wide spectral response
2) High stability
3) Low dark noise
4) High quantum efficiency
5) Low hysteresis
6) Good polarization characteristics</td><td>R928, R955, R3896
R7639
R374, R376</td></tr>
<tr><td>Atomic Absorption Spectrophotometer
This is widely used in analysis of minute quantities of metallic elements. A special elementary hollow cathode lamp for each element to be analyzed is used to irradiate a sample which is burned to atomize it. A photomultiplier tube then detects the light passing through the sample to measure the amount of absorption, which is compared with a pre-measured reference sample.</td><td>R928
R955
R7154</td></tr>
<tr><td colspan="3">●Equipment Utilizing Emission</td></tr>
<tr><td>Photoelectric Emission Spectrophotometer
When external energy is applied to a sample, that sample then emits light. . By using a monochromator to disperse this light emission into characteristic spectral lines of elements and measuring their presence and intensity simultaneously with photomultiplier tubes, the photoelectric emission spectrophotometer can perform rapid qualitative and quantitative analysis of the elements contained in the sample.</td><td rowspan="2">1) High sensitivity
2) Low dark noise
3) High stability</td><td>R6350, R6352, R6354
R6355, R6356, R7311
1P28, R212, R1527
R7446, R8487</td></tr>
<tr><td>Fluorescence Spectrophotometer
The fluorescence spectrophotometer is used in biological science, especially 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 then analyzed qualitatively and quanti-</td><td>R6353, R6358, R6357
R3788, R4220, R1527
R928, R3896</td></tr>
<tr><td>Raman Spectroscopy
When monochromatic light strikes a substance and scatters, a process called Raman scattering also occurs at a wavelength different from the excitation light. Since this wavelength differential is a unique characteristic of a molecule, spectral measurement of Raman scattering can provide qualitative and quantitative data of molecules. Raman scattering is extremely weak and a sophisticated optical system is required for measurement, with the photomultiplier tube operated in the photon counting mode.</td><td>1) High quantum efficiency
2) Less dark count
3) Single photon discrimination ability</td><td>R2949
R1463P, R649
R943-02
R7400U-20</td></tr>
<tr><td>Other Spectrophotometric Equipment Using Photomultiplier Tubes
• Liquid or gas chromatography
• X-ray diffractometers, X-ray fluorescence analyzers
• Electron microscopes</td><td></td><td>R3788, R4220
R647-01, R1166, R6095, R580
R647
R7400U-01, R5900U-01</td></tr>
</table>

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. Due to the rapid progress being made in the semiconductor industry, this kind of technology is essential for measuring 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 gain 4) Low dark current	R474, R515, R596, R595 R2362, R5150-10 The above product is an electron multiplier
Pollution Monitoring		
Dust Counter A dust counter measures the density of dust or particles floating in the atmosphere or inside rooms. The dust counter makes use of light scattering or absorption of beta-rays by the dust particles.	1) Less dark count 2) Less spike noise 3) High quantum efficiency	R6350 R105, R3788 R647, R1924A, R6095
Turbidimeter When floating particles are contained in a liquid, the light incident on the liquid is absorbed, scattered or refracted by these particles. This process merely appears 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) Less spike noise 3) High quantum efficiency	R6350, R6357 R105, R7400U-01 R1924A
Other Pollution Monitoring Equipment Using Photomultiplier Tubes • NOx meters, SOx meters	1) High quantum efficiency at target wavelengths 2) Low dark current 3) Good temperature characteristic 4) High stability	NOx= R3896, R5984, R374 R2228, R5929, R5070A SOx= R6095, R3788, R1527 R5983
Biotechnology		
Flow Cytometer A flow cytometer uses a laser to irradiate cells labeled with fluorescent substance and measures the resulting fluorescence or scattered light from those cells with a photomultiplier tube, in order to identify each cell. A cell sorter is one kind of flow cytometer having the function of sorting specific cells.	1) High quantum efficiency 2) High stability 3) Low dark current 4) High gain	R6357, R6358 R928, R3788 R4220, R3896 R7400U-01, R7400U-20 R5900U-01, R5900U-01-M4 R5900U-20-L16 H7260-20
DNA Sequencer The DNA sequence is used to decode the base arrangement of DNA. When a voltage is applied across the both ends of a gelatinous substance (gel) into which DNA segments are injected, those DNA segments with a negative electric charge are drawn towards the plus electrode. The shorter the DNA segment, the faster it moves, resulting in a separation according to the DNA segment length. The base arrangement of each DNA segment can be determined by detecting the fluorescence emitted from the labeling pigment at the end of each DNA.		
DNA Microarray Scanner In this equipment, a DNA sample labeled by fluorescent dye is combined with a DNA probe having a large number of DNAs whose arrangement is known and fixed at a high density on a glass plate or silicon substrate. A laser beam is used to scan the sample and the resulting fluorescent intensity is measured to investigate the gene information.		

Selection Guide by Applications

Applications	Required Major Characteristics	Applicable PMT
Medical Applications		
Gamma Camera The gamma camera obtains an image of a radioisotope injected into the body of a patient to locate abnormalities. This equipment originated from a scintillation scanner and has been gradually improved. Its detection section uses a large diameter NaI(Tl) scintillator and light-guide coupled to a photomultiplier tube array.	1) High energy resolution 2) Good uniformity 3) High stability 4) Uniform gain (between each tube)	R6231-01 R6234-01 R6235-01 R6236-01 R1307-01 R6233-01 R6237-01 H8500
Positron CT The positron CT provides tomographic images by detecting the coincident gamma-ray emission that accompanies the annihilation of positrons 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) Fast response time 4) Compact size	R1635, R8520U-00-C12 R1450 R7899 R1548 R6427 H8500
Liquid Scintillation Counter Liquid scintillation counters are used for tracer analysis in age measurement and biochemical research. A sample containing radioisotopes is dissolved into a solution containing an organic scintillator, and this is placed in the center between a pair or photomultiplier tubes. These tubes simultaneously detect the emission of the organic scintillator.	1) High quantum efficiency 2) Low thermionic emission noise 3) Less glass scintillation at bulb and other materials 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 the specific antigen/antibody reaction characteristics of tiny amounts of insulin, hormones, drugs and viruses that are contained in blood or urine. Photomultiplier tubes are used to optically measure the amount of antigens labeled by radioisotopes or fluorescent, chemiluminescent or bioluminescent substances. • Radioimmunoassay (RIA) Uses radioactive isotopes for labeling and scintillators for measurement. • Chemiluminoassay CLIA (Chemilulminoassay) CLEIA (Enzyme-intensified chemiluminoassay) Uses luminescent substances for labeling to measure chemiluminescence or bioluminescence. • Fluoroimmunoassay Uses fluorescent substances for labeling.	1) High quantum efficiency 2) High stability 3) Low dark current	R1166, R5611-01 R6350, R6352, R6353 R6356, R6357 R4220, R928, R3788, R3896 R647, R1463 R1925A, R1924A, R3550A R6095, R374
Others • X-ray phototimer This equipment automatically controls the X-ray film exposure during X-ray examinations. The X-rays transmitting through a subject are converted into visible light by a phosphor screen. A photomultiplier tube detects this light and converts it into electrical signals. When the accumulated electrical signal reaches a preset level, the X-ray irradiation is shut off, to allow obtaining 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 Area monitors are designed to continuously measure changes in environmental radiation levels. Area monitors use a photomultiplier tube coupled to a scintillator to monitor low level gamma-rays and beta-rays.	1) Long term stability 2) Low background noise 3) Good plateau characteristic	R1306 R329-02, R4607-01 R1307 R877, R877-01
Survey Meter Survey meters are used to measure low level gamma-rays and beta-rays by using a photomultiplier tube coupled to a scintillator.	1) Long term stability 2) Low background noise 3) Good plateau characteristic	R1635 R647 R1924A R6095 R7400U
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 on oil well as it is being drilled. The scattered radiation or natural radiation from the geological formation is detected and analyzed, to determine the type and density of the rock that surrounds the well.	1) Stable operation at high temperatures up to 175 °C 2) Rugged structure resistant to shock and vibration	R4177-01 R3991 R1288A, R1288A-01
Industrial Measurement		
Thickness Meter The thickness meter uses a radiation source and a scintillator/photomultiplier tube detector to measure product thickness such as for paper, plastic, copper sheet on factory production lines. Beta-rays are used as a radiation source to measure small density products such as rubber, plastic, and paper. Gamma-rays are used for large density products such as copper plates. X-ray fluorescence is utilized to measure film thickness for plating, evaporation, etc.)	1) Wide dynamic range 2) High energy resolution	R647, R7899 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. In wafer inspection, the wafer is scanned by a laser beam, and the scattered light caused by dirt or defects is detected by a photomultiplier tube.	1) High quantum efficiency at target wavelengths 2) Good uniformity 2) Low spike noise	R928, R3896 R647, R1463
Photography and Printing		
Color Scanner To print-out color pictures and photographs, color scanners separate the original colors into the three primary colors (RGB) and black. Color scanners use photomultiplier tubes combined with optical filters to provide the different colors as image data.	1) High quantum efficiency at RGB wavelengths 2) Low dark current 3) Fast signal pulse fall time 4) High stability 5) Good repeatability with changes in input signal	R3788 R3810, R3811 R647, R1463 R1924A, R1925A

Selection Guide by Applications

<table>
<tr><th>Applications</th><th>Required Major Characteristics</th><th>Applicable PMT</th></tr>
<tr><td colspan="3"><h2>High Energy Physics</h2>●Accelerator Experiment</td></tr>
<tr><td>Hodoscope
Photomultiplier tubes are coupled to the ends of long, thin plastic scintillator arrays arranged in two layers intersecting with each other in order to measure the time and position at which charged particles pass through the scintillator arrays.</td><td rowspan="3">1) Fast response time
2) Compact size
3) Resistance to magnetic fields (when used in magnetic fields)</td><td>R7400U Series, R7600U Series
R1635 (H3164-10)
R647-01 (H3165-10)
R1450 (H6524), R1166 (H6520)</td></tr>
<tr><td rowspan="2">TOF Counter
Two counters are arranged along a path of charged particles, with each counter consisting of a scintillator and a photomultiplier tube. The velocity of the particles is measured by the time difference between the two counters.</td><td>R7400U Series, R7600U Series
R7899, R1635 (H3164-10)
R1450 (H6524), R4998 (H6533)
R1828-01 (H1949-51)
R2083 (H2431-50)</td></tr>
<tr><td>R5505-70 (H6152-70)
R7761-70 (H8409-70)
R5924-70 (H6614-70)
R6504-70 (H8318-70)</td></tr>
<tr><td rowspan="2">Cherenkov Counter
A Cherenkov counter is used to identify secondary particles generated by the collision reaction of particles. Cherenkov radiation is emitted from charged particles with energy higher than a certain level when they pass through a gas or silicon aerogel. This weak Cherenkov radiation is detected by a photomultiplier tube. These particles are then identified by measuring the Cherenkov radiation emission angle.</td><td rowspan="2">1) High quantum efficiency
2) Single photon discrimination ability
3) High gain
4) Fast response time
5) Resistance to magnetic fields (when used in magnetic fields)</td><td>R329-02 (H6410), R5113-02
R1250 (H6527), R1584 (H6528)</td></tr>
<tr><td>R5505-70 (H6152-70)
R7761-70 (H8409-70)
R5924-70 (H6614-70)
R6504-70 (H8318-70)
H7546B, H8711</td></tr>
<tr><td>Calorimeter
The calorimeter measures the accurate energy of secondary particles generated by the collision reaction of particles.</td><td>1) Good pulse linearity
2) High energy resolution
3) High stability
4) Resistance to magnetic fields</td><td>R580 (H3178-51)
R329-02 (H6410)
R5924 (H6614-70)
R6091 (H6559), R7600U Series</td></tr>
<tr><td colspan="3">●Neutrino and Proton Decay Experiment, Cosmic Ray Detection</td></tr>
<tr><td>Neutrino Experiment
Research on solar neutrinos or particle astophysics is utilized in a neutrino experiment. This experimental system consists of a large amount of a medium surrounded by a great number of large-diameter photomultiplier tubes. When cosmic rays such as neutrinos enter and pass through the medium, their energy and traveling direction are measured by detecting Cherenkov radiation that occurs from interaction with the me-</td><td rowspan="3">1) Large photocathode area
2) Fast time response
3) High stability
4) Less dark count</td><td rowspan="2">R5912</td></tr>
<tr><td>Neutrino and Proton Decay Experiment
In the neutrino and proton decay experiments being conducted at Kamioka, Japan, 11,200 photomultiplier tubes each 20" diameter are installed to surround from all directions a huge tank storing 50,000 t of pure water. The photomultiplier tubes are used to watch the subtle flash of Cherenkov radiation that occurs when proton decays or solar neutrinos pass through the pure water tank.</td></tr>
<tr><td>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 radiation emitted in this air shower are detected by photomultiplier tubes arranged in a lattice array on the ground.</td><td>R1166 (H6520)
R580 (H3178-51)
R329-02 (H6410)
R6091 (H6559)
R1250 (H6527)
R6234</td></tr>
</table>

The assembly type is given in parentheses.

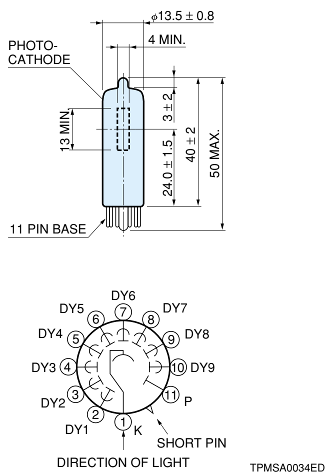
Applications	Required Major Characteristics	Applicable PMT
Aerospace		
Astronomical X-ray Measurement X-rays from outer space include information on the enigmas of space. As an example, the X-ray observation satellite "Asuka" developed by a group of the ISAS (Institute of Space and Astronomical Science - Japan), uses a gas-scintillation proportional counter in conjunction with a position-sensitive photomultiplier tube to measure X-rays from supernovas, etc.	1) High energy resolution 2) Resistance to shock and vibration	R2486 Ruggedized PMT with high resistance to vibration and shock will be required. Consult with our sales office.
Measurement of Scattered Light from Fixed Stars and Interstellar Dust Ultraviolet rays from space contain a great deal of information about the surface temperatures of stars and interstellar substances. However, these ultraviolet rays are absorbed by the earth's atmosphere making is impossible to measure them from the earth's surface. So photomultiplier tubes are mounted in rockets or artificial satellites, to measure ultraviolet rays with wavelengths shorter than 300 nm.	1) Resistance to shock and vibration 2) Sensitivity only in VUV to UV range (Solar blind response with no sensitivity to visible light: See page 6 for Cs-Te and CsI photocathodes)	R1080, R976 R6834, R6835, R6836 Ruggedized PMT with high resistance to vibration and shock will be required. Consult with our sales office.
Lasers		
Laser Radar The laser radar is used in applications such as atmospheric measurement for highly accurate range finding or aerosol scattering detection.	1) Fast time response 2) Less dark count 3) High gain 4) Less afterpulses	R3809U Series R5916U Series R3234-01, R3237-01 R7400U-20, R3896
Fluorescence Lifetime Measurement A laser is used as an excitation light for fluorescence lifetime measurement. The molecular structure of a substance can be studied by measuring the changes in temporal intensity in the emitted fluorescence.		R3809U Series R5916U Series R7400U-01, -20 R5900U-01, R5900U-01-M4
Plasma		
Plasma Observation Photomultiplier tubes are 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 on plasma using Thompson scattering and the Doppler effect to observe the spatial distribution of plasma, and to measure impurities in the plasma with the objective of controlling impurities and ions.	1) High detection capability at low light level 2) Quantum efficiency with less wavelength dependence 3) Gate operation	R2257 R943-02

Side-on Type Photomultiplier Tubes

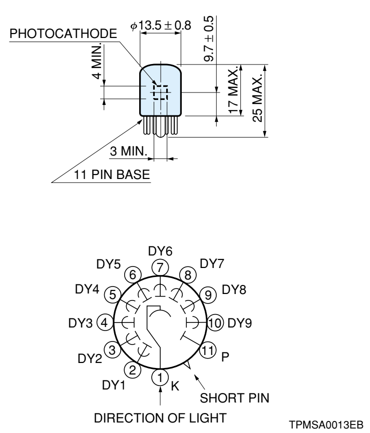
Type No. (A)	Spectral Response: Effective Area (mm) / Wavelength (nm) 100–1000	Curve Code (B)	Peak Wave-length (nm)	Photo-cathode Material (C)	Win-dow Mate-rial (D)	Out-line No. (E)	Dynode Structure / Stages (F)	Socket & Socket Assembly (G)	Max. Ratings (H): Anode to Cathode Voltage (V)	Max. Ratings (H): Average Anode Current (mA) (J)	Anode to Cathode Supply Voltage (V) (L)
13 mm (1/2") Dia. Types											
R6350	4 × 13	350U	340	Sb-Cs	U	❶	CC/9	E678-11U* ①②	1250	0.01	1000 ⑧
R6352	4 × 13	452U	420	BA	U	❶	CC/9	E678-11U* ①②	1250	0.01	1000 ⑧
R6353	4 × 13	456U	400	LBA	U	❶	CC/9	E678-11U* ①②	1250	0.01	1000 ⑧
R6355	4 × 13	550U	530	MA	U	❶	CC/9	E678-11U* ①②	1250	0.01	1000 ⑧
R6356-06	4 × 13	—	400	MA	U	❶	CC/9	E678-11U* ①②	1250	0.01	1000 ⑧
R6357	4 × 13	—	450	MA	U	❶	CC/9	E678-11U* ①②	1250	0.01	1000 ⑧
R6358	4 × 13	561U	530	MA	U	❶	CC/9	E678-11U* ①②	1250	0.01	1000 ⑧
13 mm (1/2") Dia. Subminiature Types											
R3810	3 × 4	350U	340	Sb-Cs	U	❷	CC/9	E678-11U* ①②	1250	0.01	1000 ⑧
R3811	3 × 4	550U	530	MA	U	❷	CC/9	E678-11U* ①②	1250	0.01	1000 ⑧

Dimensional Outlines (Unit: mm)

❶ R6350, R6352, R6353 etc.



❷ R3810, R3811

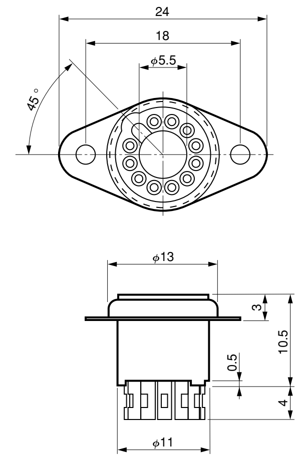


(at 25 °C)

Cathode Characteristics					Anode Characteristics Ⓜ										
Luminous		Blue Sensitivity Index (CS 5-58)	Red/White Ratio (R-68)	Ⓚ Radiant	Luminous		Radiant	Gain	Dark Current (After 30 min.)		Time Response		Notes	Ⓐ Type No.
Min. (μA/lm)	Typ. (μA/lm)	Typ.	Typ.	Typ. (mA/W)	Min. (A/lm)	Typ. (A/lm)	Typ. (A/W)	Typ.	Typ. (nA)	Max. (nA)	Rise Time Typ. (ns)	Transit Time Typ. (ns)		
20	40	5.0	—	48	50	300	3.6×10^5	7.5×10^6	0.5	5	1.4	15	Photon counting type: R6350P Silica glass window type: R6351	R6350
80	120	10.0	—	90	100	700	5.2×10^5	5.8×10^6	1	10	1.4	15		R6352
30	70	6.5	—	65	100	400	3.7×10^5	5.7×10^6	0.1	2	1.4	15	Photon counting type: R6353P	R6353
80	150	6.0	0.15	45	100	600	1.8×10^5	4.0×10^6	1	10	1.4	15		R6355
200	300	10.0	0.3	77	400	2000	5.2×10^5	6.7×10^6	1	10	1.4	15		R6356-06
350	500	13.0	0.4	105	1000	2000	4.2×10^5	4.0×10^6	2	10	1.4	15		R6357
140	200	7.5	0.15	70	300	700	2.5×10^5	3.5×10^6	0.1	1	1.4	15	Photon counting type: R6358P	R6358
20	40	5.0	—	48	50	300	3.6×10^5	7.5×10^6	0.5	5	1.4	15	Photon counting type: R3810P	R3810
50	150	6.0	0.15	45	50	200	5.9×10^4	1.3×10^6	1	10	1.4	15		R3811

Dimensional Outline of Socket (Unit: mm)

E678-11U



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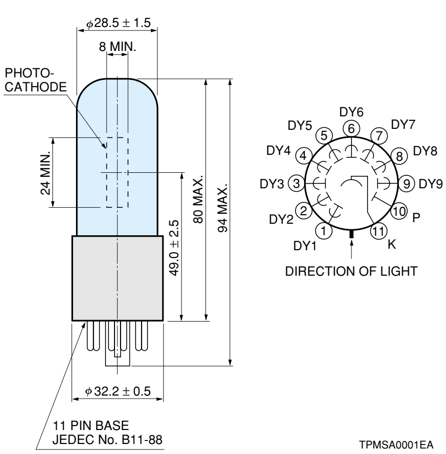
Side-on Type Photomultiplier Tubes

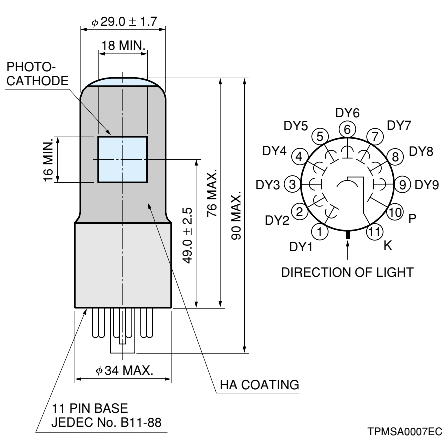
Type No.	Spectral Response: Effective Area (mm) / ← Wavelength (nm) → 100 200 300 400 500 600 700 800 900 1000	Spectral Response: Curve Code Ⓑ	Spectral Response: Peak Wave-length (nm)	Remarks: Photo-cathode Material Ⓒ	Remarks: Win-dow Mate-rial Ⓓ	Remarks: Out-line No. Ⓔ	Remarks: Dynode Structure / Stages Ⓕ	Remarks: Socket & Socket Assembly Ⓖ	Max. Ratings Ⓗ: Anode to Cathode Voltage (V)	Max. Ratings Ⓗ: Average Anode Current Ⓙ (mA)	Anode to Cathode Supply Voltage Ⓛ (V)
28 mm (1-1/8") Dia. Types with UV to Visible Sensitivity											
931A	8 × 24	350K	400	Sb-Cs	K	❶	CC/9	E678-11A ③④⑤	1250	0.1	1000 ⑧
931B	8 × 24	453K	400	BA	K	❶	CC/9	E678-11A ③④⑤	1250	0.1	1000 ⑧
1P21	8 × 24	350K	400	Sb-Cs	K	❶	CC/9	E678-11A ③④⑤	1250	0.1	1000 ⑧
R105	8 × 24	350K	400	Sb-Cs	K	❶	CC/9	E678-11A ③④⑤	1250	0.1	1000 ⑧
1P28	8 × 24	350U	340	Sb-Cs	U	❶	CC/9	E678-11A ③④⑤	1250	0.1	1000 ⑧
R212	8 × 24	350U	340	Sb-Cs	U	❶	CC/9	E678-11A ③④⑤	1250	0.1	1000 ⑧
R1527	8 × 24	456U	400	LBA	U	❶	CC/9	E678-11A ③④⑤	1250	0.1	1000 ⑧
R4220	8 × 24	456U	410	LBA	U	❶	CC/9	E678-11A ③④⑤	1250	0.1	1000 ⑧
R3788	8 × 24	452U	420	BA	U	❶	CC/9	E678-11A ③④⑤	1250	0.1	1000 ⑧
R2693	18 × 16	430U	375	LBA	U	❷	CC/9	E678-11A ③④⑤	1250	0.1	1000 ⑧
R5983	10 × 24	456U	410	LBA	U	❸	CC/9	E678-11A ③④⑤	1250	0.1	1000 ⑧
R6925	8 × 24	456U	410	BA	U	❶	CC/9	E678-11A ③④⑤	1250	0.1	1000 ⑧

Dimensional Outlines (Unit: mm)

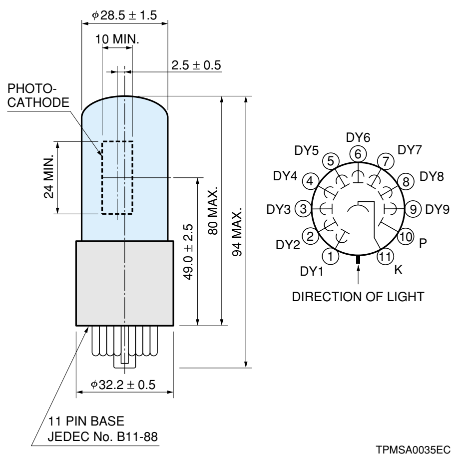
❶ 931A, 1P21, R105, R212 etc.



❷ R2693



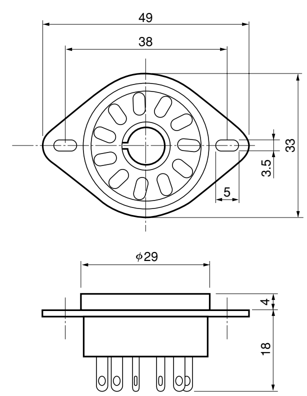
❸ R5983



Cathode Characteristics					Anode Characteristics M								(at 25 °C)	
Luminous Min. (µA/lm)	Luminous Typ. (µA/lm)	Blue Sensitivity Index (CS 5-58) Typ.	Red/White Ratio (R-68) Typ.	K Radiant Typ. (mA/W)	Luminous Min. (A/lm)	Luminous Typ. (A/lm)	Radiant Typ. (A/W)	Gain Typ.	Dark Current (After 30 min.) Typ. (nA)	Dark Current (After 30 min.) Max. (nA)	Time Response Rise Time Typ. (ns)	Time Response Transit Time Typ. (ns)	Notes	A Type No.
25	40	5.0	—	48	50	400	4.8×10^5	1.0×10^7	5	50	2.2	22		931A
30	60	7.1	—	60	50	600	6.6×10^5	1.0×10^7	5	50	2.2	22		931B
25	40	5.0	—	48	50	250	3.0×10^5	6.3×10^6	1	5	2.2	22		1P21
25	40	5.0	—	48	50	400	4.8×10^5	1.0×10^7	1	10	2.2	22		R105
25	40	5.0	—	48	20	400	4.8×10^5	1.0×10^7	5	50	2.2	22		1P28
25	40	5.0	—	48	50	300	3.6×10^5	7.5×10^6	1	10	2.2	22		R212
40	60	6.4	—	60	200	400	4.0×10^5	6.7×10^6	0.1	2	2.2	22	Photon counting type: R1527P Silica glass window type: R7446	R1527
80	100	8.0	—	70	1000	1200	8.4×10^5	1.2×10^7	0.2	2	2.2	22	Photon counting type: R4220P Silica glass window type: R7447	R4220
100	120	10.0	0.01	90	500	1200	9.0×10^5	1.0×10^7	5	50	2.2	22		R3788
30	50	7.0	—	62	100	300	3.7×10^5	6.0×10^6	0.5	5	1.2	18	Photon counting type: R2693P	R2693
60	100	8.0	—	70	500	1000	7.0×10^5	1.0×10^7	0.2	2	2.2	22	Photon counting type: R5983P	R5983
40	70	—	0.02	68	200	500	4.8×10^5	7.1×10^6	5	50	2.2	22		R6925

Dimensional Outline of Socket (Unit: mm)

E678-11A



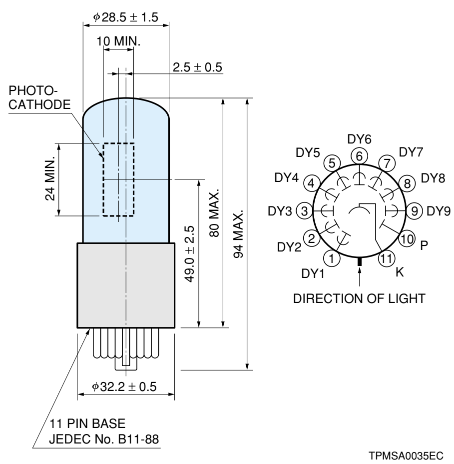
TACCA0064EA

Side-on Type Photomultiplier Tubes

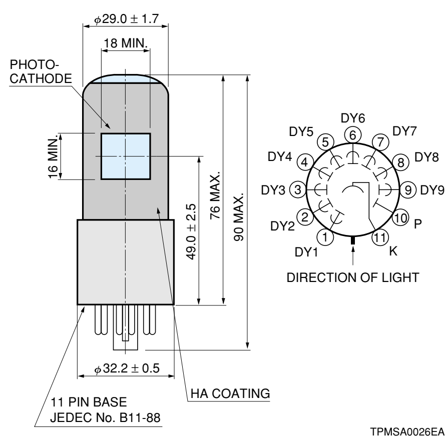
Type No. Ⓐ	Spectral Response: Effective Area (mm) / ← Wavelength (nm) → (100–1200)	Curve Code Ⓑ	Peak Wave-length (nm)	Photo-cathode Material Ⓒ	Win-dow Mate-rial Ⓓ	Out-line No. Ⓔ	Dynode Structure / Stages Ⓕ	Socket & Socket Assembly Ⓖ	Max. Ratings Ⓗ: Anode to Cathode Voltage (V)	Max. Ratings Ⓗ: Average Anode Current (mA) Ⓙ	Anode to Cathode Supply Voltage (V) Ⓛ
28 mm (1-1/8") Dia. Types with UV to Near IR Sensitivity											
R5984	10 × 24	562U	400	MA	U	❶	CC/9	E678-11A ③④⑤	1250	0.1	1000 ⑧
R2368	18 × 16	500U	420	MA	U	❷	CC/9	E678-11A ③④⑤	1250	0.1	1000 ⑧
R928	8 × 24	562U	400	MA	U	❸	CC/9	E678-11A ③④⑤	1250	0.1	1000 ⑧
R2949	8 × 6	552U	400	MA	U	❹	CC/9	E678-11A ③④⑤	1250	0.1	1000 ⑧
R3896	8 × 24	555U	450	MA	U	❸	CC/9	E678-11A ③④⑤	1250	0.1	1000 ⑧
R4632	8 × 24	556U	430	MA	U	❸	CC/9	E678-11A ③④⑤	1250	0.1	1000 ⑧
R636-10	3 × 12	650U	300-800	GaAs	U	❺	CC/9	E678-11A ③④	1500	0.001	1250 ⑧
R2658	3 × 12	850U	400	InGaAs	U	❻	CC/9	E678-11A ③④	1500	0.001	1250 ⑧
R5108	18 × 16	700K	800	Ag-O-Cs	K	❼	CC/9	E678-11A ③④	1500	0.01	1250 ⑧

Dimensional Outlines (Unit: mm)

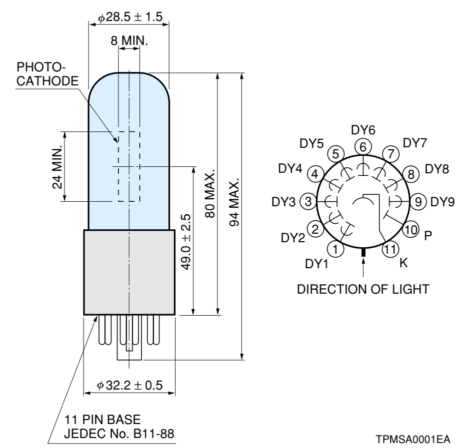
❶ R5984



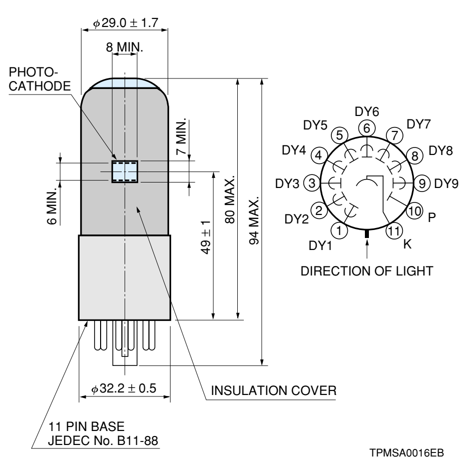
❷ R2368



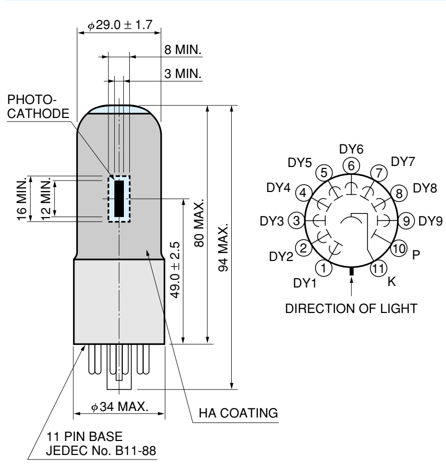
❸ R928, R3896 etc.



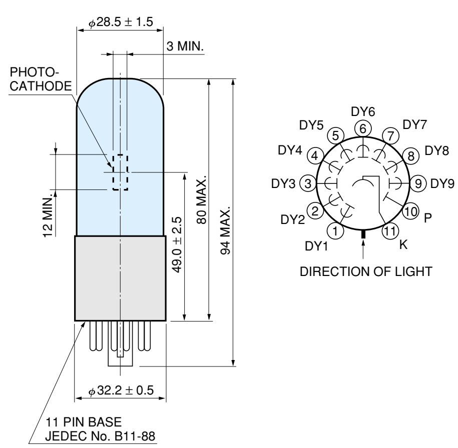
❹ R2949



❺ R636-10



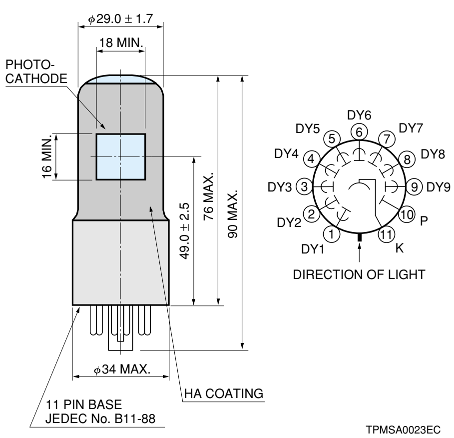
❻ R2658



(at 25 °C)

Cathode Characteristics: Luminous Min. (µA/lm)	Cathode: Luminous Typ. (µA/lm)	Cathode: Blue Sensitivity Index (CS 5-58) Typ.	Cathode: Red/White Ratio (R-68) Typ.	Cathode: (K) Radiant Typ. (mA/W)	Anode Characteristics (M): Luminous Min. (A/lm)	Anode: Luminous Typ. (A/lm)	Anode: Radiant Typ. (A/W)	Anode: Gain Typ.	Anode: Dark Current (After 30 min.) Typ. (nA)	Anode: Dark Current (After 30 min.) Max. (nA)	Anode: Time Response Rise Time Typ. (ns)	Anode: Time Response Transit Time Typ. (ns)	Notes	(A) Type No.
140	300	9.0	0.32	76	400	3000	7.6×10^5	1.0×10^7	5	50	2.2	22		**R5984**
80	150	—	0.15	64	50	200	8.3×10^4	1.3×10^6	5	50	1.2	18		**R2368**
140	250	8.0	0.3	74	400	2500	7.4×10^5	1.0×10^7	3	50	2.2	22	Silica glass window type: R955	**R928**
140	200	7.5	0.3	68	1000	2000	6.8×10^5	1.0×10^7	300(h)	500(h)	2.2	22		**R2949**
475	525	15.0	0.4	90	3000	5000	8.6×10^5	9.5×10^6	10	50	2.2	22		**R3896**
140	200	7.5	0.15	80	300	700	2.8×10^5	3.5×10^6	50(h)	100(h)	2.2	22		**R4632**
400	550	9.0	0.53	62	100	250	2.8×10^4	4.5×10^5	0.1(f)	2(f)	2.0	20	Silica glass window type: R758-10	**R636-10**
50	100	4.5	0.4	1 at 1 µm	5	16	1.6×10^2	1.6×10^5	1	10	2.0	20	Photon counting type: R2658P	**R2658**
10	25	—	—	2.2	3.5	7.5	6.6×10^2	3.0×10^5	350(e)	1000(e)	1.1	17		**R5108**

7 R5108



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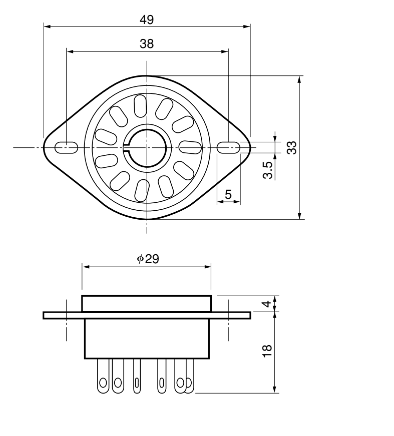
Dimensional Outline of Socket (Unit: mm)

E678-11A



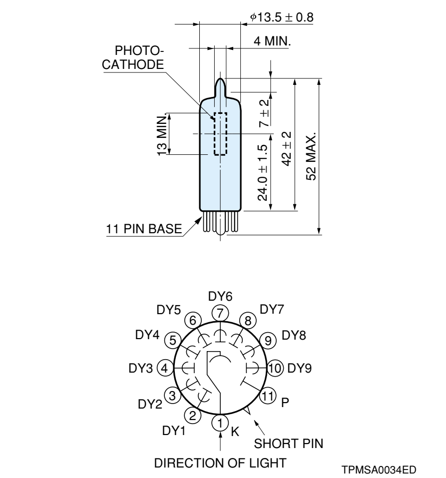
TACCA0064EA

Side-on Type Photomultiplier Tubes

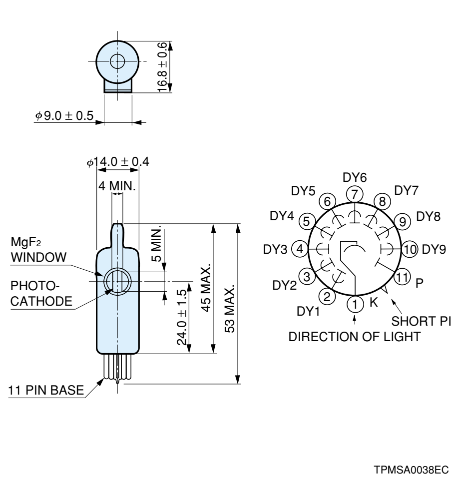
Type No. Ⓐ	Spectral Response: Effective Area (mm) / Wavelength (nm) 100–1000	Spectral Response: Curve Code Ⓑ	Spectral Response: Peak Wavelength (nm)	Remarks: Photocathode Material Ⓒ	Remarks: Window Material Ⓓ	Remarks: Outline No. Ⓔ	Remarks: Dynode Structure / Stages Ⓕ	Remarks: Socket & Socket Assembly Ⓖ	Max. Ratings Ⓗ: Anode to Cathode Voltage (V)	Max. Ratings Ⓗ: Average Anode Current (mA) Ⓙ	Anode to Cathode Supply Voltage (V) Ⓛ
13 mm (1/2") Dia. Types with Solar Blind Response											
R7511	4 × 5	150M	130	Cs-I	MF	❷	CC/9	E678-11U*	1250	0.01	1000 ⑧
R6354	4 × 13	250S	230	Cs-Te	Q	❶	CC/9	E678-11U* ①②	1250	0.01	1000 ⑧
R7311	4 × 5	250M	200	Cs-Te	MF	❷	CC/9	E678-11U*	1250	0.01	1000 ⑧
28 mm (1-1/8") Dia. Types with Solar Blind Response											
R8487	8 × 12	150M	130	Cs-I	MF	❸	CC/9	E678-11A	1250	0.1	1000 ⑧
R7154	8 × 24	250S	230	Cs-Te	Q	❹	CC/9	E678-11A ③④⑤	1250	0.1	1000 ⑧
R7639	3 x 12	—	155	DIA	MF	❺	CC/9	E678-11A ③④⑤	1250	0.1	1000 ⑧

Dimensional Outlines (Unit: mm)

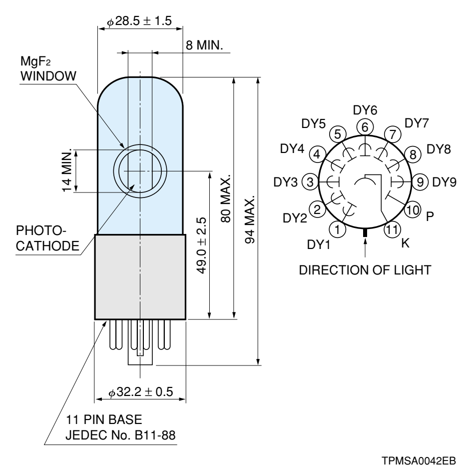
❶ R6354



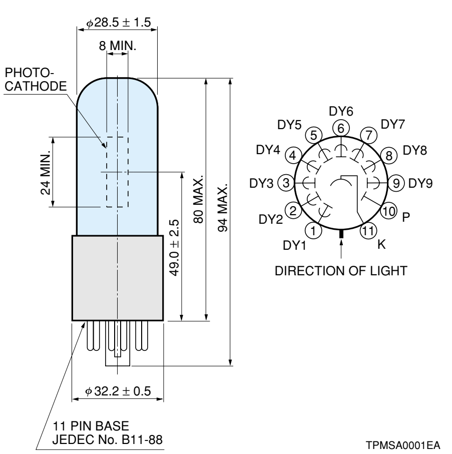
❷ R7511, R7311



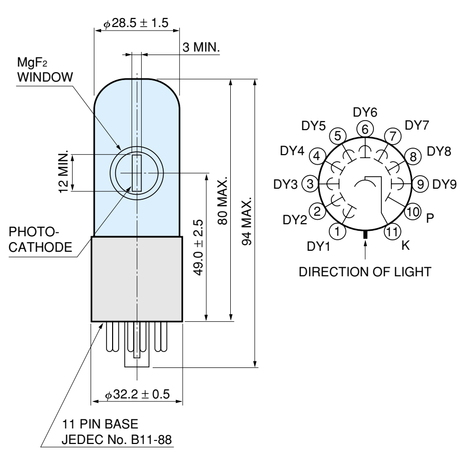
❸ R8487



❹ R7154



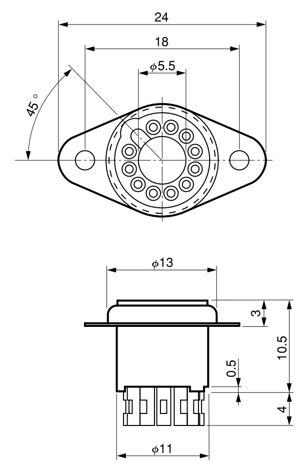
❺ R7639



Cathode Characteristics					Anode Characteristics Ⓜ									(at 25 °C)	
Luminous		Blue Sensitivity Index (CS 5-58)	Red/White Ratio (R-68)	Ⓚ Radiant	Luminous		Radiant	Gain	Dark Current (After 30 min.)		Time Response		Notes	Ⓐ Type No.
Min. (μA/lm)	Typ. (μA/lm)	Typ.	Typ.	Typ. (mA/W)	Min. (A/lm)	Typ. (A/lm)	Typ. (A/W)	Typ.	Typ. (nA)	Max. (nA)	Rise Time Typ. (ns)	Transit Time Typ. (ns)		
—	—	—	—	26ⓐ	—	—	5.2 × 10^4ⓐ	2.0 × 10^6	0.3	3	1.4	15		R7511
—	—	—	—	62ⓑ	—	—	1.8 × 10^5ⓑ	3.0 × 10^6	0.5	5	1.4	15		R6354
—	—	—	—	40ⓑ	—	—	2.8 × 10^5ⓑ	7.0 × 10^6	0.3	3	1.4	15		R7311
—	—	—	—	25.5ⓐ	—	—	1.0 × 10^5ⓐ	3.9 × 10^6	0.1	—	2.2	22	Cs-Te photocathode type: R8486	R8487
—	—	—	—	62ⓑ	—	—	6.2 × 10^5ⓑ	1.0 × 10^7	1	10	2.2	22		R7154
—	—	—	—	50	—	—	1.5 × 10^5	3.0 × 10^6	0.5	5	2.2	22		R7639

Dimensional Outline of Socket (Unit: mm)

E678-11U



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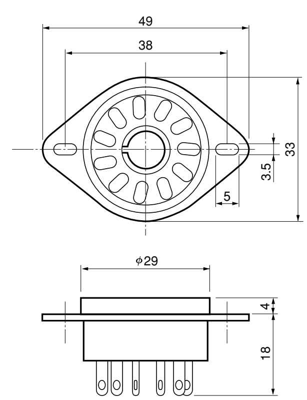
E678-11A



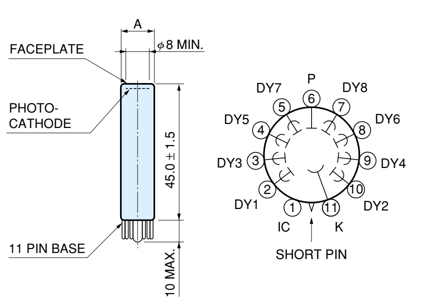
TACCA0064EA

Head-on Type Photomultiplier Tubes

Type No. (A)	Spectral Response: Effective Area (mm) / Wavelength (nm) 100–1000	Curve Code (B)	Peak Wavelength (nm)	Remarks: Photocathode Material (C)	Window Material (D)	Outline No. (E)	Dynode Structure / Stages (F)	Socket & Socket Assembly (G)	Max. Ratings (H): Anode to Cathode Voltage (V)	Average Anode Current (mA) (J)	Anode to Cathode Supply Voltage (V) (L)
10 mm (3/8") Dia. Types											
R1893	ϕ8	200S	240	Cs-Te	Q	1	L/8	E678-11N* (6)	1500	0.01	1250 (1)
R1635	ϕ8	400K	420	BA	K	1	L/8	E678-11N* (6)	1500	0.03	1250 (1)
R2496	ϕ8	400S	420	BA	Q	1	L/8	E678-11N* (7)(8)	1500	0.03	1250 (4)
R1894	ϕ8	500K	420	MA	K	1	L/8	E678-11N* (6)	1500	0.03	1250 (1)
13 mm (1/2") Dia. Types											
R1081	ϕ6	100M	140	Cs-I	MF	2	L/10	E678-12A*	2250	0.01	2000 (10)
R1080	ϕ6	200M	240	Cs-Te	MF	2	L/10	E678-12A*	1250	0.01	1000 (10)
R759	ϕ10	200S	240	Cs-Te	Q	3	L/10	E678-13A* (9)(10)	1250	0.01	1000 (10)
R647	ϕ10	400K	420	BA	K	3	L/10	E678-13A* (9)(10)	1250	0.1	1000 (10)
R4124	ϕ10	400K	420	BA	K	4	L/10	E678-13A* (11)	1250	0.03	1000 (16)
R2557	ϕ10	402K	375	LBA	K	3	L/10	E678-13A* (12)	1500	0.03	1250 (13)
R4177-01	ϕ10	401K	375	HBA	K	5	L/10	E678-13E*	1800	0.02	1500 (10)
R1463	ϕ10	500U	420	MA	U	3	L/10	E678-13A* (9)(10)	1250	0.03	1000 (10)

Dimensional Outlines (Unit: mm)

1 R1893, R1635, R2496 etc.

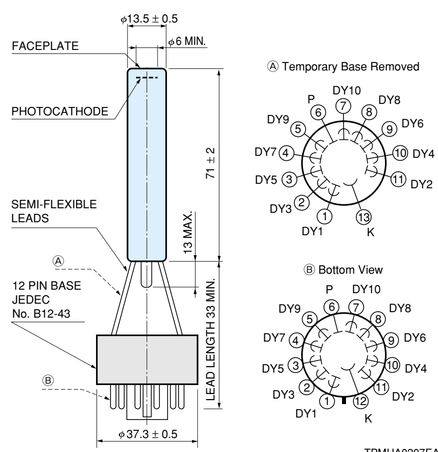


	R1635	R1893, R2496	Others
A	ϕ9.7 ± 0.4	ϕ10.5 ± 0.5	ϕ9.7 ± 0.4

R2496 has a plano-concave faceplate.

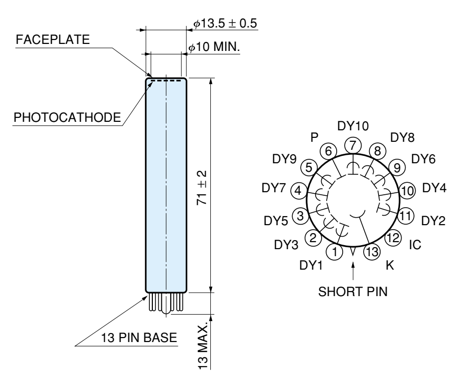
TPMHA0100EB

2 R1081, R1080



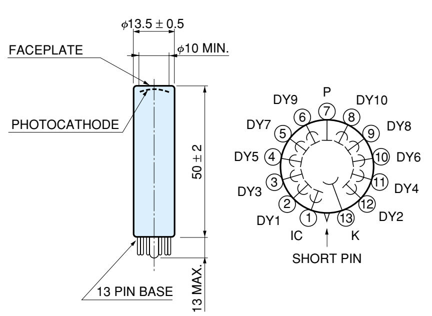
TPMHA0207EA

3 R759, R647, R2557, R1463



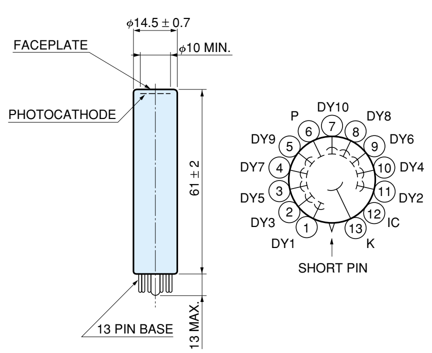
TPMHA0014EA

4 R4124



TPMHA0102EA

5 R4177-01

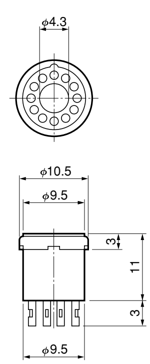


TPMHA0006EA

Cathode Characteristics					Anode Characteristics Ⓜ									(at 25 °C)
Luminous		Blue Sensitivity Index (CS 5-58)	Red/ White Ratio (R-68)	Ⓚ Radiant	Luminous		Radiant	Gain	Dark Current (After 30 min.)		Time Response		Notes	Ⓐ Type No.
Min. (µA/lm)	Typ. (µA/lm)	Typ.	Typ.	Typ. (mA/W)	Min. (A/lm)	Typ. (A/lm)	Typ. (A/W)	Typ.	Typ. (nA)	Max. (nA)	Rise Time Typ. (ns)	Transit Time Typ. (ns)		
—	—	—	—	24ⓑ	1.2×10^3 (A/W)ⓑ	—	3.6×10^3ⓑ	1.5×10^5	0.5	2.5	0.8	7.8		**R1893**
60	100	10	—	80	30	100	8.0×10^4	1.0×10^6	1	50	0.8	9.0	Photon counting type: R1635P UV glass window type: R3878	**R1635**
60	100	10	—	80	30	100	8.0×10^4	1.0×10^6	2	50	0.7	9.0		**R2496**
80	120	—	0.2	51	10	50	2.1×10^4	4.2×10^5	2	20	0.8	7.8		**R1894**
—	—	—	—	12ⓐ	2×10^2 (A/W)ⓐ	—	1.2×10^3ⓐ	1.0×10^5	0.03	0.05	1.8	18		**R1081**
—	—	—	—	28ⓑ	4×10^3 (A/W)ⓑ	—	1.4×10^4ⓑ	5.0×10^5	0.3	1	2.5	24	Photon counting type: R1080P	**R1080**
—	—	—	—	28ⓑ	4×10^3 (A/W)ⓑ	—	1.4×10^4ⓑ	5.0×10^5	0.3	1	2.5	24		**R759**
40	110	10	—	80	30	110	8.0×10^4	1.0×10^6	1	15	2.5	24	Photon counting type: R647P UV glass window type: R960 Silica glass window type: R760	**R647**
40	100	10	—	80	30	100	8.0×10^4	1.0×10^6	1	15	1.1	12	UV glass window type: R4141	**R4124**
25	40	5.5	—	50	50	200	2.5×10^5	5.0×10^6	0.4	4	2.2	22	Photon counting type: R2557P	**R2557**
20	40	6.0	—	51	10	20	2.5×10^5	5.0×10^5	0.5	10	2.0	20	High temp. operation type: -30 °C to +175 °C	**R4177-01**
80	120	—	0.2	51	30	120	5.1×10^4	1.0×10^6	4	20	2.5	24	Photon counting type: R1463P	**R1463**

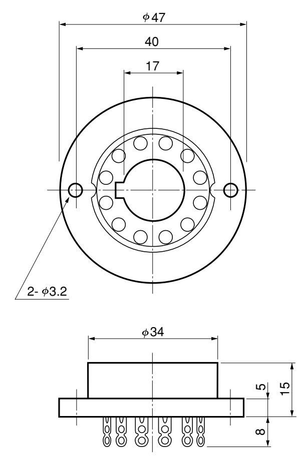
Dimensional Outline of Socket (Unit: mm)

E678-11N



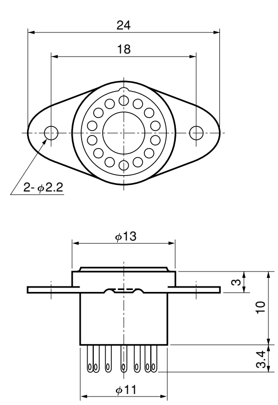
TACCA0043EA

E678-12A



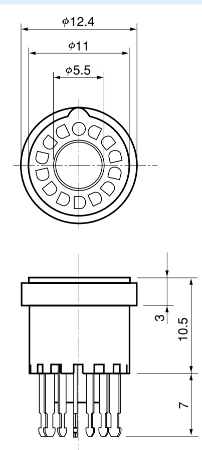
TACCA0009EB

E678-13A



TACCA0005EA

E678-13E



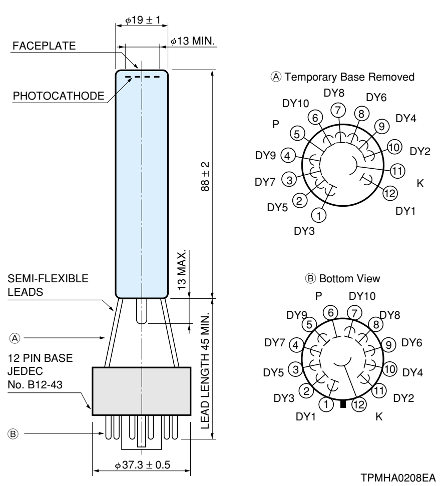
TACCA0013EB

Head-on Type Photomultiplier Tubes

Type No. (A)	Spectral Response: Effective Area (mm) / Wavelength (nm) 100–1200	Curve Code (B)	Peak Wavelength (nm)	Photocathode Material (C)	Window Material (D)	Outline No. (E)	Dynode Structure / Stages (F)	Socket & Socket Assembly (G)	Max. Ratings (H): Anode to Cathode Voltage (V)	Average Anode Current (mA) (J)	Anode to Cathode Supply Voltage (V) (L)
19 mm (3/4") Dia. Types											
R972	φ13	100M	140	Cs-I	MF	❶	L/10	E678-12A* ⑬	2250	0.01	2000 ⑫
R821	φ15	200S	240	Cs-Te	Q	❷	L/10	E678-12L* ⑭⑮⑯	1250	0.01	1000 ⑫
R1166	φ15	400K	420	BA	K	❷	L/10	E678-12L* ⑭⑮⑯	1250	0.1	1000 ⑫
R1450	φ15	400K	420	BA	K	❷	L/10	E678-12L* ⑰	1800	0.1	1500 ⑭
R3478	φ15	400K	420	BA	K	❸	L/8	E678-12L* ⑱⑲	1800	0.1	1700 ⑤
R5610	φ15	402K	375	LBA	K	❹	CC/10	E678-12L*	1250	0.1	1000 ⑮
R5611-01	φ15	400K	420	BA	K	❺	CC/10	E678-12A*	1250	0.1	1000 ⑮
R3991	φ15	401K	375	HBA	K	❺	CC/10	E678-12A*	1800	0.02	1500 ⑮
R1617	φ15	500K	420	MA	K	❷	L/10	E678-12L* ⑭⑮⑯	1250	0.1	1000 ⑫
R1878	φ4	500K	420	MA	K	❻	L/10	E678-12L* ⑳	1500	0.1	1000 ⑬
R632-01	φ15	700K	800	Ag-O-Cs	K	❷	L/10	E678-12L* ⑭⑮⑯	1500	0.01	1250 ⑫

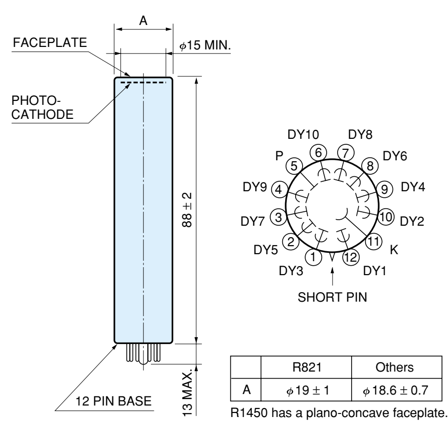
Dimensional Outlines (Unit: mm)

❶ R972



TPMHA0208EA

❷ R821, R1166, R1450 etc.

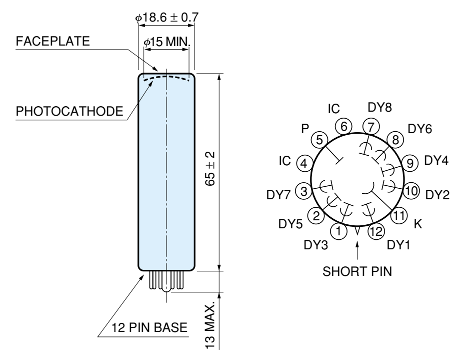


	R821	Others
A	φ19 ± 1	φ18.6 ± 0.7

R1450 has a plano-concave faceplate.

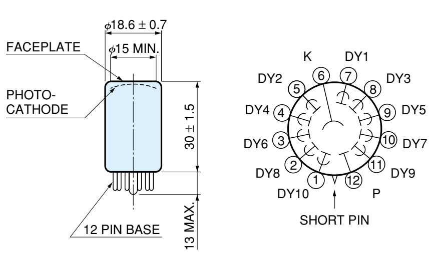
TPMHA0012EB

❸ R3478



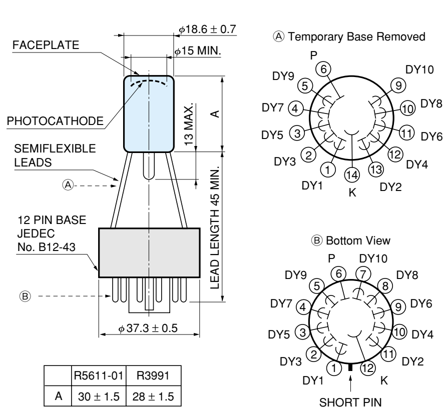
TPMHA0119EB

❹ R5610



TPMHA0269EA

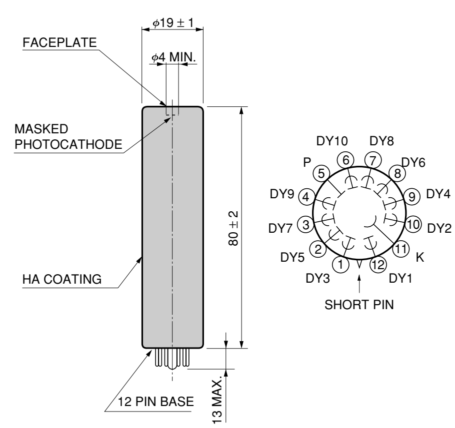
❺ R5611-01, R3991



	R5611-01	R3991
A	30 ± 1.5	28 ± 1.5

TPMHA0036EB

❻ R1878



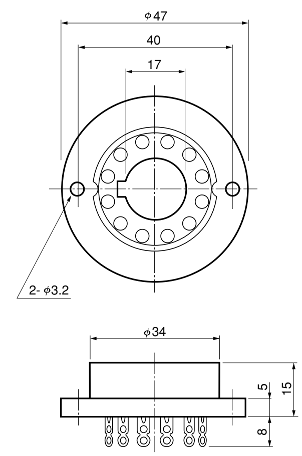
TPMHA0027EA

(at 25 °C)

Cathode Characteristics: Luminous Min. (µA/lm)	Cathode: Luminous Typ. (µA/lm)	Cathode: Blue Sensitivity Index (CS 5-58) Typ.	Cathode: Red/White Ratio (R-68) Typ.	Cathode: Radiant Typ. (mA/W) Ⓚ	Anode Characteristics Ⓜ: Luminous Min. (A/lm)	Anode: Luminous Typ. (A/lm)	Anode: Radiant Typ. (A/W)	Anode: Gain Typ.	Anode: Dark Current (After 30 min.) Typ. (nA)	Anode: Dark Current (After 30 min.) Max. (nA)	Anode: Time Response Rise Time Typ. (ns)	Anode: Time Response Transit Time Typ. (ns)	Notes	Type No. Ⓐ
—	—	—	—	12ⓐ	2×10^2 (A/W)ⓐ	—	12×10^3ⓐ	1.0×10^5	0.03	0.05	1.6	17		R972
—	—	—	—	28ⓑ	4×10^3 (A/W)ⓑ	—	1.0×10^4ⓑ	3.6×10^5	0.3	0.5	2.5	27	MgF_2 window type: R976 (Dimensional Outline: ①)	R821
70	110	10.5	—	85	10	110	8.5×10^4	1.0×10^6	1	5	2.5	27	Photon counting type: R1166P UV glass window type: R750	R1166
70	115	11.0	—	88	100	200	1.5×10^5	1.7×10^6	3	50	1.8	19	Flexible lead type: R1450-13	R1450
70	115	11.0	—	88	100	200	1.5×10^5	1.7×10^6	10	300	1.3	14	UV glass window type: R3479 Silica glass window type: R2076	R3478
30	50	6.5	—	50	20	100	1.0×10^5	2.0×10^6	0.5	4	1.5	17	Photon counting type: R5610P	R5610
60	90	10.5	—	85	10	50	4.7×10^4	5.5×10^5	3	20	1.5	17	Button stem type: R5611	R5611-01
20	40	6.0	—	51	5	15	1.9×10^4	3.8×10^5	0.1	10	1.0	13	High temp. operation type: -30 °C to +175 °C	R3991
80	120	—	0.2	51	30	120	5.1×10^4	1.0×10^6	4	20	2.5	27	UV glass window type: R1464 Silica glass window type: R2027	R1617
80	120	—	0.2	51	30	150	6.1×10^4	1.2×10^6	100ⓗ	250ⓗ	1.7	24	Bialkali photocathode type: R2295	R1878
10	20	—	0.14ⓓ	1.9	5	10	9.5×10^2	5.0×10^5	800ⓔ	2000ⓔ	2.2	25		R632-01

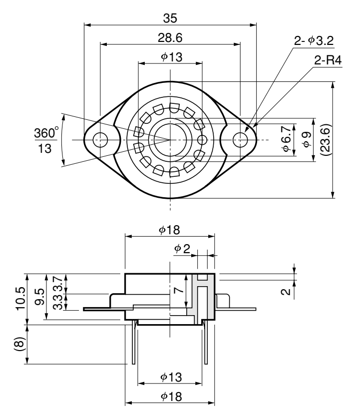
Dimensional Outline of Socket (Unit: mm)

E678-12A



TACCA0009EB

E678-12L



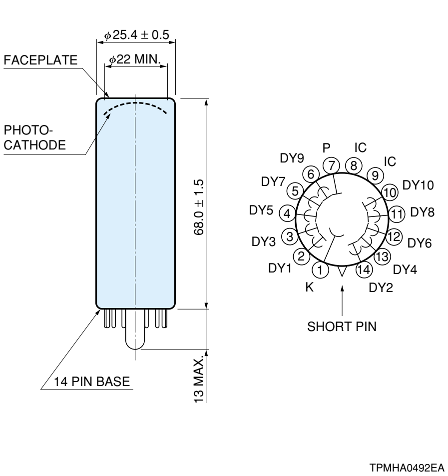
TACCA0047EA

Head-on Type Photomultiplier Tubes

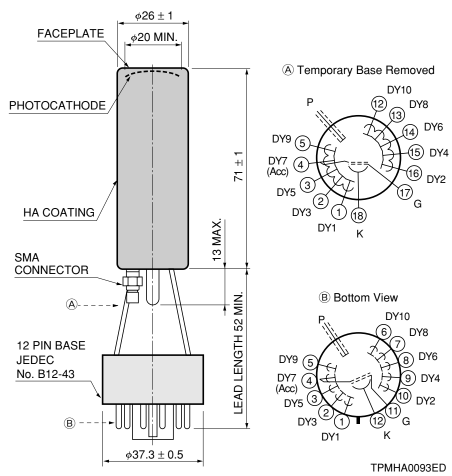
Type No. (A)	Spectral Response: Effective Area (mm) / ← Wavelength (nm) → 100 200 300 400 500 600 700 800 900 1000	Spectral Response: Curve Code (B)	Spectral Response: Peak Wave-length (nm)	Remarks: Photo-cathode Material (C)	Remarks: Win-dow Mate-rial (D)	Remarks: Out-line No. (E)	Remarks: Dynode Structure / Stages (F)	Remarks: Socket & Socket Assembly (G)	Max. Ratings (H): Anode to Cathode Voltage (V)	Max. Ratings (H): Average Anode Current (mA) (J)	Anode to Cathode Supply Voltage (V) (L)
25 mm (1") Dia. Types											
R7899	φ22	400K	420	BA	K	1	L/10	E678-14C* (21)	1800	0.1	1250 (16)
R4998	φ20	400K	420	BA	K	2	L/10	E678-12A*	2500	0.1	2250 (19)
R2078	φ21	201S	240	Cs-Te	Q	3	CC/10	E678-12A*	2000	0.015	1500 (15)
R1924A	φ22	400K	420	BA	K	4	L/10	E678-14C* (22)(23)(24)	1250	0.1	1000 (15)
R3550A	φ22	402K	375	LBA	K	4	L/10	E678-14C* (22)(23)(24)	1250	0.1	1000 (15)
R1288A	φ22	401K	375	HBA	K	3	L/10	E678-12R*	1800	0.02	1500 (15)
R1925A	φ22	500K	420	MA	K	4	L/10	E678-14C* (22)(23)(24)	1250	0.1	1000 (15)
R5070A	φ21	502K	420	MA	K	5	CC/10	E678-14C* (22)(23)(24)	1250	0.1	1000 (15)

Dimensional Outlines (Unit: mm)

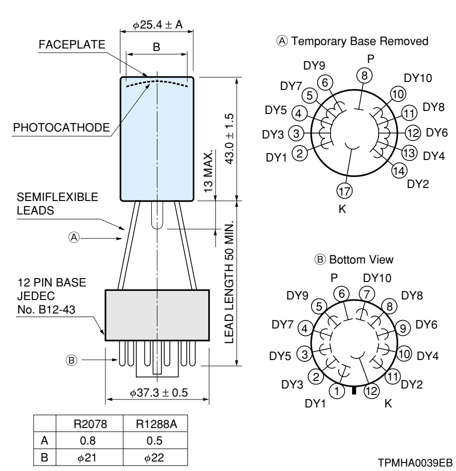
1 R7899



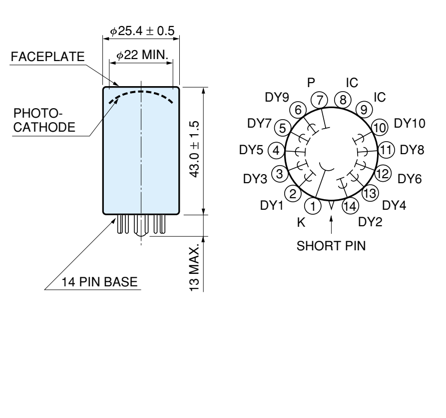
2 R4998



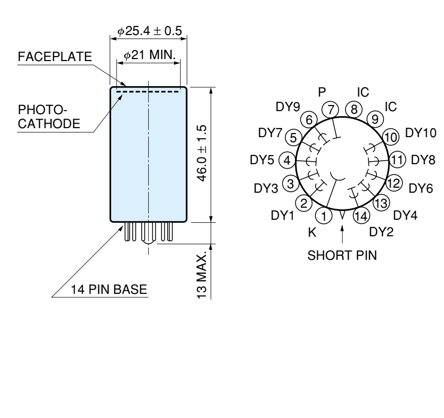
3 R2078, R1288A



4 R1924A, R3550A, R1925A



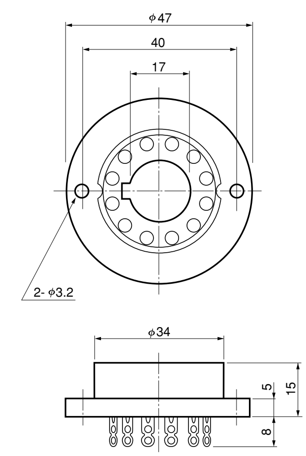
5 R5070A



Cathode Characteristics					Anode Characteristics M									(at 25 °C)
Luminous		Blue Sensitivity Index (CS 5-58)	Red/White Ratio (R-68)	Radiant K	Luminous		Radiant	Gain	Dark Current (After 30 min.)		Time Response		Notes	Type No. A
Min. (µA/lm)	Typ. (µA/lm)	Typ.	Typ.	Typ. (mA/W)	Min. (A/lm)	Typ. (A/lm)	Typ. (A/W)	Typ.	Typ. (nA)	Max. (nA)	Rise Time Typ. (ns)	Transit Time Typ. (ns)		
70	95	11.0	—	88	—	190	1.7×10^5	2.0×10^6	2	15	1.6	17	Semiflexible leads type : R7899-01	R7899
60	70	9.0	—	72	100	400	4.1×10^5	5.7×10^6	100	800	0.7	10	Assembly type H6533 (Recommended) Silica glass window type: R5320	R4998
—	—	—	—	29 b	2×10^3 (A/W) b	—	1.5×10^4 b	5.0×10^5	0.015	0.1	1.5	14		R2078
60	90	10.5	—	85	40	180	1.7×10^5	2.0×10^6	3	20	1.5	17	Photon counting type R1924P	R1924A
30	50	7.0	—	55	30	100	1.1×10^5	2.0×10^6	0.5	4	1.5	17	Photon counting type: R3550P	R3550A
20	40	6.0	—	51	8	15	1.9×10^4	3.8×10^5	0.1	10	1.3	13	Button stem type: R1288A-01 High temp. operation type: -30 °C to +175 °C	R1288A
80	150	—	0.2	64	20	75	3.2×10^4	5.0×10^5	3	20	1.5	17	Silica glass window type: R1926A	R1925A
130	230	—	0.25	65	20	100	2.8×10^4	4.3×10^5	3	20	2.2	19	Prism window type	R5070A

Dimensional Outline of Socket (Unit: mm)

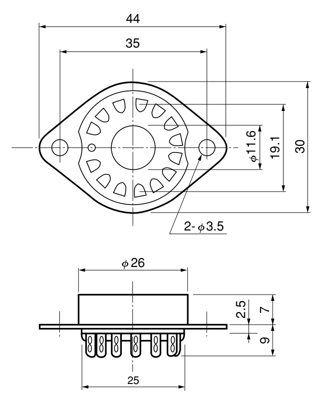
E678-12A, E678-12R*



* Gold Plating type

TACCA0009EB

E678-14C



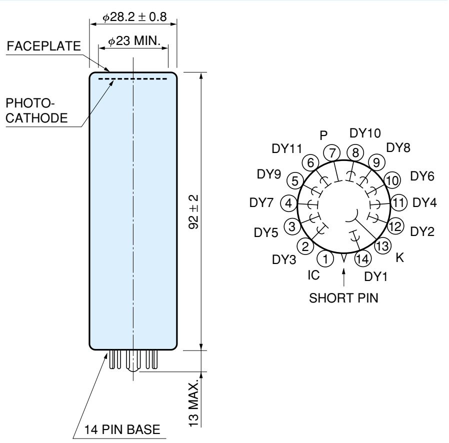
TACCA0004EA

Head-on Type Photomultiplier Tubes

Type No. (A)	Spectral Response: Effective Area (mm) / Wavelength (nm) 100–1200	Curve Code (B)	Peak Wavelength (nm)	Photocathode Material (C)	Window Material (D)	Outline No. (E)	Dynode Structure / Stages (F)	Socket & Socket Assembly (G)	Max. Ratings (H): Anode to Cathode Voltage (V)	Max. Ratings (H): Average Anode Current (mA) (J)	Anode to Cathode Supply Voltage (V) (L)
28 mm (1-1/8") Dia. Types											
R6835	φ23	100M	140	Cs-I	MF	❶	B+L/11	E678-14C*	2500	0.01	2000 ㉓
R6836	φ23	200M	240	Cs-Te	MF	❶	B+L/11	E678-14C*	1500	0.01	1000 ㉓
R6834	φ25	200S	240	Cs-Te	Q	❷	B+L/11	E678-14C* ㉕㉖㉗	1500	0.01	1000 ㉓
R6095	φ25	400K	420	BA	K	❸	B+L/11	E678-14C* ㉕㉖㉗	1500	0.1	1000 ㉓
R6094	φ25	400K	420	BA	K	❹	B+L/11	E678-14C* ㉕㉖㉗	1500	0.1	1000 ㉓
R6427	φ25	400K	420	BA	K	❻	L/10	E678-14C* ㉘㉙㉚	2000	0.2	1500 ⑱
R374	φ25	500U	420	MA	U	❸	B/11	E678-14C* ㉕㉖㉗	1500	0.1	1000 ㉓
R5929	φ25	502K	420	MA	K	❸	B/11	E678-14C* ㉕㉖㉗	1500	0.1	1000 ㉓
R2228	φ25	501K	600	MA	K	❸	B/11	E678-14C* ㉕㉖㉗	1500	0.1	1000 ㉓
R316-02	φ25	700K	800	Ag-O-Cs	K	❸	B/11	E678-14C* ㉕㉖㉗	1500	0.01	1250 ㉓
R7205-01	φ10	400K	420	BA	K	❺	B+L/11	E678-14C* ㉛	1500	0.01	1000 ㉕
R7206-01	φ10	500K	420	MA	K	❺	B+L/11	E678-14C* ㉛	1500	0.01	1000 ㉕
*R3998-02	φ25	400K	420	BA	K	❼	B+L/9	E678-14C* ㉜	1500	0.1	1000 ⑨
R7111	φ25	400K	420	BA	K	❽	L/10	E678-14C* ㉒㉓㉔	1250	0.1	1000 ⑮

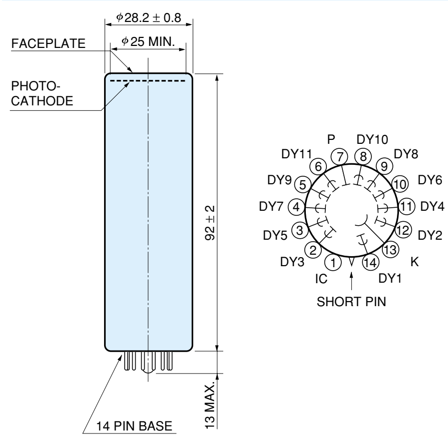
Dimensional Outlines (Unit: mm)

❶ R6835, R6836



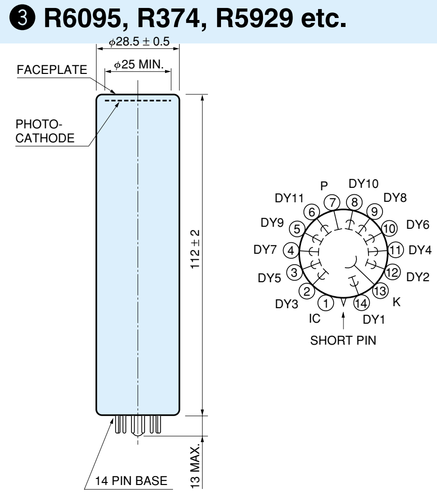
TPMHA0115EC

❷ R6834



TPMHA0226EC

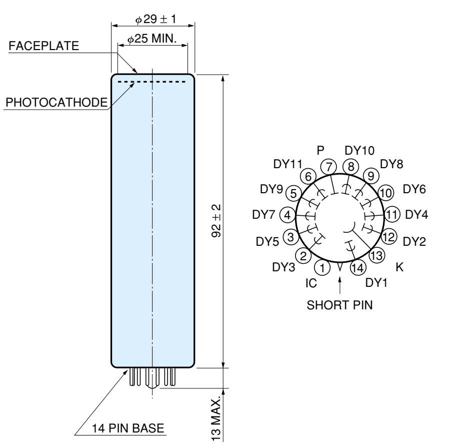
❸ R6095, R374, R5929 etc.



R2228, R5929 has a plano-concave faceplate.

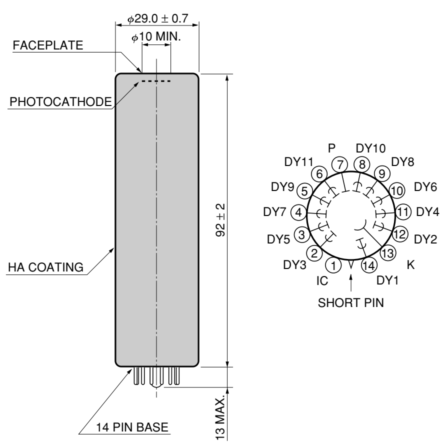
TPMHA0482EA

❹ R6094



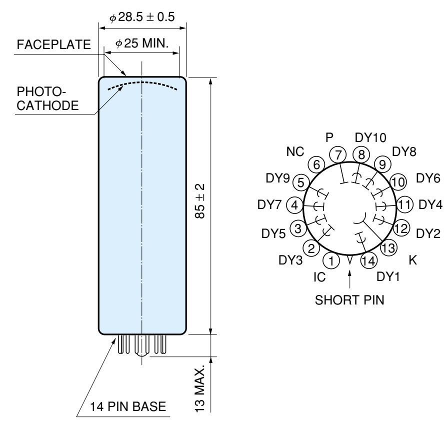
TPMHA0493EA

❺ R7205-01, R7206-01



TPMHA0412EB

❻ R6427

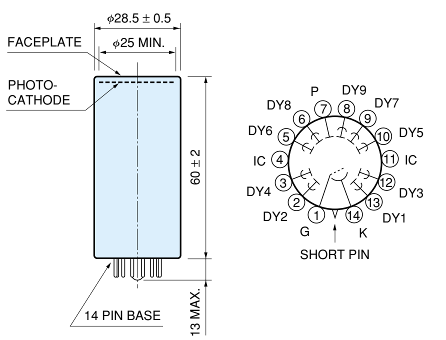


TPMHA0387EA

(at 25 °C)

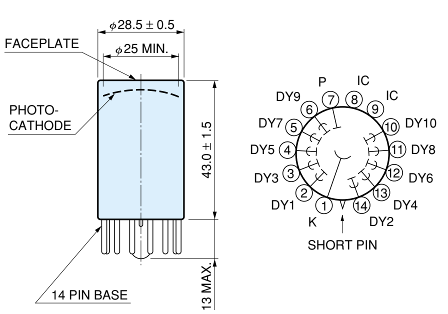
Cathode Characteristics: Luminous Min. (µA/lm)	Cathode: Luminous Typ. (µA/lm)	Cathode: Blue Sensitivity Index (CS 5-58) Typ.	Cathode: Red/White Ratio (R-68) Typ.	Cathode: Radiant (K) Typ. (mA/W)	Anode Characteristics (M): Luminous Min. (A/lm)	Anode: Luminous Typ. (A/lm)	Anode: Radiant Typ. (A/W)	Anode: 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: Transit Time Typ. (ns)	Notes	(A) Type No.
—	—	—	—	12 (a)	—	—	1.2×10^3 (a)	1.0×10^5	0.03	0.05	2.8	22		R6835
—	—	—	—	28 (b)	4×10^3 (A/W) (b)	—	1.4×10^4 (b)	5.0×10^5	0.3	1	4	30		R6836
—	—	—	—	28 (b)	4×10^3 (A/W) (b)	—	1.4×10^4 (b)	5.0×10^5	0.3	1	4	30		R6834
60	95	11.0	—	88	50	200	1.8×10^5	2.1×10^6	2	10	4	30	Photon counting type: R6095P UV glass window type: R7449 Silica glass window type: R7459	R6095
60	95	11.0	—	88	50	200	1.8×10^5	2.1×10^6	2	10	4	30		R6094
60	95	11.0	—	88	—	475	4.4×10^5	5.0×10^6	10	200	1.7	16	UV glass window type: R7056	R6427
80	150	—	0.2	64	20	80	3.4×10^4	5.3×10^5	3	15	15	60	High gain type: R1104	R374
130	230	—	0.25	65	30	180	5.1×10^4	7.8×10^5	5	25	15	60	Prism window type	R5929
100	200	—	0.3	40	20	150	3.0×10^4	7.5×10^5	8	30	15	60		R2228
10	20	—	0.14 (d)	1.9	5	10	9.5×10^2	5.0×10^5	2000 (e)	5000 (e)	10	50		R316-02
40	70	9.0	—	72	200	700	7.5×10^5	1.0×10^7	10 (h)	30 (h)	1.7	26	Silica glass window type: R7207-01	R7205-01
80	150	—	0.2	64	—	1500	6.4×10^5	1.0×10^7	300 (h)	1000 (h)	1.7	26		R7206-01
60	90	10.5	—	85	50	120	1.1×10^5	1.3×10^6	2	10	3.4	23		R3998-02
60	90	10.5	—	85	40	180	1.7×10^5	2.0×10^6	3	20	1.6	18		R7111*

7 R3998-02



TPMHA0114EA

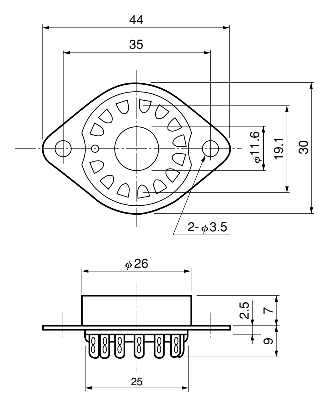
8 R7111



TPMHA0395EA

Dimensional Outline of Socket (Unit: mm)

E678-14C



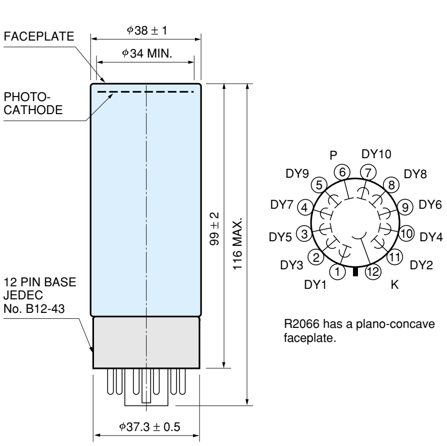
TACCA0004EA

Head-on Type Photomultiplier Tubes

Type No. Ⓐ	Spectral Response: Effective Area (mm) / Wavelength (nm) (100–1200)	Curve Code Ⓑ	Peak Wave-length (nm)	Photo-cathode Material Ⓒ	Win-dow Mate-rial Ⓓ	Out-line No. Ⓔ	Dynode Structure / Stages Ⓕ	Socket & Socket Assembly Ⓖ	Max. Ratings Ⓗ: Anode to Cathode Voltage (V)	Max. Ratings Ⓗ: Average Anode Current (mA) Ⓙ	Anode to Cathode Supply Voltage (V) Ⓛ
38 mm (1-1/2") Dia. Types											
R980	φ34	400K	420	BA	K	❶	CC/10	E678-12A* ㉝㉞	1250	0.1	1000 ⑬
R3886	φ34	400K	420	BA	K	❷	CC/10	E678-12A* ㉝㉞	1250	0.1	1000 ⑬
R580	φ34	400K	420	BA	K	❸	L/10	E678-12A* ㉝㉞	1750	0.1	1250 ⑬
R1705	φ34	401K	375	HBA	K	❹	CC/10	E678-12R* ㉝㉞	1800	0.02	1500 ⑬
R1387	φ34	500K	420	MA	K	❶	CC/10	E678-12A* ㉝㉞	1250	0.2	1000 ⑬
R2066	φ34	501K	600	MA	K	❶	CC/10	E678-12A* ㉝㉞	1500	0.2	1000 ⑬
R1767	φ34	700K	800	Ag-O-Cs	K	❶	CC/10	E678-12A* ㉝㉞	1500	0.01	1250 ⑬

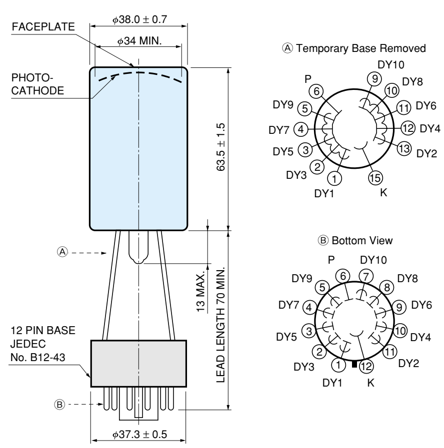
Dimensional Outlines (Unit: mm)

❶ R980, R1387, R2066 etc.



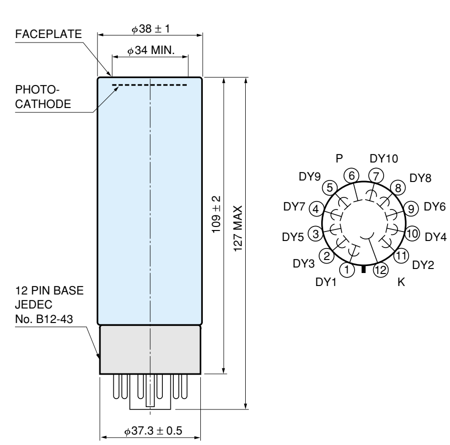
TPMHA0228EA

❷ R3886



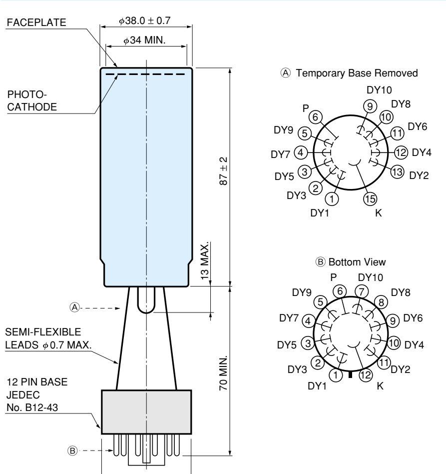
TPMHA0104EA

❸ R580



TPMHA0121EA

❹ R1705



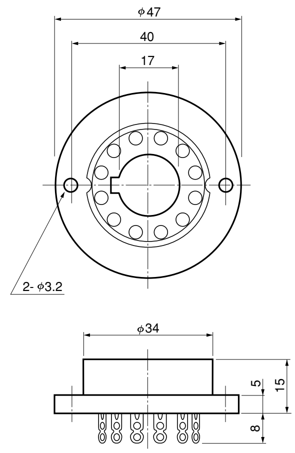
TPMHA0042EB

(at 25 °C)

Cathode Characteristics: Luminous Min. (µA/lm)	Cathode: Luminous Typ. (µA/lm)	Cathode: Blue Sensitivity Index (CS 5-58) Typ.	Cathode: Red/White Ratio (R-68) Typ.	Cathode: Radiant Ⓚ Typ. (mA/W)	Anode Characteristics Ⓜ: Luminous Min. (A/lm)	Anode: Luminous Typ. (A/lm)	Anode: Radiant Typ. (A/W)	Anode: Gain Typ.	Anode: Dark Current (After 30 min.) Typ. (nA)	Anode: Dark Current (After 30 min.) Max. (nA)	Anode: Time Response Rise Time Typ. (ns)	Anode: Time Response Transit Time Typ. (ns)	Notes	Ⓐ Type No.
70	100	11.5	—	90	10	100	9.0×10^4	1.0×10^6	3	5	2.8	40		R980
70	90	10.5	—	85	10	45	4.3×10^4	5.0×10^5	3	5	2.5	32		R3886
70	95	11.0	—	88	10	100	9.7×10^4	1.1×10^6	3	20	2.7	37		R580
20	40	6.0	—	51	5	20	2.5×10^4	5.0×10^5	0.5	10	2.0	35	High temp. operation type: -30 °C to +175 °C	R1705
80	150	—	0.2	64	10	50	2.1×10^4	3.3×10^5	4	25	2.8	40	UV glass window type: R1508 Silica glass window type: R1509	R1387
120	200	—	0.3	40	20	50	1.0×10^4	2.5×10^5	8	30	2.8	40		R2066
10	25	—	0.14ⓓ	2.4	1	5	4.8×10^2	2.0×10^5	7000ⓔ	20000ⓔ	2.2	37		R1767

Dimensional Outline of Socket (Unit: mm)

E678-12A, E678-12R*



* Gold Plating type

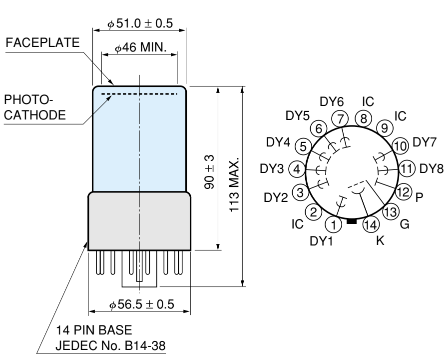
TACCA0009EB

Head-on Type Photomultiplier Tubes

Type No. (A)	Spectral Response: Effective Area (mm) / Wavelength (nm) 100–1000	Spectral Response: Curve Code (B)	Spectral Response: Peak Wavelength (nm)	Remarks: Photocathode Material (C)	Remarks: Window Material (D)	Remarks: Outline No. (E)	Remarks: Dynode Structure / Stages (F)	Remarks: Socket & Socket Assembly (G)	Max. Ratings (H): Anode to Cathode Voltage (V)	Max. Ratings (H): Average Anode Current (mA) (J)	Anode to Cathode Supply Voltage (V) (L)
51 mm (2") Dia. Types with Plastic Base											
R6231	ϕ46	400K	420	BA	K	❶	B+L/8	E678-14V ㉟㊱	1500	0.1	1000 ⑥
R1306	ϕ46	400K	420	BA	K	❷	B/8	E678-14V ㊲㊳	1500	0.1	1000 ②
R2154-02	ϕ46	400K	420	BA	K	❸	L/10	E678-14V ㊴	1750	0.1	1250 ⑬
R1828-01	ϕ46	400K	420	BA	K	❹	L/12	E678-20A* ㊵	3000	0.2	2500 ㉖
R3234-01	ϕ10	400K	420	BA	K	❺	L/12	E678-20A* ㊶	2500	0.1	2000 ㉚
R550	ϕ46	500K	420	MA	K	❻	B/10	E678-14V ㊷㊸㊹㊺	1500	0.3	1000 ⑪

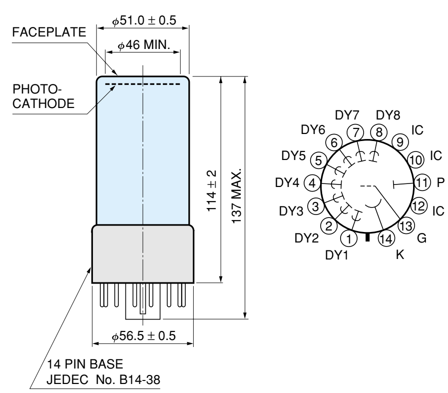
Dimensional Outlines (Unit: mm)

❶ R6231



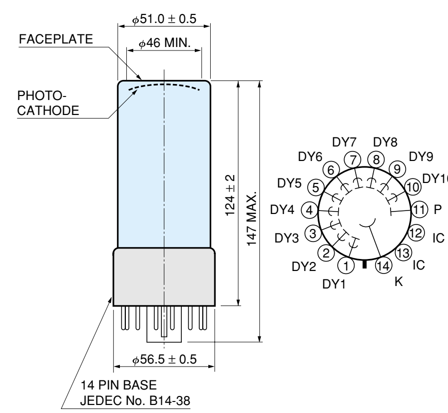
TPMHA0388EB

❷ R1306



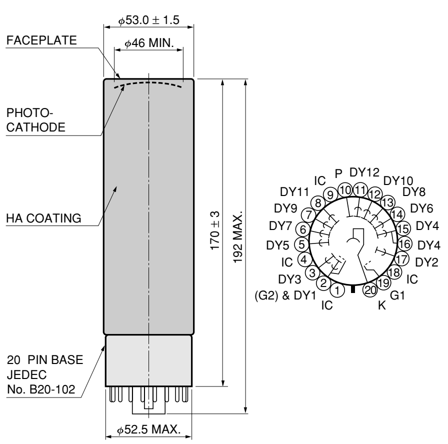
TPMHA0089EC

❸ R2154-02



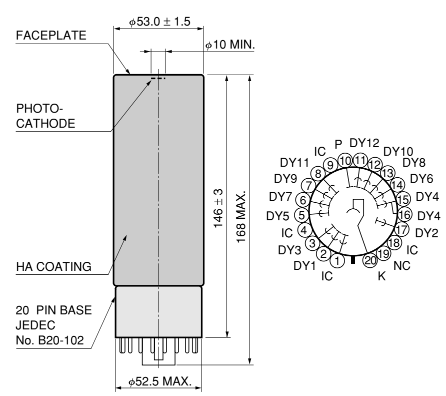
TPMHA0296EA

❹ R1828-01



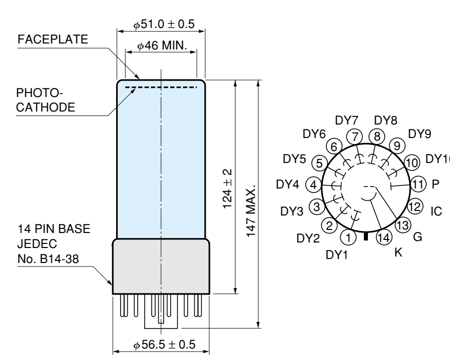
TPMHA0064EC

❺ R3234-01



TPMHA0004EB

❻ R550



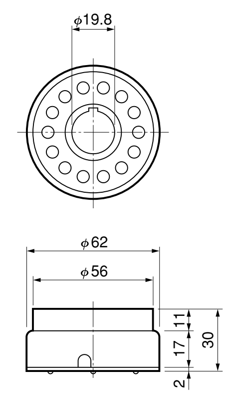
TPMHA0210EB

(at 25 °C)

Cathode Characteristics: Luminous Min. (µA/lm)	Cathode Characteristics: Luminous Typ. (µA/lm)	Blue Sensitivity Index (CS 5-58) Typ.	Red/White Ratio (R-68) Typ.	Ⓚ Radiant Typ. (mA/W)	Anode Characteristics Ⓜ: Luminous Min. (A/lm)	Anode Characteristics Ⓜ: Luminous Typ. (A/lm)	Radiant Typ. (A/W)	Gain Typ.	Dark Current (After 30 min.) Typ. (nA)	Dark Current (After 30 min.) Max. (nA)	Time Response: Rise Time Typ. (ns)	Time Response: Transit Time Typ. (ns)	Notes	Ⓐ Type No.
80	110	12.0	—	95	3	30	2.6×10^4	2.7×10^5	2	20	5.0	48		R6231
80	110	12.0	—	95	3	30	2.6×10^4	2.7×10^5	2	20	7.0	60		R1306
60	90	10.5	—	85	20	90	8.5×10^4	1.0×10^6	5	20	3.4	31	Multialkali photocathode type: R3256	R2154-02
60	90	10.5	—	85	200	1800	1.7×10^6	2.0×10^7	50	400	1.3	28	Silica glass window type: R2059	R1828-01
60	80	9.0	—	72	500	2000	2.0×10^6	2.5×10^7	1	10	1.3	28	Silica glass window type: R3235-01	R3234-01
100	150	—	0.2	64	20	100	4.3×10^4	6.7×10^5	10	30	9.0	70		R550

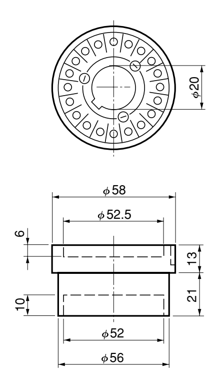
Dimensional Outline of Socket (Unit: mm)

E678-14V



TACCA0200EA

E678-20A



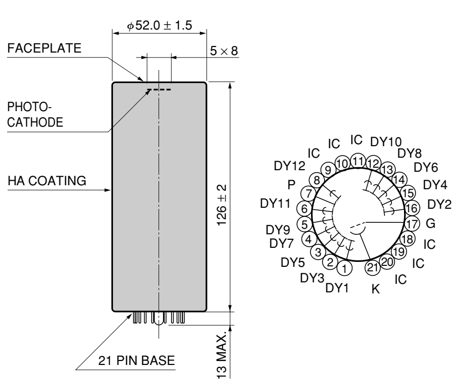
TACCA0003EA

Head-on Type Photomultiplier Tubes

Type No. Ⓐ	Spectral Response: Effective Area (mm) / Wavelength (nm) (100–1000)	Spectral Response: Curve Code Ⓑ	Spectral Response: Peak Wavelength (nm)	Remarks: Photocathode Material Ⓒ	Remarks: Window Material Ⓓ	Remarks: Outline No. Ⓔ	Remarks: Dynode Structure / Stages Ⓕ	Remarks: Socket & Socket Assembly Ⓖ	Max. Ratings Ⓗ: Anode to Cathode Voltage (V)	Max. Ratings Ⓗ: Average Anode Current Ⓙ (mA)	Anode to Cathode Supply Voltage Ⓛ (V)
51 mm (2") Dia. Types with Glass Base											
R464	5 × 8	400K	420	BA	K	❶	B/12	E678-21C* ㊻	1500	0.01	1000 ㉘
R329-02	ϕ46	400K	420	BA	K	❷	L/12	E678-21C* ㊼㊽㊾	2700	0.2	1500 ㉗
R331-05	ϕ46	400K	420	BA	K	❸	L/12	E678-21C* ㊼㊽㊾	2500	0.2	1500 ㉗
R2083	ϕ46	400K	420	BA	K	❹	L/8	E678-19F*	3500	0.2	3000 ③
R4607-01	ϕ46	401K	375	HBA	K	❺	CC/10	E678-15B*	1800	0.02	1500 ⑬
R649	5 × 8	500K	420	MA	K	❶	B/12	E678-21C* ㊻	1500	0.01	1000 ㉘

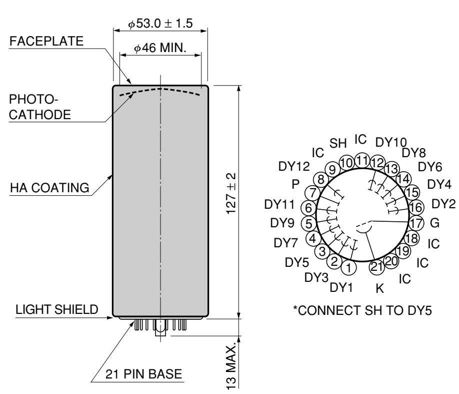
Dimensional Outlines (Unit: mm)

❶ R464, R649



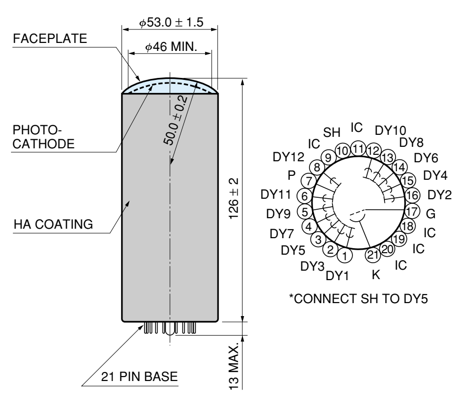
TPMHA0216EB

❷ R329-02



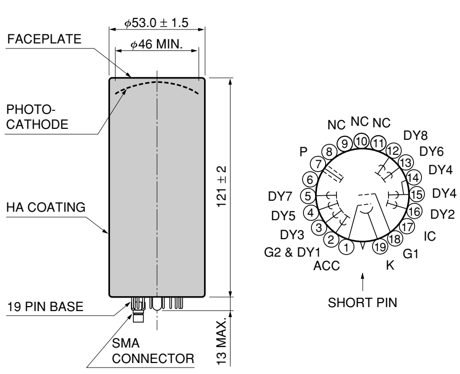
TPMHA0123EE

❸ R331-05



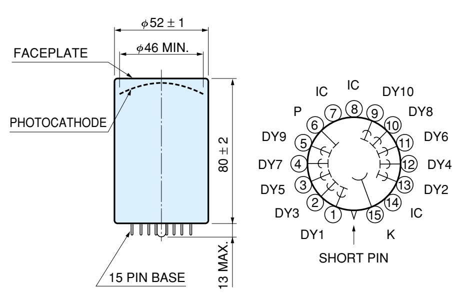
TPMHA0072EC

❹ R2083



TPMHA0185EC

❺ R4607-01



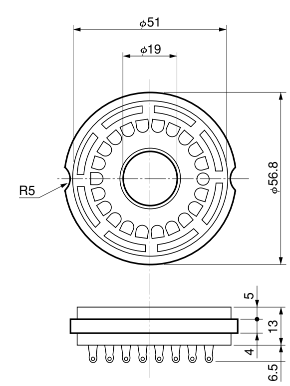
TPMHA0003EC

(at 25 °C)

Cathode Characteristics: Luminous Min. (µA/lm)	Cathode Characteristics: Luminous Typ. (µA/lm)	Blue Sensitivity Index (CS 5-58) Typ.	Red/White Ratio (R-68) Typ.	K Radiant Typ. (mA/W)	Anode Characteristics M: Luminous Min. (A/lm)	Anode Characteristics M: Luminous Typ. (A/lm)	Radiant Typ. (A/W)	Gain Typ.	Dark Current (After 30 min.) Typ. (nA)	Dark Current (After 30 min.) Max. (nA)	Time Response: Rise Time Typ. (ns)	Time Response: Transit Time Typ. (ns)	Notes	A Type No.
30	50	—	—	50	100	300	3.0×10^5	6.0×10^6	5 h	15 h	13	70	Silica glass window type: R585	R464
60	90	10.5	—	85	30	100	9.4×10^4	1.1×10^6	6	40	2.6	48	UV glass window type: R5113-02 Silica glass window type: R2256-02	R329-02
60	90	10.5	—	85	30	120	1.1×10^5	1.3×10^6	200 h	600 h	2.6	48	Silica glass window type: R331	R331-05
60	80	10.0	—	80	50	200	2.0×10^5	2.5×10^6	100	800	0.7	16	Assembly type: H2431-50 (Recommended) Silica glass window type: H3378-50	R2083
20	40	6.0	—	51	5	20	2.5×10^4	5.0×10^5	3	50	2.5	29	High temp. operation type: -30 °C to +175 °C	R4607-01
80	120	—	0.2	51	100	800	3.4×10^5	6.7×10^6	200 h	350 h	13	70		R649

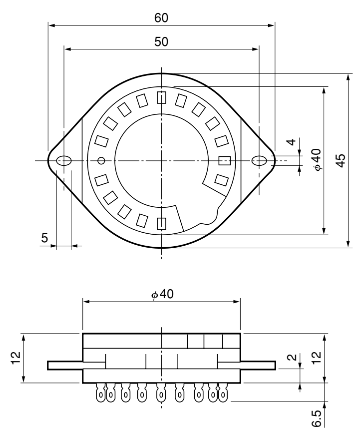
Dimensional Outline of Socket (Unit: mm)

E678-21C



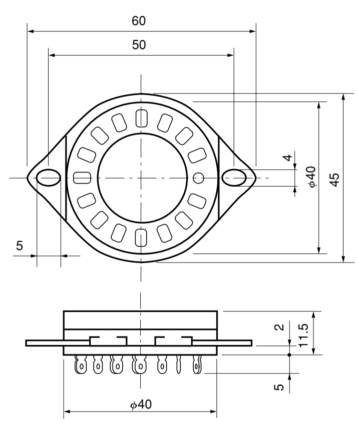
TACCA0066EC

E678-19F



TACCA0203EA

E678-15B



TACCA0201EA

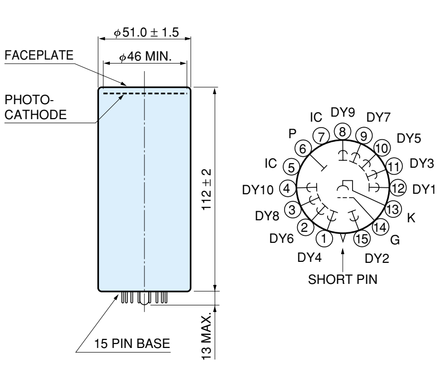
Head-on Type Photomultiplier Tubes

Type No. (A)	Spectral Response: Effective Area (mm) / Wavelength (nm) 100–1100	Curve Code (B)	Peak Wavelength (nm)	Photocathode Material (C)	Window Material (D)	Outline No. (E)	Dynode Structure / Stages (F)	Socket & Socket Assembly (G)	Max. Ratings (H): Anode to Cathode Voltage (V)	Average Anode Current (mA) (J)	Anode to Cathode Supply Voltage (V) (L)
51 mm (2") Dia. Types with Glass Base											
R375	φ46	500S	420	MA	Q	1	B/10	E678-15B* (50)	1500	0.1	1000 (11)
R669	φ46	501K	600	EMA	K	1	B/10	E678-15B* (50)	1500	0.1	1000 (11)
R943-02	□10	650S	300-800	GaAs	Q	2	L/10	(NOTE) E678-21C*	2200	0.001	1500 (17)
R3310-02	□10	851K	400	InGaAs	K	2	L/10	(NOTE) E678-21C*	2200	0.001	1500 (17)
R2257	φ46	501K	600	EMA	K	3	L/12	E678-21C* (47)(48)(49)	2700	0.2	1500 (27)

(NOTE) For cooling operation, another ceramic socket, type number E678-21D (sold separately) is recommended.

Dimensional Outlines (Unit: mm)

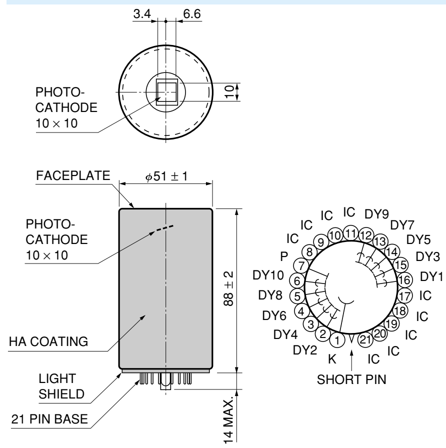
1 R375, R669



R669 has a plano-concave faceplate.

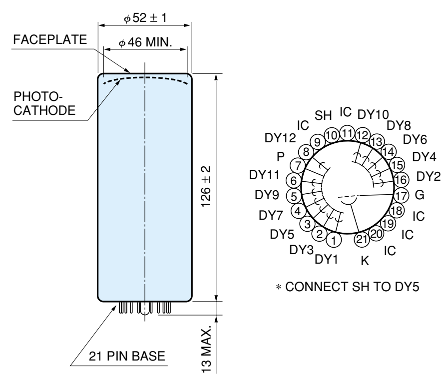
TPMHA0211EA

2 R943-02, R3310-02



TPMHA0021EE

3 R2257



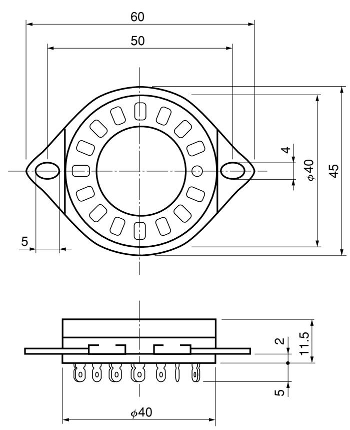
TPMHA0359EA

(at 25 °C)

Cathode Characteristics: Luminous Min. (µA/lm)	Cathode Characteristics: Luminous Typ. (µA/lm)	Blue Sensitivity Index (CS 5-58) Typ.	Red/White Ratio (R-68) Typ.	Ⓚ Radiant Typ. (mA/W)	Anode Characteristics Ⓜ: Luminous Min. (A/lm)	Anode Characteristics Ⓜ: Luminous Typ. (A/lm)	Radiant Typ. (A/W)	Gain Typ.	Dark Current (After 30 min.) Typ. (nA)	Dark Current (After 30 min.) Max. (nA)	Time Response: Rise Time Typ. (ns)	Time Response: Transit Time Typ. (ns)	Notes	Ⓐ Type No.
80	150	—	0.2	64	20	80	3.4×10^4	5.3×10^5	5	20	9.0	70		R375
140	230	—	0.35	50	20	75	1.7×10^4	3.3×10^5	7	15	9.0	70		R669
300	600	—	0.58	71	150	300	3.6×10^4	5.0×10^5	20ⓙ	50ⓙ	3.0	23		R943-02
80	150	—	0.4	9.4ⓒ	15	50	3.1×10^3	3.3×10^5	30ⓙ	150ⓙ	3.0	23		R3310-02
140	230	—	0.35	50	15	100	2.2×10^4	4.3×10^5	30	100	2.6	48		R2257

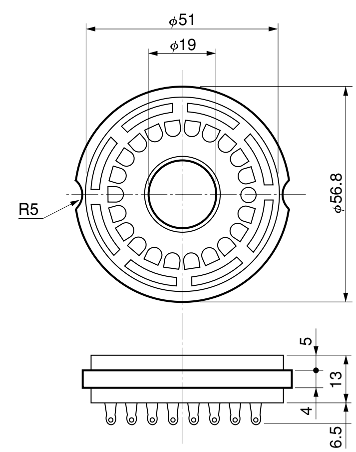
Dimensional Outline of Socket (Unit: mm)

E678-15B



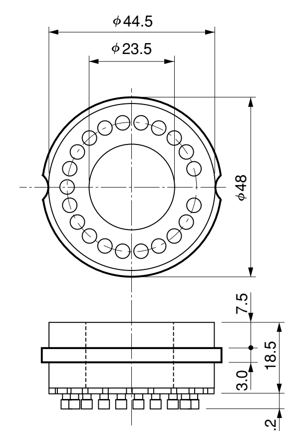
TACCA0201EA

E678-21C



TACCA0066EA

E678-21D



TACCA0054EB

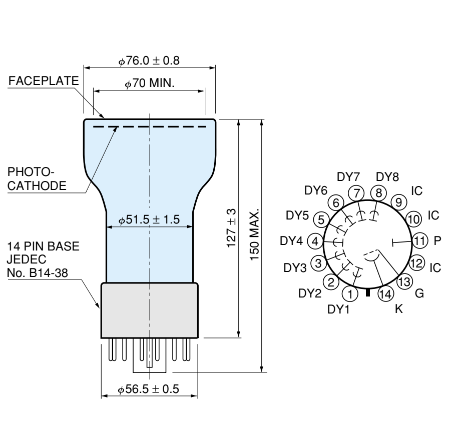
Head-on Type Photomultiplier Tubes

Type No. (A)	Spectral Response: Effective Area (mm)	Curve Code (B)	Peak Wave-length (nm)	Photo-cathode Material (C)	Win-dow Mate-rial (D)	Out-line No. (E)	Dynode Structure / Stages (F)	Socket & Socket Assembly (G)	Max. Ratings (H): Anode to Cathode Voltage (V)	Max. Ratings: Average Anode Current (J) (mA)	Anode to Cathode Supply Voltage (L) (V)
76 mm (3") Dia. Types											
R1307	φ70	400K	420	BA	K	1	B/8	E678-14V 37 38	1500	0.1	1000 2
R6233	φ70	400K	420	BA	K	2	B+L/8	E678-14V 35 36	1500	0.1	1000 6
R4143	φ65	400K	420	BA	K	3	L/12	E678-20A*	3000	0.2	2500 29
R6091	φ65	400K	420	BA	K	4	L/12	E678-21C* 47 48 49	2500	0.2	1500 27
127 mm (5") Dia. Types											
R877	φ111	400K	420	BA	K	5	B/10	E678-14V 42 43 44 45	1500	0.1	1250 11
R1250	φ120	400K	420	BA	K	6	L/14	E678-20A* 51	3000	0.2	2000 32
R1513	φ111	500K	420	MA	K	5	VB/10	E678-14V 42 43 44 45	2000	0.1	1500 11
R1584	φ120	400U	420	BA	U	7	L/14	E678-20A* 51	3000	0.2	2000 32

Wavelength (nm): 100 200 300 400 500 600 700 800 900 1000

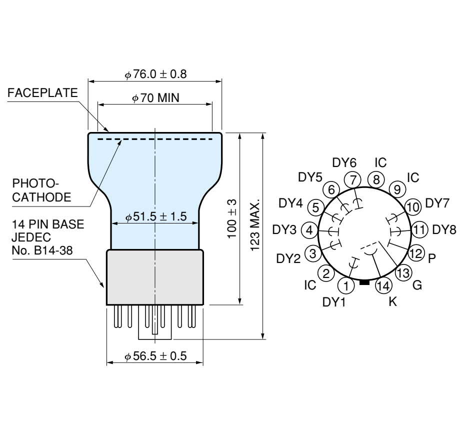
Dimensional Outlines (Unit: mm)

1 R1307



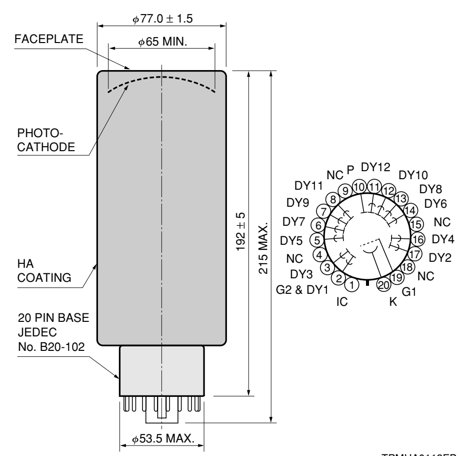
TPMHA0078EA

2 R6233



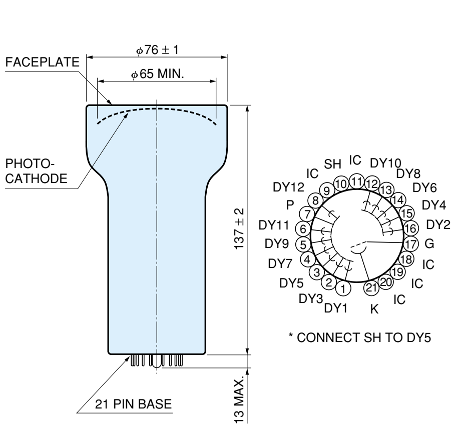
TPMHA0389EB

3 R4143



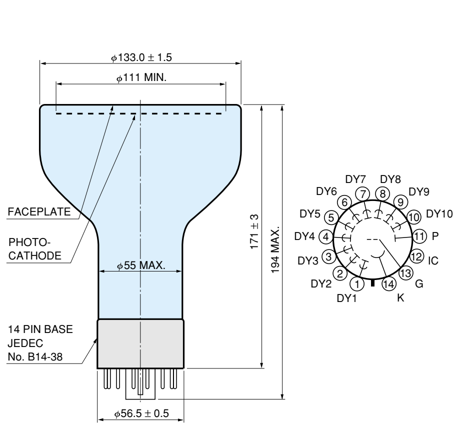
TPMHA0112EB

4 R6091



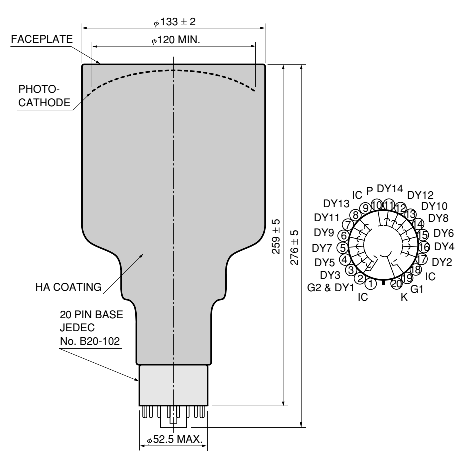
TPMHA0285EB

5 R877, R1513



TPMHA0074EC

6 R1250

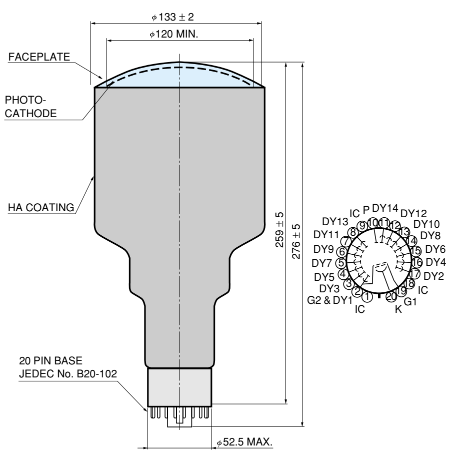


TPMHA0018EB

Cathode Characteristics					Anode Characteristics									(at 25 °C)
Luminous		Blue Sensitivity Index (CS 5-58)	Red/White Ratio (R-68)	Radiant	Luminous		Radiant	Gain	Dark Current (After 30 min.)		Time Response		Notes	Type No.
Min. (µA/lm)	Typ. (µA/lm)	Typ.	Typ.	Typ. (mA/W)	Min. (A/lm)	Typ. (A/lm)	Typ. (A/W)	Typ.	Typ. (nA)	Max. (nA)	Rise Time Typ. (ns)	Transit Time Typ. (ns)		
80	110	12.0	—	95	3	30	2.6×10^4	2.7×10^5	2	20	8.0	64		R1307
80	110	12.0	—	95	3	30	2.6×10^4	2.7×10^5	2	20	6.0	52		R6233
60	80	9.5	—	76	100	400	3.8×10^5	5.0×10^6	50	500	1.8	32		R4143
60	90	10.5	—	85	50	450	4.3×10^5	5.0×10^6	10	60	2.6	48		R6091
60	95	11.0	—	88	20	40	3.7×10^4	4.2×10^5	10	50	10	90	K-free borosilicate glass type: R877-01	R877
55	70	9.0	—	72	300	1000	1.0×10^6	1.4×10^7	50	300	2.5	54		R1250
100	150	—	0.2	64	10	50	2.1×10^4	3.3×10^5	30	150	7.0	82		R1513
55	70	9.0	—	72	300	1000	1.0×10^6	1.4×10^7	50	300	2.5	54		R1584

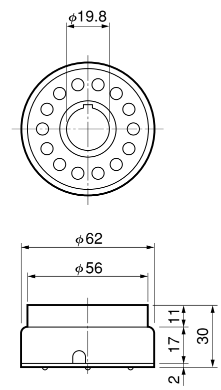
Dimensional Outline of Socket (Unit: mm)

7 R1584



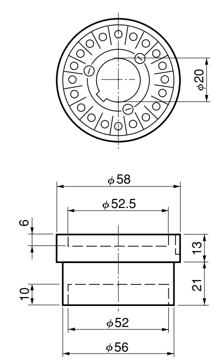
TPMHA0187EC

E678-14V



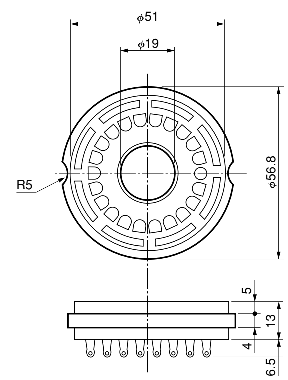
TACCA0200EA

E678-20A



TACCA0003EA

E678-21C



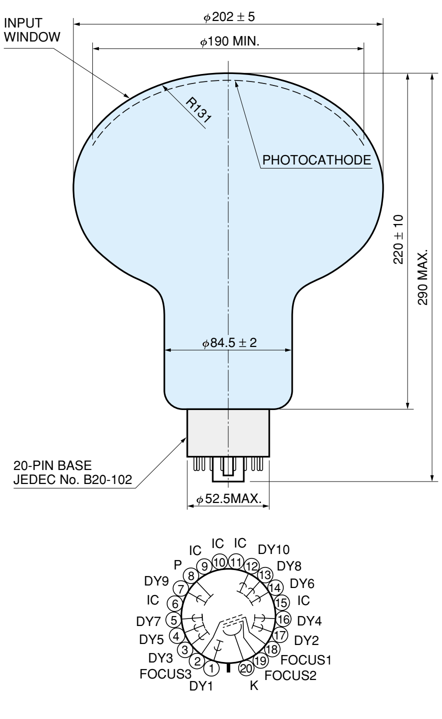
TACCA0066EC

Hemispherical Envelope Type, Special Envelope Type Photomultiplier Tubes

(A) Type No.	Spectral Response: Effective Area (mm) / Wavelength (nm) 100–1000	(B) Curve Code	Peak Wave-length (nm)	Remarks: (C) Photo-cathode Material	(D) Win-dow Mate-rial	(E) Out-line No.	(F) Dynode Structure / Stages	(G) Socket & Socket Assembly	Max. Ratings (H): Anode to Cathode Voltage (V)	(J) Average Anode Current (mA)	(L) Anode to Cathode Supply Voltage (V)
Hemispherical Envelope Types											
R5912	φ190	400K	420	BA	K	❶	B+L/10	E678-20A* (52)(53)	1800	0.1	1500 (22)
Special Envelope Types											
R6234	55 (6)	400K	420	BA	K	❷	B+L/8	E678-14V (35)(36)	1500	0.1	1000 (6)
R6236	□54	400K	420	BA	K	❸	B+L/8	E678-14V (35)(36)	1500	0.1	1000 (6)
R6235	70 (6)	400K	420	BA	K	❹	B+L/8	E678-14V (35)(36)	1500	0.1	1000 (6)
R6237	□70	400K	420	BA	K	❺	B+L/8	E678-14V (35)(36)	1500	0.1	1000 (6)
R2248	□8	400K	420	BA	K	❻	L/8	E678-11N* (6)	1500	0.03	1250 (1)
*R1548-07	8 × 18 × (2)	400K	420	BA	K	❼	L/10	E678-17A*	1750	0.1	1250 (18)

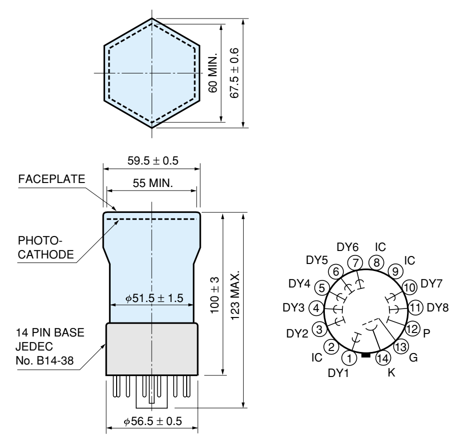
Dimensional Outlines (Unit: mm)

❶ R5912



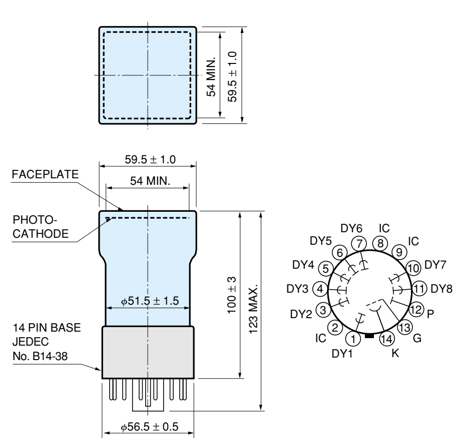
TPMHA0261EC

❷ R6234



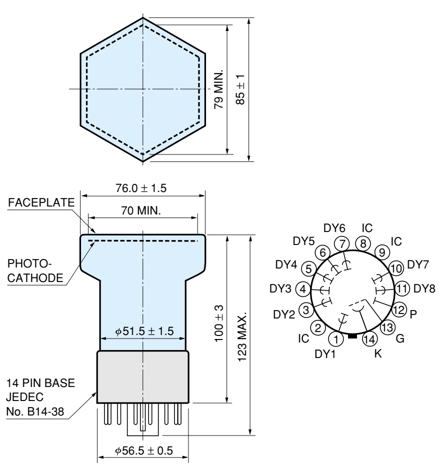
TPMHA0390EB

❸ R6236



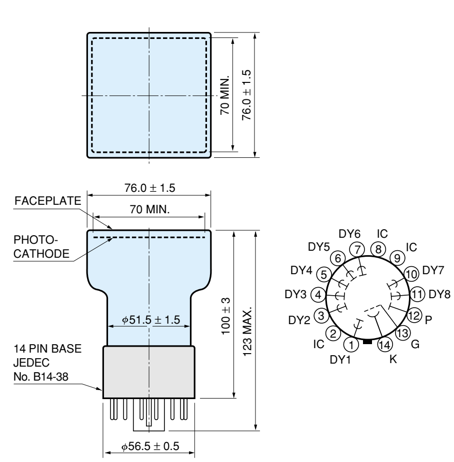
TPMHA0392EB

❹ R6235



TPMHA0391EB

❺ R6237



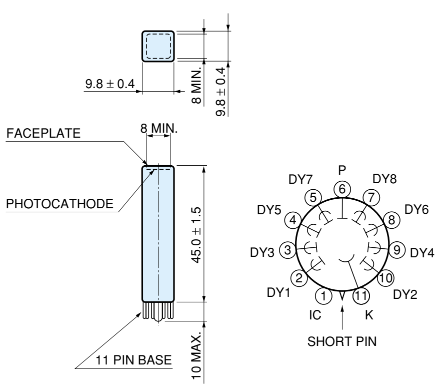
TPMHA0393EB

(at 25 °C)

Cathode Characteristics: Luminous Min. (µA/lm)	Cathode: Luminous Typ. (µA/lm)	Cathode: Blue Sensitivity Index (CS 5-58) Typ.	Cathode: Red/White Ratio (R-68) Typ.	Cathode: Radiant Ⓚ Typ. (mA/W)	Anode Characteristics Ⓜ: Luminous Min. (A/lm)	Anode: Luminous Typ. (A/lm)	Anode: Radiant Typ. (A/W)	Anode: Gain Typ.	Anode: Dark Current (After 30 min.) Typ. (nA)	Anode: Dark Current (After 30 min.) Max. (nA)	Anode: Time Response Rise Time Typ. (ns)	Anode: Time Response Transit Time Typ. (ns)	Notes	Type No. Ⓐ
—	70	9.0	—	72	—	700	7.2×10^5	1.0×10^7	50	700	3.8	55		R5912
80	110	12.0	—	95	3	30	2.6×10^4	2.7×10^5	2	20	6.0	52		R6234
80	110	12.0	—	95	3	30	2.6×10^4	2.7×10^5	2	20	6.0	52		R6236
80	110	12.0	—	95	3	30	2.6×10^4	2.7×10^5	2	20	6.0	52		R6235
80	110	12.0	—	95	3	30	2.6×10^4	2.7×10^5	2	20	6.0	52		R6237
60	95	9.5	—	76	30	100	8.0×10^4	1.1×10^6	1	50	0.9	9		R2248
60	80	9.5	—	76	50	200	1.9×10^5	2.5×10^6	20	250	1.8	20		R1548-07*

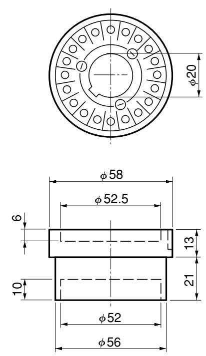
Dimensional Outline of Socket (Unit: mm)

❻ R2248



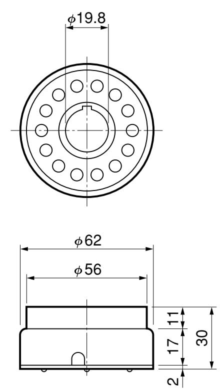
TPMHA0098EB

E678-20A



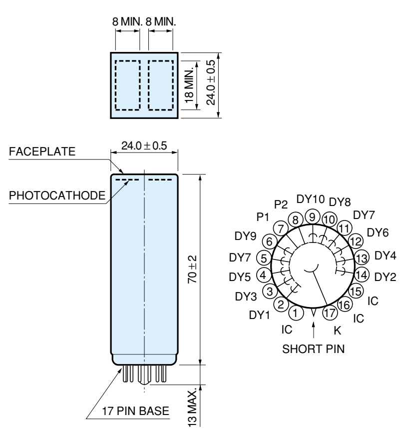
TACCA0003EA

E678-14V



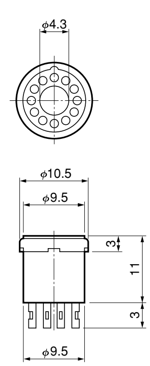
TACCA0200EA

❼ R1548-07



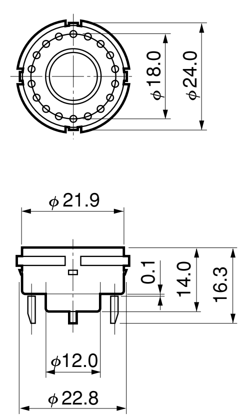
TPMHA0223EA

E678-11N



TACCA0043EA

E678-17A



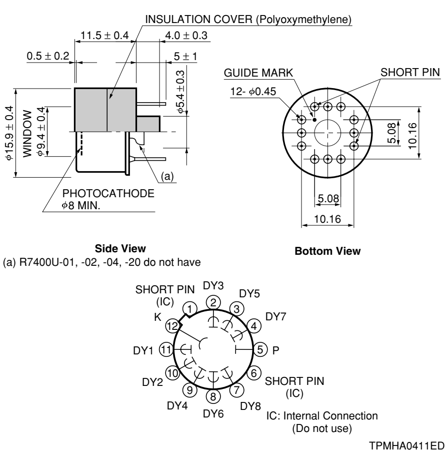
TACCA0046EB

Metal Package Photomultiplier Tubes

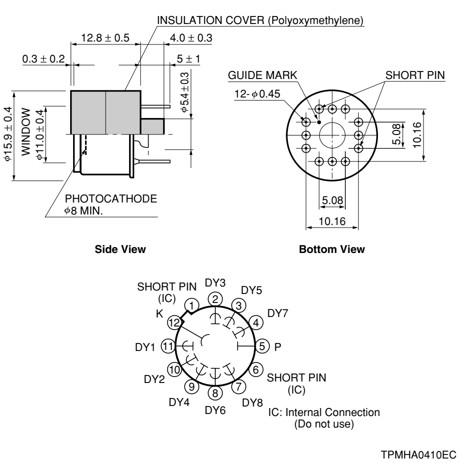
Type No. (A)	Spectral Response: Effective Area (mm) / Wavelength (nm) 100–1000	Peak Wave-length (nm)	Photo-cathode Material (C)	Win-dow Mate-rial (D)	Out-line No. (E)	Dynode Structure / Stages (F)	Socket & Socket Assembly (G)	Max. Ratings (H): Anode to Cathode Voltage (V)	Max. Ratings (H): Average Anode Current (mA) (J)	Anode to Cathode Supply Voltage (V) (L)
R7400U	φ8	420	BA	K	1	MC/8	E678-12M (54)	1000	0.1	800 (7)
R7400U-01	φ8	400	MA	K	1	MC/8	E678-12M (54)	1000	0.1	800 (7)
R7400U-02	φ8	500	MA	K	1	MC/8	E678-12M (54)	1000	0.1	800 (7)
R7400U-03	φ8	420	BA	U	1	MC/8	E678-12M (54)	1000	0.1	800 (7)
R7400U-04	φ8	400	MA	U	1	MC/8	E678-12M (54)	1000	0.1	800 (7)
R7400U-06	φ8	420	BA	Q	2	MC/8	E678-12M (54)	1000	0.1	800 (7)
*R7400U-09	φ8	240	Cs-Te	Q	2	MC/8	E678-12M (54)	1000	0.01	800 (7)
*R7400U-20	φ8	630	MA	K	1	MC/8	E678-12M (54)	1000	0.1	800 (7)
R7401	φ8	420	BA	K	3	MC/8	E678-12M (54)	1000	0.1	800 (7)
R7402	φ8	400	MA	K	3	MC/8	E678-12M (54)	1000	0.1	800 (7)

Dimensional Outlines (Unit: mm)

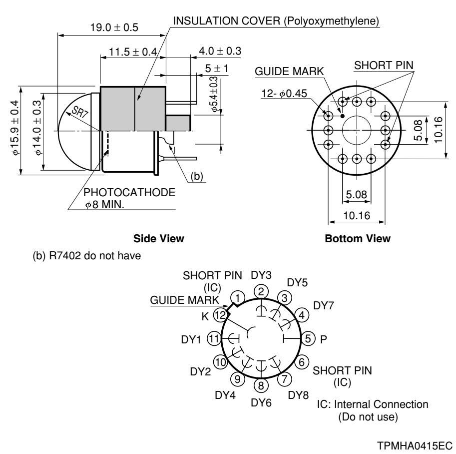
1 R7400U, -01, -02, -03, -04, -20



2 R7400U-06, -09



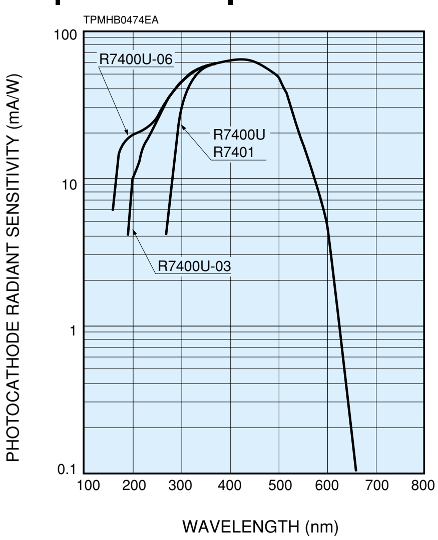
3 R7401, R7402

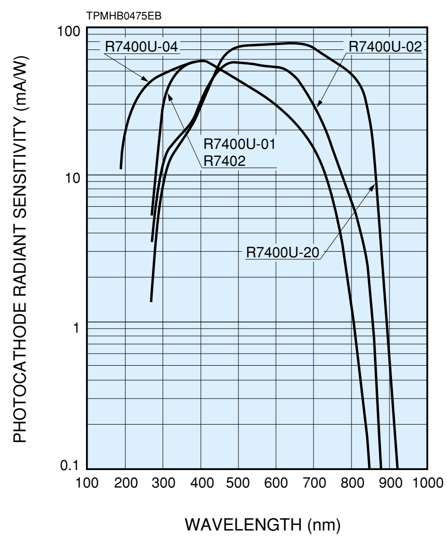


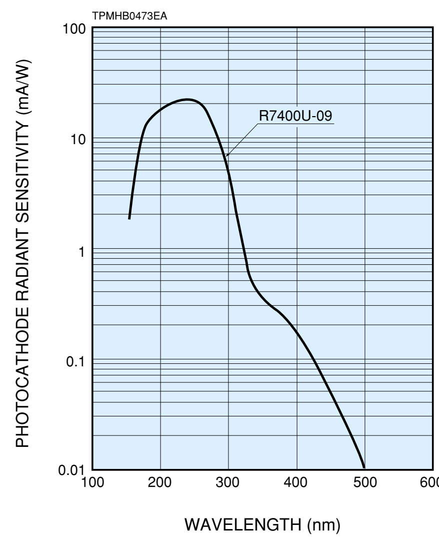
(at 25 °C)

Cathode Characteristics					Anode Characteristics Ⓜ									
Luminous		Blue Sensitivity Index (CS 5-58)	Red/White Ratio (R-68)	Ⓚ Radiant	Luminous		Radiant	Gain	Dark Current (After 30 min.)		Time Response		Notes	Ⓐ Type No.
Min. (µA/lm)	Typ. (µA/lm)	Typ.	Typ.	Typ. (mA/W)	Min. (A/lm)	Typ. (A/lm)	Typ. (A/W)	Typ.	Typ. (nA)	Max. (nA)	Rise Time Typ. (ns)	Transit Time Typ. (ns)		
40	70	8.0	—	62	10	50	4.3×10^4	7.0×10^5	0.2	2	0.78	5.4	Photon counting type: R7400P	R7400U
80	150	—	0.2	60	15	75	3.0×10^4	5.0×10^5	0.4	4	0.78	5.4		R7400U-01
200	250	—	0.25	58	25	125	2.9×10^4	5.0×10^5	2.0	20	0.78	5.4	with condenser lens: R7402-02	R7400U-02
40	70	8.0	—	62	10	50	4.3×10^4	7.0×10^5	0.2	2	0.78	5.4		R7400U-03
80	150	—	0.2	60	15	75	3.0×10^4	5.0×10^5	0.4	4	0.78	5.4		R7400U-04
40	70	8.0	—	62	10	50	4.3×10^4	7.0×10^5	0.2	2	0.78	5.4		R7400U-06
—	—	—	—	22ⓑ	—	—	1100ⓑ	5.0×10^4	0.025	0.5	0.78	5.4		R7400U-09*
350	500	—	0.45	78	35	250	3.9×10^4	5.0×10^5	2.0	20	0.78	5.4	with condenser lens: R7402-20	R7400U-20*
40	70	8.0	—	62	10	50	4.3×10^4	7.0×10^5	0.2	2	0.78	5.4		R7401
80	150	—	0.2	60	15	75	3.0×10^4	5.0×10^5	0.4	4	0.78	5.4		R7402

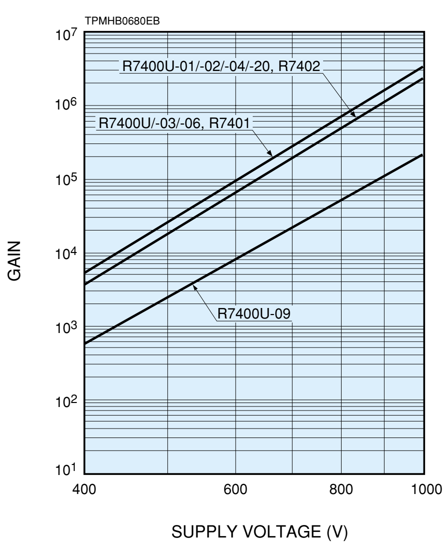
■Spectral Response





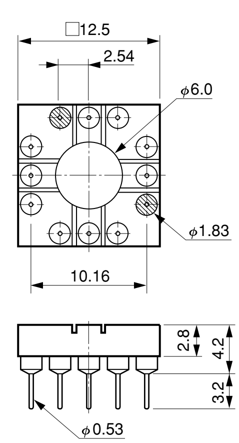


■Gain



Dimensional Outline of Socket (Unit: mm)

E678-12M



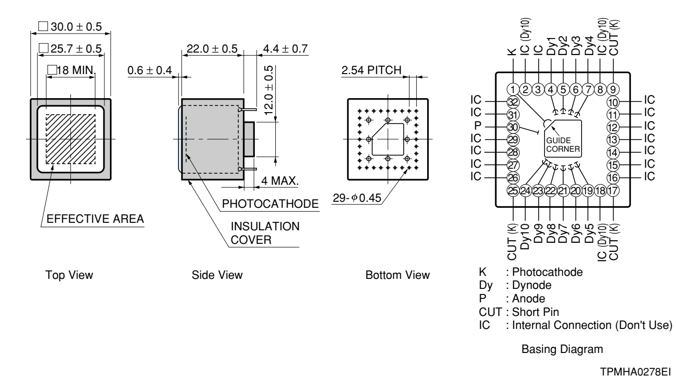
Metal Package Photomultiplier Tubes

Type No. (A)	Spectral Response: Effective Area (mm) / Wavelength (nm) 100–1000	Peak Wave-length (nm)	Remarks: Photo-cathode Material (C)	Win-dow Mate-rial (D)	Out-line No. (E)	Dynode Structure / Stages (F)	Socket & Socket Assembly (G)	Max. Ratings (H): Anode to Cathode Voltage (V)	Average Anode Current (mA) (J)	Anode to Cathode Supply Voltage (V) (L)
*R7600U	18 × 18	420	BA	K	1	MC/10	E678-32B (55)	900	0.1	800 (21)
*R7600U-00-M4	8.9 × 8.9 × (4)	420	BA	K	2	MC/10	E678-32B (56)	900	0.1	800 (21)
R5900U-00-L16	0.8 × 16 × (16)	420	BA	K	3	MC/10	E678-32B (57)	900	0.1	800 (10)
*R5900U-01	18 × 18	400	MA	K	1	MC/10	E678-32B (55)	900	0.1	800 (21)
*R5900U-01-M4	8.9 × 8.9 × (4)	400	MA	K	2	MC/10	E678-32B (56)	900	0.1	800 (21)
R5900U-01-L16	0.8 × 16 × (16)	420	MA	K	3	MC/10	E678-32B (57)	900	0.1	800 (10)
*R5900U-20-L16	0.8 × 16 × (16)	630	MA	K	3	MC/10	E678-32B (57)	900	0.1	800 (10)
R8520U-00-C12	22 × 22	420	BA	K	4	MC/11	E678-32B (58)	1000	0.1	800 (24)

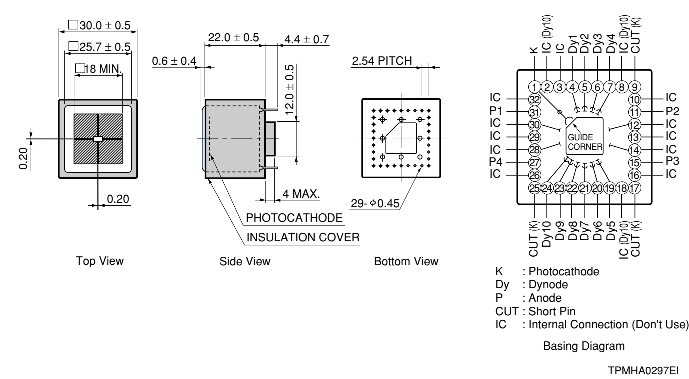
Multianode photomultiplier tubes R7600-00-M16 and R7600-00-M64 are listed in the group of photomultiplier tube assemblies on page 64.

Dimensional Outlines (Unit: mm)

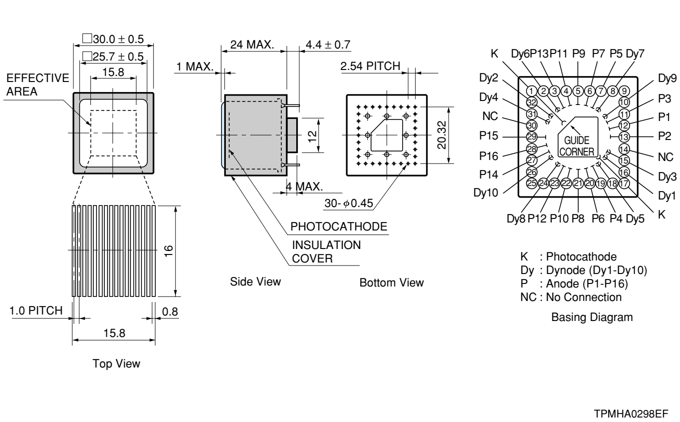
1 R7600U, R5900U-01



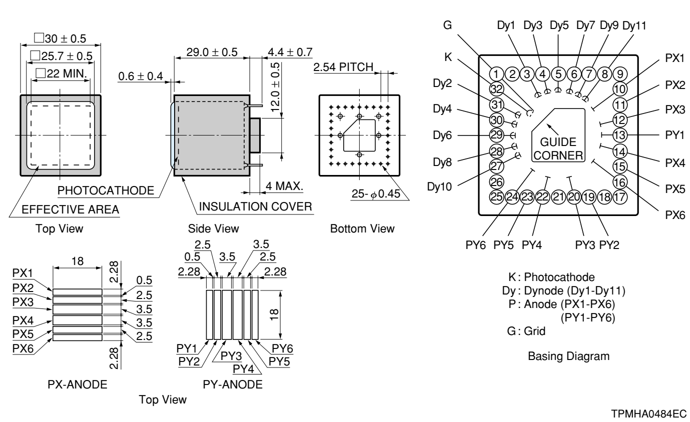
2 R7600U-00-M4, R5900U-01-M4



3 R5900U-00-L16, R5900U-01-L16, R5900U-20-L16



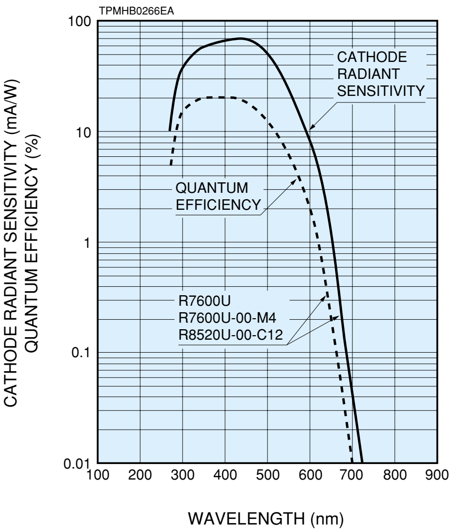
4 R8520U-00-C12

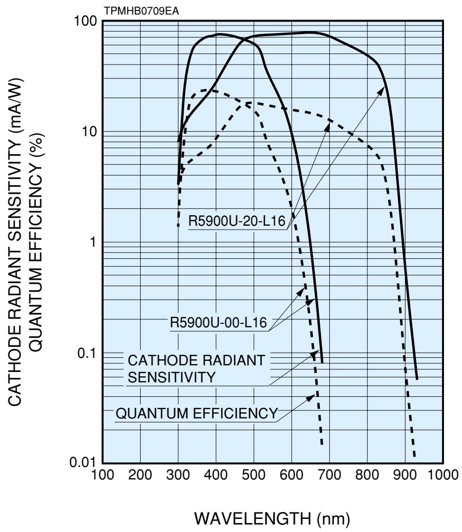


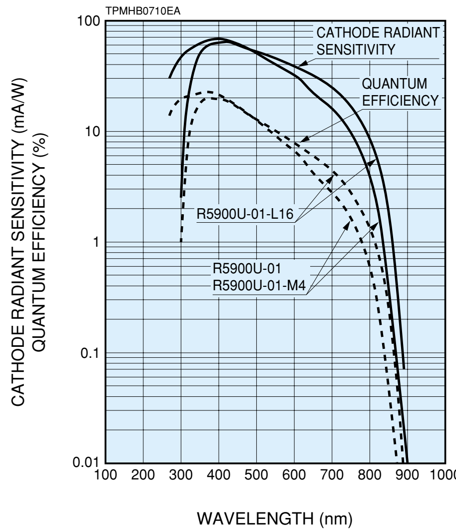
(at 25 °C)

Cathode Characteristics: Luminous Min. (μA/lm)	Cathode: Luminous Typ. (μA/lm)	Cathode: Blue Sensitivity Index (CS 5-58) Typ.	Cathode: Red/White Ratio (R-68) Typ.	Cathode: Ⓚ Radiant Typ. (mA/W)	Anode Characteristics Ⓜ: Luminous Min. (A/lm)	Anode: Luminous Typ. (A/lm)	Anode: Radiant Typ. (A/W)	Gain Typ.	Dark Current (After 30 min.) Typ. (nA)	Dark Current (After 30 min.) Max. (nA)	Time Response: Rise Time Typ. (ns)	Time Response: Transit Time Typ. (ns)	Notes	Ⓐ Type No.
60	70	8.0	—	72	40	140	1.4 × 10⁵	2.0 × 10⁶	2	20	1.4	8.8	UV glass window type: R7600U-03	R7600U*
60	70	8.0	—	72	25	140	1.4 × 10⁵	2.0 × 10⁶	0.5/ch	5/ch	1.2	8.8	UV glass window type: R7600U-03-M4	R7600U-00-M4*
50	70	8.5	—	72	50	280	2.9 × 10⁵	4.0 × 10⁶	0.2/ch	2/ch	0.6	8.8	UV glass window type: R5900U-03-L16 Silica glass window type: R5900U-06-L16	R5900U-00-L16
150	200	—	0.2	70	50	200	7.0 × 10⁴	1.0 × 10⁶	10	50	1.4	8.8	UV glass window type: R5900U-04	R5900U-01*
150	200	—	0.2	70	50	160	5.6 × 10⁴	0.8 × 10⁶	2.5/ch	25/ch	1.2	8.8	UV glass window type: R5900U-04-M4	R5900U-01-M4*
150	250	—	0.3	65	75	250	6.5 × 10⁴	1.0 × 10⁶	0.5/ch	5/ch	0.6	8.8	UV glass window type: R5900U-04-L16 Silica glass window type: R5900U-07-L16	R5900U-01-L16
350	500	—	0.45	78	175	500	7.8 × 10⁴	1.0 × 10⁶	1/ch	10/ch	0.6	8.8		R5900U-20-L16*
50	70	8.5	—	72	15	70	7.2 × 10⁴	1.0 × 10⁶	2	10	1.4	11.5		R8520U-00-C12

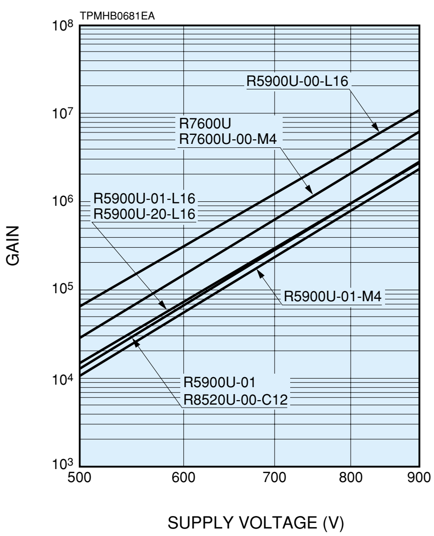
■Spectral Response





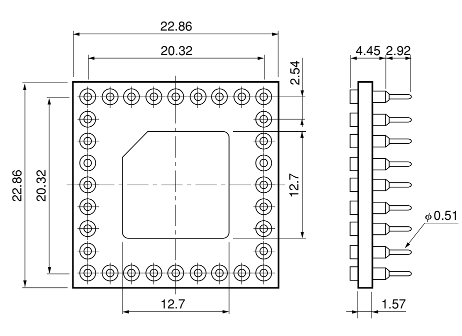


■Gain



Dimensional Outline of Socket (Unit: mm)

E678-32B



MATERIAL: Glass Epoxy

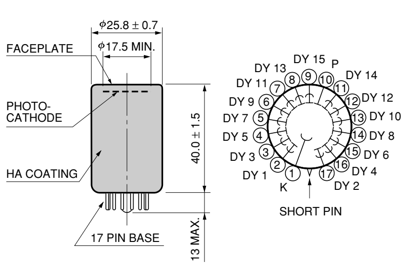
TACCA0094ED

Photomultiplier Tubes for High Magnetic Environments

Type No. (A)	Tube Diameter mm (inch)	Spectral Response: Effective Area (mm) / Wavelength (nm) 100–1000	Peak Wave-length (nm)	(C) Photo-cathode Material	(D) Win-dow Mate-rial	(E) Out-line No.	(F) Dynode Structure / Stages	(G) Socket & Socket Assembly	Max. Ratings (H): Anode to Cathode Voltage (V)	(J) Average Anode Current (mA)	(L) Anode to Cathode Supply Voltage (V)
*R5505-70	25 (1)	φ17.5	420	BA	K	❶	FM/15	E678-17A* 59	2300	0.01	2000 33
*R7761-70	38 (1-1/2)	φ27	420	BA	K	❷	FM/19	—	2300	0.01	2000 34
*R5924-70	51 (2)	φ39	420	BA	K	❸	FM/19	—	2300	0.1	2000 34
*R6504-70	64 (2-1/2)	φ51	420	BA	K	❹	FM/19	—	2300	0.1	2000 34

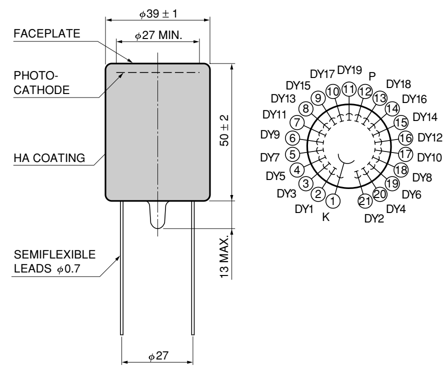
Dimensional Outlines (Unit: mm)

❶ R5505-70



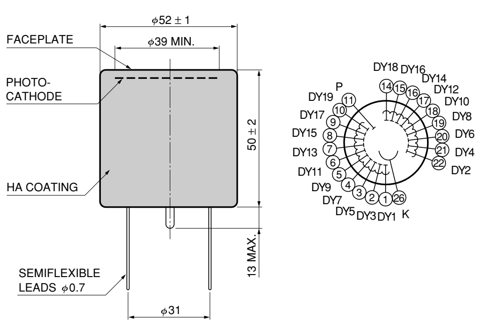
TPMHA0236EA

❷ R7761-70



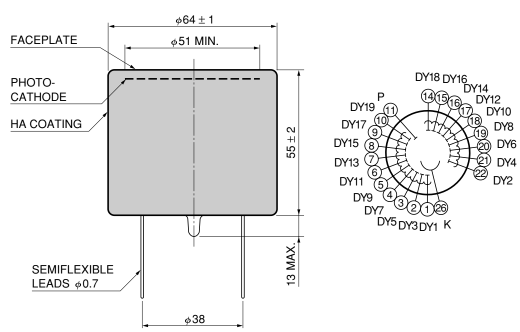
TPMHA0469EA

❸ R5924-70



TPMHA0490EA

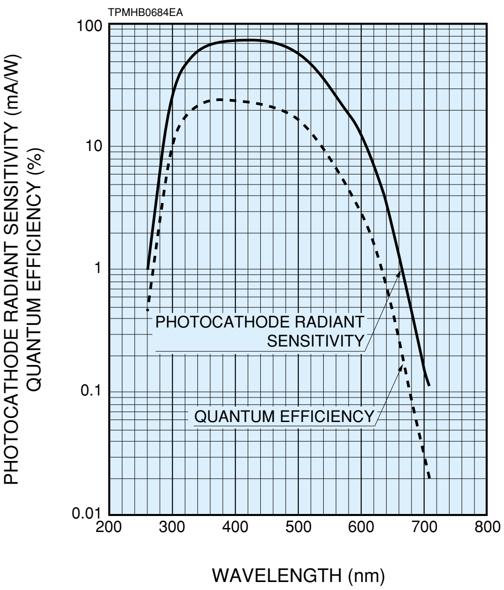
❹ R6504-70



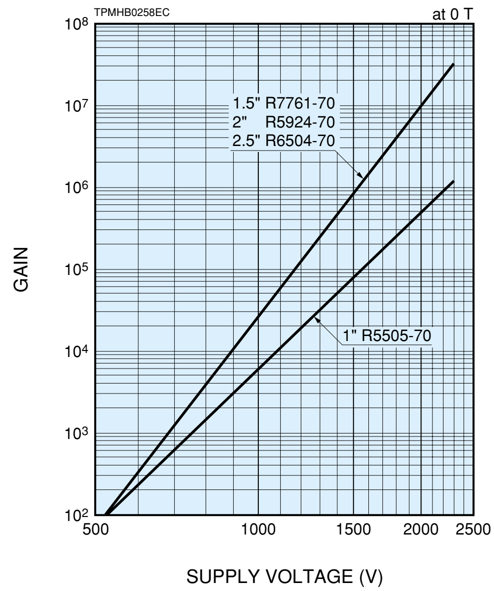
TPMHA0336EA

Cathode Characteristics			Anode Characteristics Ⓜ									(at 25 °C)
Quantum Efficiency at 390 nm (%)	Luminous Typ. (µA/lm)	Blue Sensitivity Index (CS 5-58) Typ.	Luminous Typ. (A/lm)	Gain at 0 T Typ.	Gain at 0.5 T Typ.	Gain at 1.0 T Typ.	Dark Current (After 30 min.) Typ. (nA)	Dark Current (After 30 min.) Max. (nA)	Time Response Rise Time Typ. (ns)	Time Response Transit Time Typ. (ns)	Notes	Ⓐ Type No.
23	80	9.5	40	5.0×10^5	2.3×10^5	1.8×10^4	5	30	1.5	5.6	Assembly type: H6152-70 Recommended (For +HV operation)	R5505-70*
23	80	9.5	800	1.0×10^7	3.0×10^6	1.5×10^5	15	100	2.1	7.5	Assembly type: H8409-70 Recommended (For +HV operation)	R7761-70*
22	70	9.0	700	1.0×10^7	4.1×10^6	2.5×10^5	30	200	2.5	9.5	Assembly type: H6614-70 Recommended (For +HV operation)	R5924-70*
22	70	9.0	700	1.0×10^7	4.1×10^6	2.0×10^5	50	300	2.7	11.0	Assembly type: H8318-70 Recommended (For +HV operation)	R6504-70*

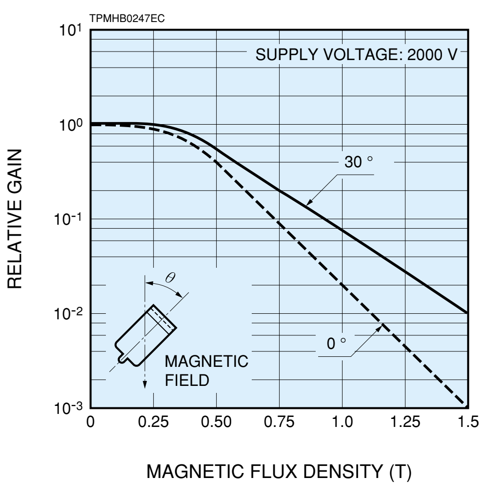
■Spectral Response



■Gain

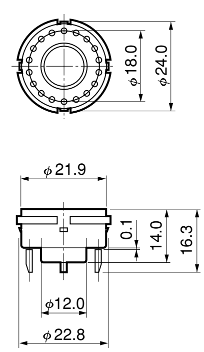


■R5924-70, R6504-70 Relative Gain in Magnetic Fields



Dimensional Outline of Socket (Unit: mm)

E678-17A

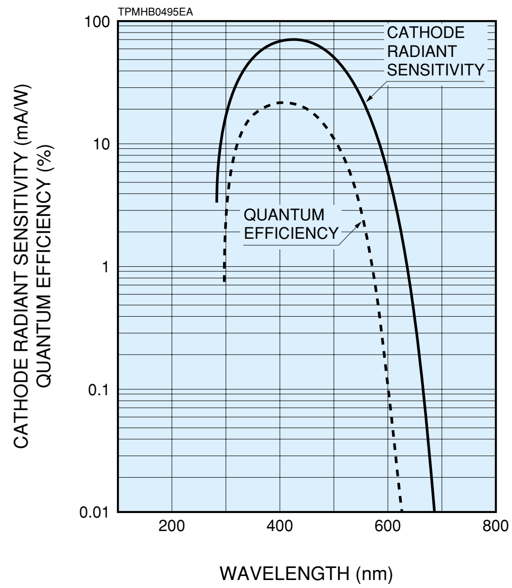


TACCA0046EB

Position Sensitive Type Photomultiplier Tubes

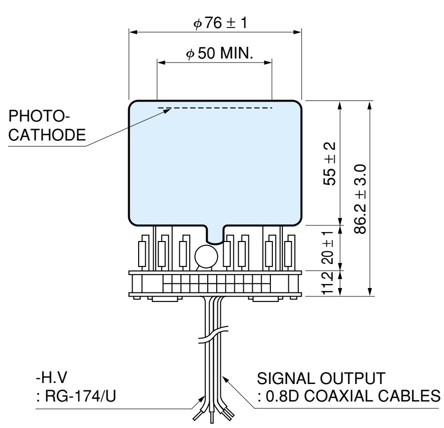
Type No.	Spectral Response: Effective Area (mm) / ← Wavelength (nm) → (100–1000)	Peak Wavelength (nm)	Photocathode Material (C)	Window Material (D)	Anode Matrixes	Outline No. (E)	Dynode Structure / Stages (F)	Max. Ratings (H): Anode to Cathode Voltage (V)	Max. Ratings (H): Average Anode Current (mA) (J)	Anode to Cathode Supply Voltage (V) (L)
R2486-02	ϕ50	420	BA	K	16(X) + 16(Y)	❶	CM/12	1300	0.06	1250 ㉛
R3292-02	ϕ100	420	BA	K	28(X) + 28(Y)	❷	CM/12	1300	0.06	1250 ㉛

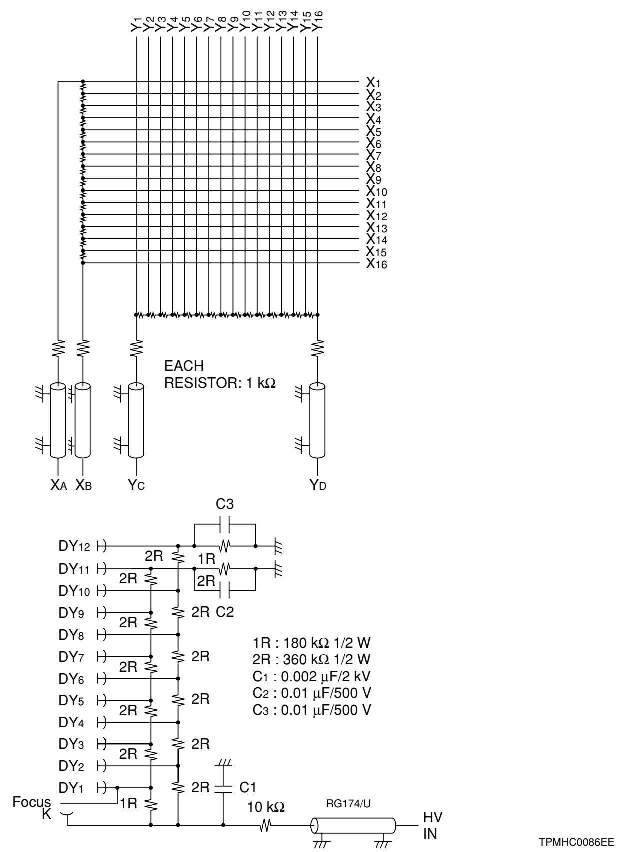
■Spectral Response



Dimensional Outlines (Unit: mm)

❶ R2486-02



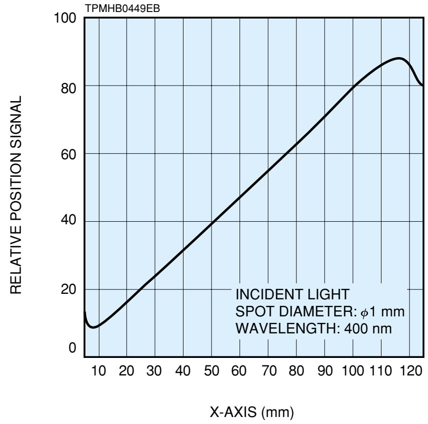


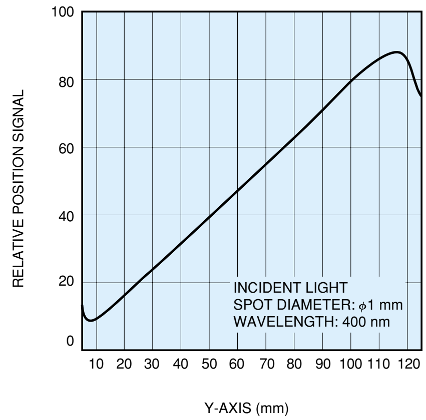
(at 25 °C)

Cathode Characteristics: Luminous Min. (µA/lm)	Cathode: Luminous Typ. (µA/lm)	Cathode: Blue Sensitivity Index (CS 5-58) Typ.	Cathode: Red/White Ratio (R-68) Typ.	Cathode: Radiant Typ. (mA/W) Ⓚ	Anode Characteristics Ⓜ: Luminous Min. (A/lm)	Anode: Luminous Typ. (A/lm)	Anode: Radiant Typ. (A/W)	Anode: Gain Typ.	Anode: Dark Current (After 30 min.) Typ. (nA)	Anode: Dark Current (After 30 min.) Max. (nA)	Anode: Time Response Rise Time Typ. (ns)	Anode: Time Response Transit Time Typ. (ns)	Notes	Type No. Ⓐ
50	80	9.0	—	72	5.0	40	3.6×10^4	5.0×10^5	20	50	5.5	17		R2486-02
50	80	9.0	—	72	5.0	10	9.4×10^3	1.3×10^5	40	150	6.0	20		R3292-02

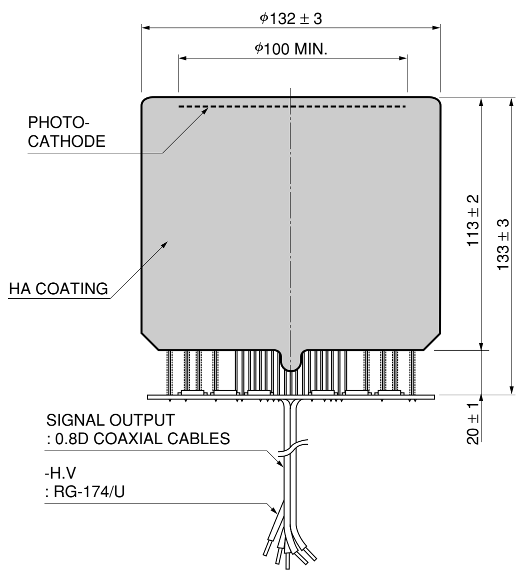
R3292-02 Position Signal Linearity

TPMHB0449EB

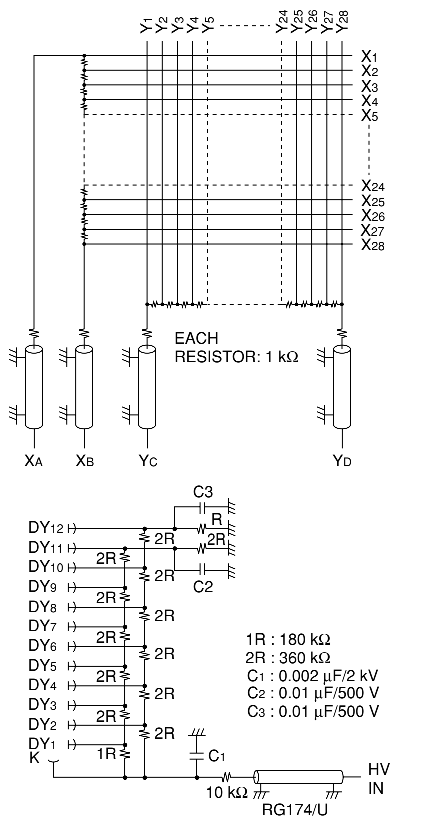




❷ R3292-02



TPMHA0162EE



TPMHC0088EE

Microchannel Plate-Photomultiplier Tubes (MCP-PMTs)

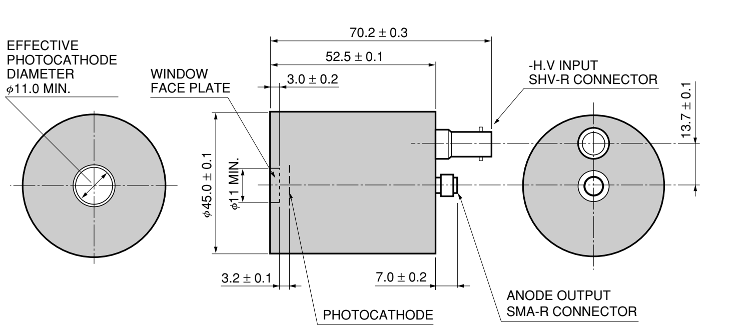
Type No. (A)	Spectral Response: Effective Area (mm) / ← Wavelength (nm) → (100–1200)	Curve Code (B)	Peak Wavelength (nm)	Photocathode Material (C)	Window Material (D)	Outline No. (E)	No. of MCP Stage	-HV Input Terminals	Signal Output Terminals	Anode to Cathode Voltage (V)	Anode Current Continuous (nA)	Anode Current Pulsed Peak (mA)
Standard Types												
R3809U-50	ϕ11	500S	430	MA	Q	❶	2	SHV-R	SMA-R	-3400	100	350
R3809U-51	ϕ11	501S	600	EMA	Q	❶	2	SHV-R	SMA-R	-3400	100	350
R3809U-52	ϕ11	403K	400	BA	Q	❶	2	SHV-R	SMA-R	-3400	100	350
R3809U-57	ϕ11	201M	230	Cs-Te	MF	❶	2	SHV-R	SMA-R	-3400	100	350
R3809U-58	ϕ11	500M	430	MA	MF	❶	2	SHV-R	SMA-R	-3400	100	350
R3809U-59	ϕ11	700M	800	Ag-O-Cs	K	❶	2	SHV-R	SMA-R	-3400	100	350
Gated Types												
R5916U-50	ϕ10	500S	430	MA	Q	❷	2	SHV-R	SMA-R	-3400	100	350
R5916U-51	ϕ10	501S	600	EMA	Q	❷	2	SHV-R	SMA-R	-3400	100	350
R5916U-52	ϕ10	403K	400	BA	Q	❷	2	SHV-R	SMA-R	-3400	100	350

Max. Ratings (H): Anode to Cathode Voltage, Anode Current.

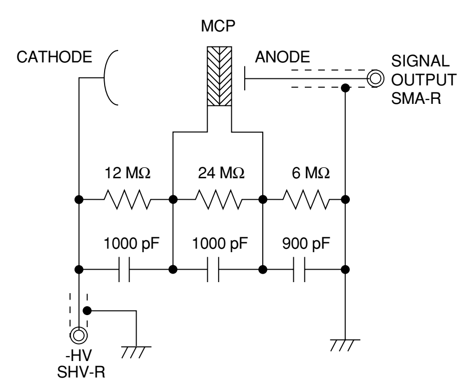
The R5916 series can be gated by input of a +15 V gate signal. Standard types are normally OFF, but normally ON types are also available.
Gate operation is 5 ns, though this depends on the gate signal input pulse.

Dimensional Outlines (Unit: mm)

❶ R3809U-50, -51, -52, -57, -58, -59



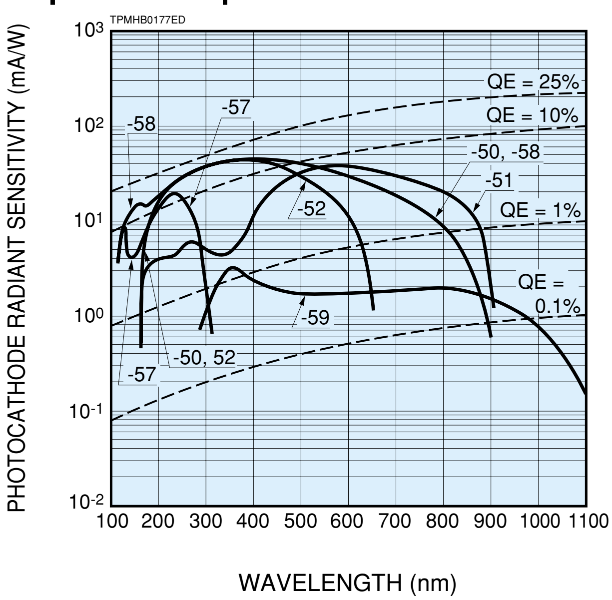
TPMHA0352EB



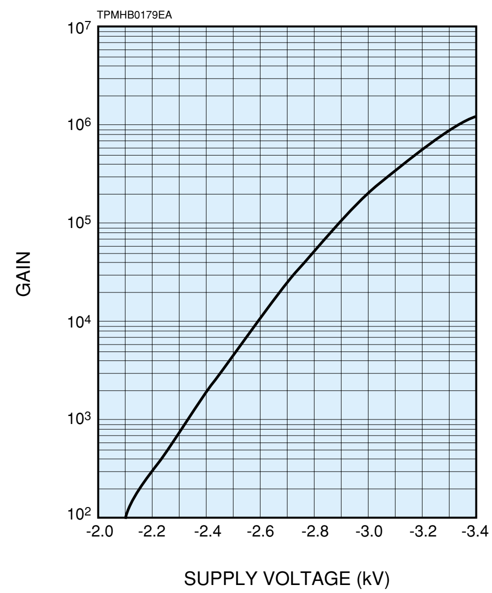
TPMHC0089EC

Anode to Cathode Supply Voltage (V)	Cathode Characteristics: Quantum Efficiency at peak (%)	Cathode Characteristics: Luminous Min. (µA/lm)	Cathode Characteristics: Luminous Typ. (µA/lm)	Anode Characteristics Ⓜ: Luminous Typ. (A/lm)	Anode Characteristics Ⓜ: Gain Typ.	Anode Characteristics Ⓜ: Dark Current (After 30 min.) Max. (nA)	Anode Characteristics Ⓜ: Time Response: Rise Time Typ. (ns)	Anode Characteristics Ⓜ: Time Response: Transit Time Typ. (ns)	Anode Characteristics Ⓜ: Time Response: Transit Time Spread Typ. (ps)	Notes	Ⓐ Type No.
-3000	20	100	150	30	2.0×10^5	10	0.15	0.55	25		**R3809U-50**
-3000	8.3	240	350	70	2.0×10^5	10	0.15	0.55	25		**R3809U-51**
-3000	20	20	50	10	2.0×10^5	0.5	0.15	0.55	25		**R3809U-52**
-3000	11	—	—	—	2.0×10^5	0.1	0.15	0.55	25		**R3809U-57**
-3000	20	100	150	30	2.0×10^5	10	0.15	0.55	25		**R3809U-58**
-3000	0.25	12	25	5	2.0×10^5	10	0.15	0.55	25		**R3809U-59**
-3000	15	100	150	30	2.0×10^5	10	0.18	1.0	90		**R5916U-50**
-3000	7.6	200	300	60	2.0×10^5	10	0.18	1.0	90		**R5916U-51**
-3000	15	20	45	9	2.0×10^5	0.5	0.18	1.0	90		**R5916U-52**

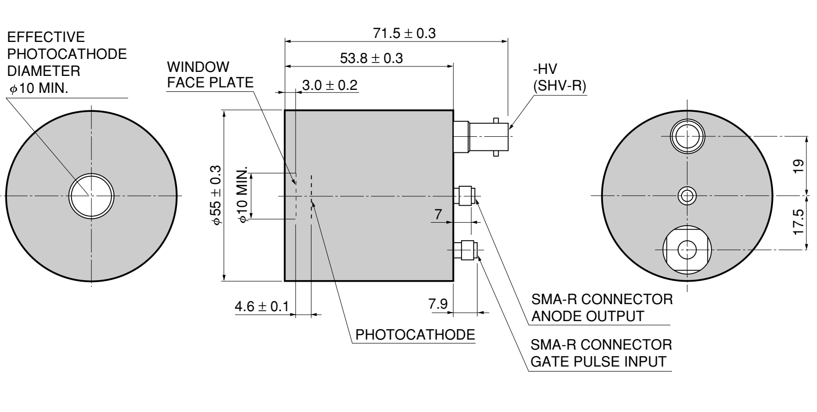
■Spectral Response

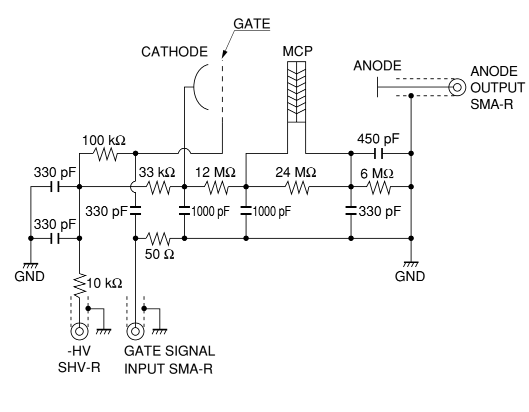


■Gain



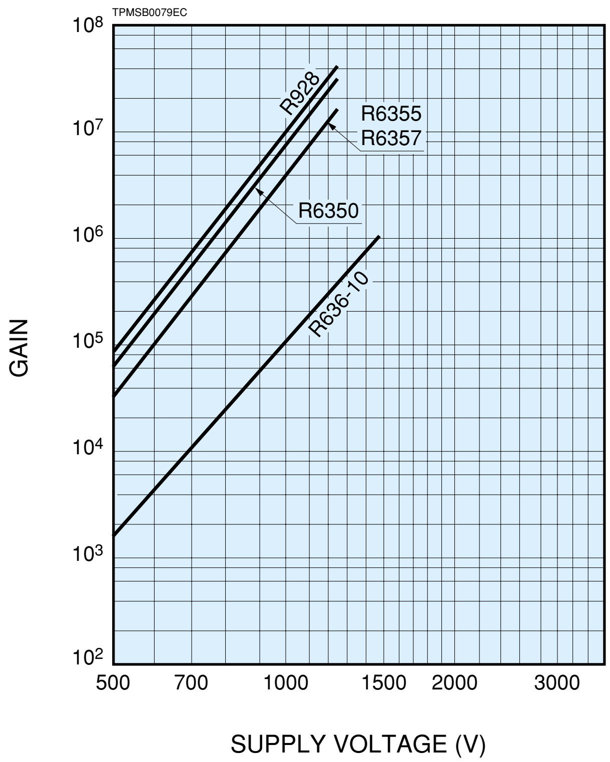
❷ R5916U-50, -51, -52



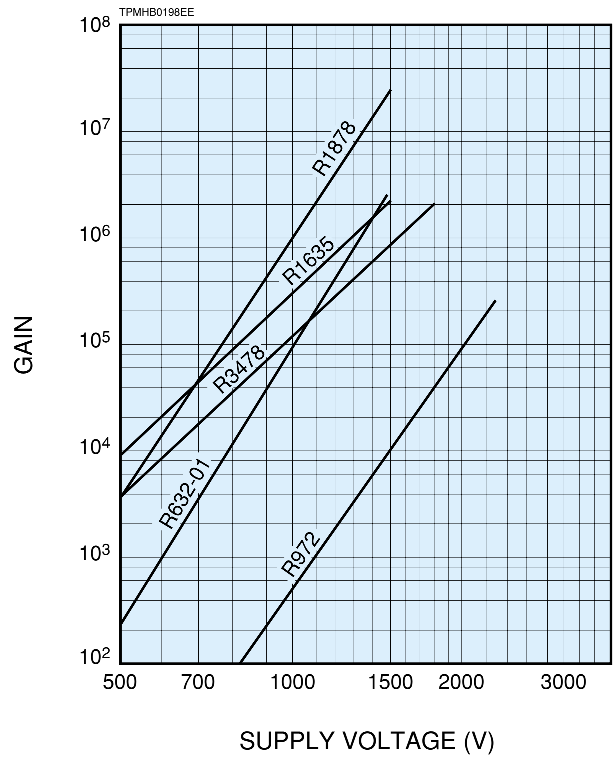


For tubes not listed here, please consult our sales office.

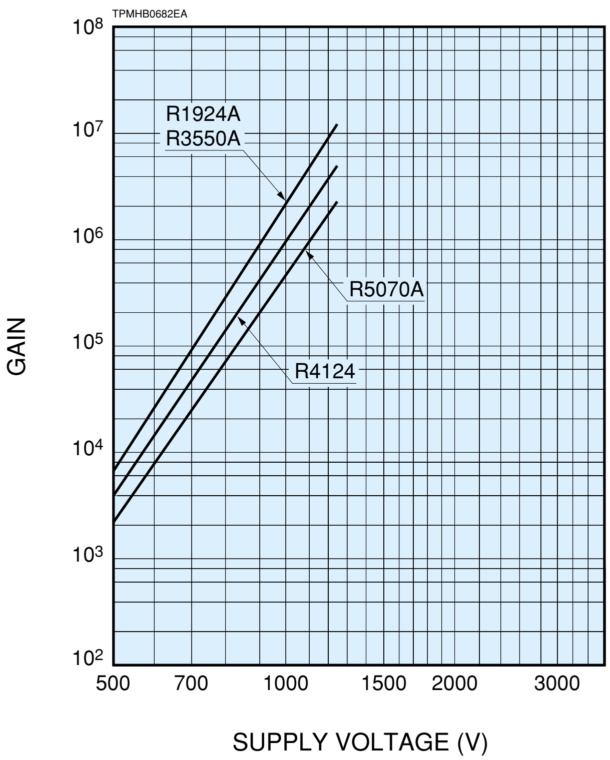
Side-on Types



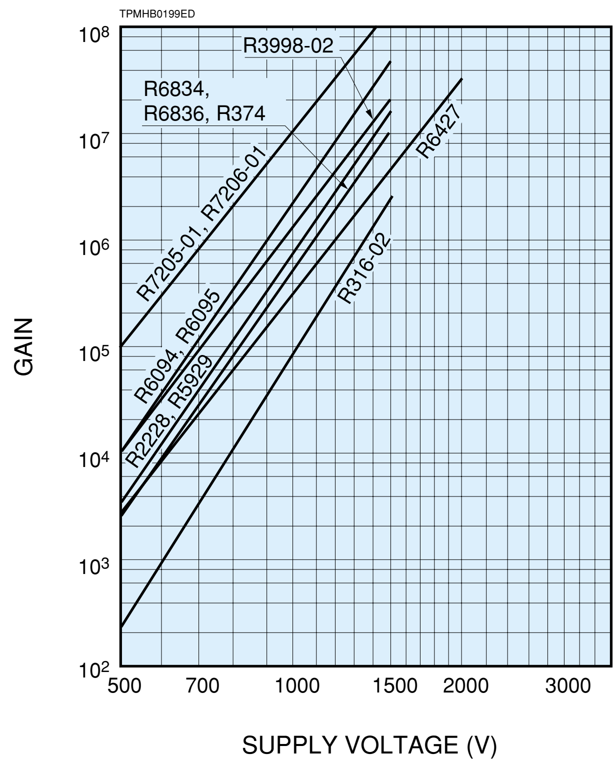
Head-on Types (10 mm and 19 mm Dia.)



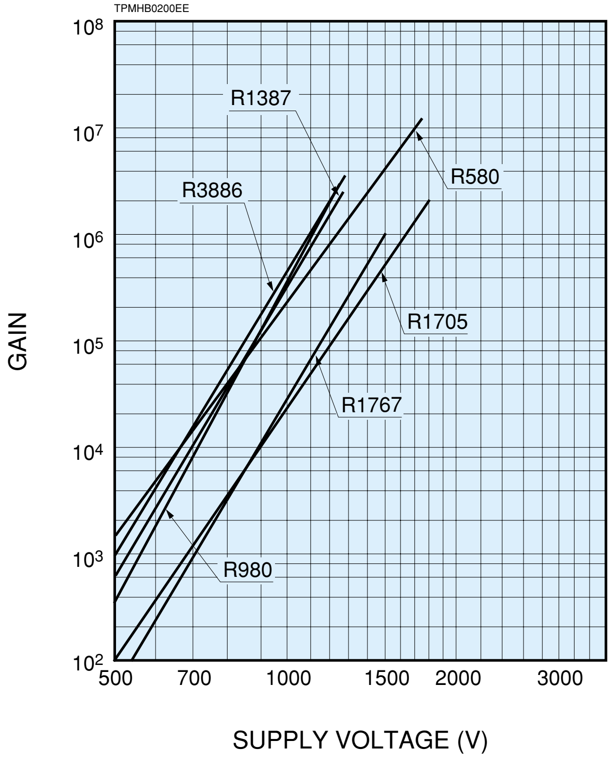
Head-on Types (13 mm and 25 mm Dia.)



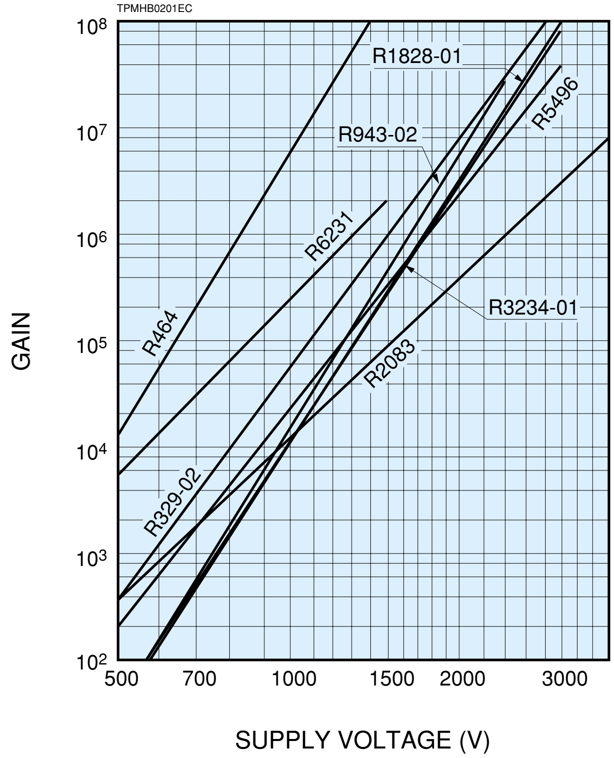
Head-on Types (28 mm Dia.)



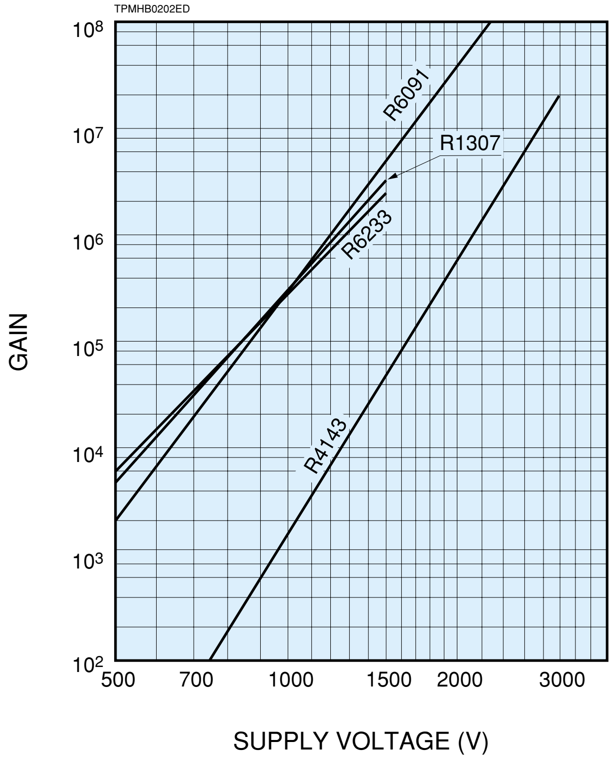
Head-on Types (38 mm Dia.)



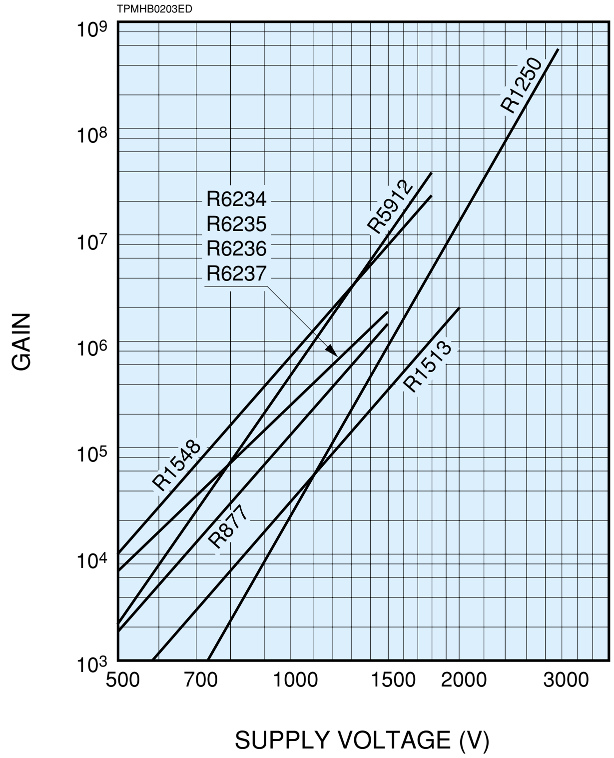
Head-on Types (51 mm Dia.)



Head-on Types (76 mm Dia.)



Head-on Types (127 mm Dia.) and 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	1.5	1	1	1	1	—	1	1							
⑤		7	—	1	1.5	1	1	1	1	—	1	1							
⑥		2	2	1	1	1	1	1	1	—	1	1							
⑦		1	—	1	1	1	1	1	1	—	1	0.5							
	9	K	G	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	P						
⑧		1	—	1	1	1	1	1	1	1	1	1							
⑨		3	1	1	1	1	1	1.5	1	1	1	1							
	10	K	G	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	P					
⑩		1	—	1	1	1	1	1	1	1	1	1	1						
⑪		1	1	1	1	1	1	1	1	1	1	1	1						
⑫		1.5	—	1	1	1	1	1	1	1	1	1	1						
⑬		2	—	1	1	1	1	1	1	1	1	1	1						
⑭		2	—	1	1.5	1	1	1	1	1	1	1	0.75						
⑮		3	—	1	1	1	1	1	1	1	1	1	1						
⑯		3	—	1	1.5	1	1	1	1	1	1	1	1						
⑰		3	—	1.5	1	1	1	1	1	1	1	1	1						
⑱		4	—	1	1.5	1	1	1	1	1	1	1	1						
⑲		1.3	4.8	1.2	1.8	1	1	1	1	1	1.5	3	2.5 (Note 2)						
⑳		1.5	—	1.5	1.5	1	1	1	1	1	1	1	0.5						
㉑		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			
㉒		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				
㉓		1	—	1	1	1	1	1	1	1	1	1	1	1					
㉔		0.5	1.5	2	1	1	1	1	1	1	1	1	1	0.5					
㉕		2	—	1	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			
㉖		1.2	2.8	1.2	1.8	1	1	1	1	1	1	1.5	1.5	3	2.5				
㉗		4	0	1	1.4	1	1	1	1	1	1	1	1	1	1 (Note 1)				
㉘		4	0	2.5	1.5	1	1	1	1	1	1	1	1	1	1				
㉙		1	3	1.2	1.8	1	1	1	1	1	1	1.5	1.5	3	2.5				
㉚		4	0	1.2	1.8	1	1	1	1	1	1	1	1	1	1				
㉛		1	—	1	1	1	1	1	1	1	1	1	1	1	1				
	14	K	G1	G2	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	Dy11	Dy12	Dy13	Dy14	P
㉜		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 1	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	Dy11	Dy12	Dy13	Dy14	Dy15	P	
㉝		2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
	19	K	Dy1	Dy2	Dy3	·	·	·	·	·	·	·	·	·	Dy17	Dy18	Dy19	P	
㉞		2	1	1	1	·	·	·	·	·	·	·	·	·	1	1	1	1	

Note 1: The shield pin should be connected to Dy5.
2: Please connect ACC of R5496 to Dy7.

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 connection.

BURLE	Hamamatsu

Side-on Types

1P21	1P21* R105**
1P28	1P28*
1P28/V1	R212* 1P28**
4832	R636-10***
931A, 931VA	931A*
931B	931B* R105**

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***
C31000AJ4	R4607-01***
C31000AP4	R4607-01***
C31000AJ-175	R4607-01***
C31000AP-175	R4607-01***
C31016G4	R1288A***
C31016H5	R1288A***
C31031	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***

ETL	Hamamatsu

Side-on Types

9780B	1P28** 931A** 1P21**
9781B	1P28** R212**
9781R	R3788**
9783B	R106*

Head-on Types

9078B	R1166**
9082B	R1450**
9102KB, 9902KB, 9903KB	R580**
9110FLB	R1288A**
9111B, 9112B	R1924A**
9113B	R1925A**
9124B, 9125B, 9128B	R6094** R6095**
9135B	R7899***
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***
9821B, 9921B	R6091***
9822B	R6091***
9823KB	R1250**
9826B	R1450*** R3478***
9828B	R5929**
9829B, 9849B	R331-05*
9865B	R649***
9881B	R1450*** R3478***
9882B	R1617***
9884B, 9887B	R329-02***
9893KB/350	R3234-01***
9899B	R331-05***
9972KB, 9973KB	R1387**

PHOTONIS	Hamamatsu

Head-on Types

XP1911	R1166** R1450* R3478***
XP2012B, XP2072B	R580**
XP2013B	R1387***
XP2015B	R1767***
XP2017B	R2066***
XP2020	R1828-01*
XP2050	R877***
XP2052B	R980**
XP2202B	R2154-02**
XP2206B	R4607-01***
XP2262B	R329-02***
XP2282B	R2083***
XP2312B	R6091***
XP2802	R1166***
XP2971, XP2972	R6427**
XP3462B	R6091***
XP4500B	R1584***
XP4512B	R1250***

Photomultiplier Tube Assemblies

TACCF0133

Photomultiplier Tube Assemblies

Photomultiplier tube assemblies are made up of a photomultiplier tube, a voltage-divider circuit and other components, all integrated into a single case.

Type No.	Assembly Dia. (mm)	PMT Dia. mm (inch)	Built-in PMT	Curve Code	Wavelength (nm)	Out-line No.	F Dynode Structure / Stages	Max. Rating: Anode to Cathode Voltage Max. (V)	Max. Rating: Divider Current Max. (mA)	Anode to Cathode Supply Voltage (V)	Cathode Sensitivity: Luminous Typ. (μA/lm)	Cathode Sensitivity: Blue Sensitivity Index (CS 5-58) Typ.
H3164-10	ϕ10.5	10 (3/8)	R1635	400K	300 to 650	1	L/8	-1500	0.41	-1250	100	9.5
H3695-10	ϕ11.3	10 (3/8)	R2496	400S	160 to 650	2	L/8	-1500	0.37	-1250	100	9.5
H3165-10	ϕ14.3	13 (1/2)	R647	400K	300 to 650	3	L/10	-1250	0.34	-1000	110	10.0
H6520	ϕ23.5	19 (3/4)	R1166	400K	300 to 650	4	L/10	-1250	0.33	-1000	110	10.5
H6524	ϕ23.5	19 (3/4)	R1450	400K	300 to 650	5	L/10	-1800	0.43	-1500	115	11.0
H6612	ϕ23.5	19 (3/4)	R3478	400K	300 to 650	6	L/8	-1800	0.35	-1700	115	11.0
H6152-70	ϕ31.0	25 (1)	R5505-70	—	300 to 650	7	FM/15	+2300	0.41	+2000	80	9.5
H6533	ϕ31.0	25 (1)	R4998	400K	300 to 650	8	L/10	-2500	0.36	-2250	70	9.0
H7415	ϕ33.0	28 (1-1/8)	R6427	400K	300 to 650	9	L/10	-2000	0.41	-1500	95	11.0
H3178-51	ϕ47.0	38 (1-1/2)	R580	400K	300 to 650	10	L/10	-1750	0.63	-1500	95	11.0
H8409-70	ϕ38.0	38 (1-1/2)	R7761-70	—	300 to 650	11	FM/19	+2300	0.33	+2000	80	9.5
H6410	ϕ60.0	51 (2)	R329-02	400K	300 to 650	12	L/12	-2700	0.67	-2000	90	10.5
H1949-51	ϕ60.0	51 (2)	R1828-01	400K	300 to 650	13	L/12	-3000	0.70	-2500	90	10.5
H2431-50	ϕ60.0	51 (2)	R2083	400K	300 to 650	14	L/8	-3500	0.61	-3000	80	10.0
H6614-70	ϕ60.0	51 (2)	R5924-70	—	300 to 650	15	FM/19	+2300	0.33	+2000	70	9.0
H6156-50	ϕ60.0	51 (2)	R5496	400K	300 to 650	16	L/10	-3000	0.71	-2500	80	10.0
H7195	ϕ60.0	51 (2)	R329-02	400K	300 to 650	17	L/12	-2700	1.23	-2000	90	10.5
H8318-70	ϕ71.0	64 (2-1/2)	R6504-70	—	300 to 650	18	FM/19	+2300	0.33	+2000	70	9.0
H6559	ϕ83.0	76 (3)	R6091	400K	300 to 650	19	L/12	-2500	0.62	-2000	90	10.5
H6527	ϕ142.0	127 (5)	R1250	400K	300 to 650	20	L/14	-3000	1.02	-2000	70	9.0
H6528	ϕ142.0	127 (5)	R1584	400U	185 to 650	20	L/14	-3000	1.02	-2000	70	9.0
H8711	□30	—	R7600-00-M16	—	300 to 650	21	MC/12	-1000	0.35	-800	80	8.5
H7546B	□30	—	R7600-00-M64	—	300 to 650	22	MC/12	-1000	0.45	-800	80	8.5
H7260-20	▭ 52 × 24	—	R7259-20	—	300 to 920	23	MC/10	-900	0.37	-800	500	—
H8500	□52	—	R8400-00-M64	—	300 to 650	24	MC/12	-1100	0.18	-1000	55	7.5

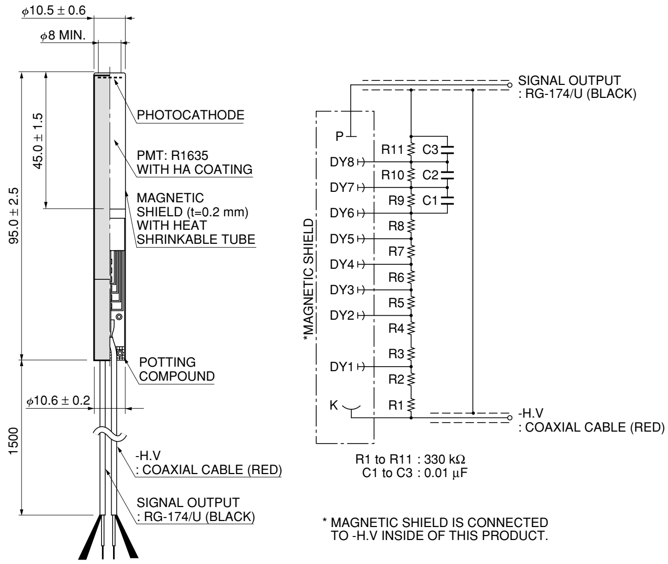
CAUTION: Photomultiplier tube assemblies are not designed to operate in a vacuum.

Anode Characteristics

Luminous Typ. (A/lm)	Gain Typ.	Dark Current Typ. (nA)	Dark Current Max. (nA)	Time Response Rise Time Typ. (ns)	Time Response Transit Time Typ. (ns)	Time Response Transit Time Spread Typ. (ns)	Pulse Linearity 2 % Typ. (mA)	Pulse Linearity 5 % Typ. (mA)	Notes	Type No.
100	1.0×10^6	1	50	0.8	9.0	0.5	3	7	H3164-11 (with 50 Ω *)	H3164-10
100	1.0×10^6	2	50	0.7	9.0	0.5	3	7	H3695-11 (with 50 Ω *)	H3695-10
150	1.4×10^6	1	2	2.5	24	1.6	3	7	H3165-11 (with 50 Ω *)	H3165-10
110	1.0×10^6	1	5	2.5	27	2.8	4	7	H6520-01 (with 50 Ω *)	H6520
200	1.7×10^6	3	50	1.8	19	0.76	4	8	H6524-01 (with 50 Ω *)	H6524
200	1.7×10^6	10	300	1.3	14	0.36	4	8	H6612-01 (with 50 Ω *)	H6612
40	5.0×10^5	5	30	1.5	5.6	0.35	180	250		H6152-70
400	5.7×10^6	100	800	0.7	10	0.16	40	70	H6610 (R5320)	H6533
475	5.0×10^6	10	200	1.7	16	0.5	10	30	H7415-01 (with 50 Ω *) H7416 (R7056)	H7415
75	7.9×10^5	2	15	2.7	40	4.5	150	200		H3178-51
800	1.0×10^7	15	100	2.1	7.5	0.35	350	500		H8409-70
270	3.0×10^6	10	100	2.7	40	1.1	100	200	H6521 (R2256) H6522 (R5113)	H6410
1800	2.0×10^7	50	400	1.3	28	0.55	100	200	H3177-50 (R2059)	H1949-51
200	2.5×10^6	100	800	0.7	16	0.37	100	150	H3378-50 (R3377)	H2431-50
700	1.0×10^7	30	200	2.5	9.5	0.44	500	700		H6614-70
1000	1.3×10^7	100	800	1.5	24	0.27	100	150		H6156-50
270	3.0×10^6	10	100	2.7	40	1.1	80	110		H7195
700	1.0×10^7	50	300	2.7	11	0.47	700	1000		H8318-70
900	1.0×10^7	30	120	2.3	40	1.5	80	110		H6559
1000	1.4×10^7	50	300	2.5	54	1.2	100	150		H6527
1000	1.4×10^7	50	300	2.5	54	1.2	100	150		H6528
280	3.5×10^6	0.8/ch	—	0.83	10.9	0.3	0.5/ch	1/ch	16 Multianode H8711-10 (Taper Divider Type)	H8711
24	3.0×10^5	0.2/ch	—	1.0	10.9	0.3	0.3/ch	0.6/ch	64 Multianode	H7546B
500	1.0×10^6	1/ch	10/ch	0.6	8.8	0.18	0.6/ch	0.8/ch	32 Linearanode H7260A-20 (-HV Cable Input Type)	H7260-20
55	1.0×10^6	0.5/ch	—	0.8	6.0	0.4	1/ch	2/ch		H8500

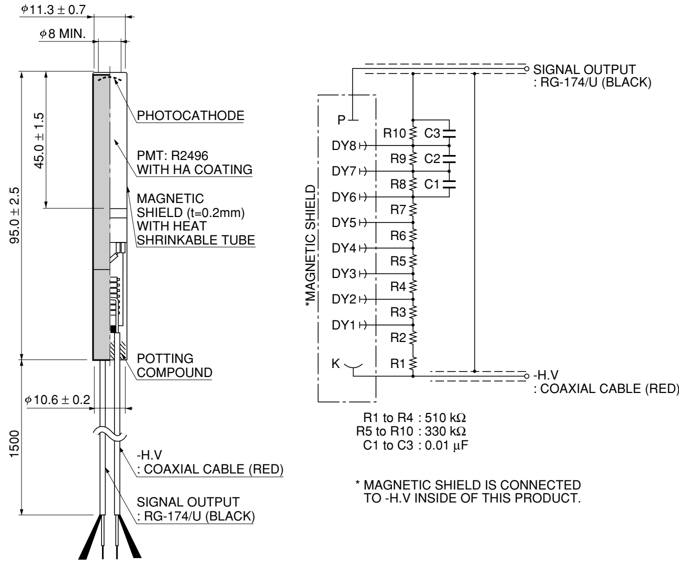
Note: * marks = 50 Ω is a terminal resistor at anode output.

1 H3164-10



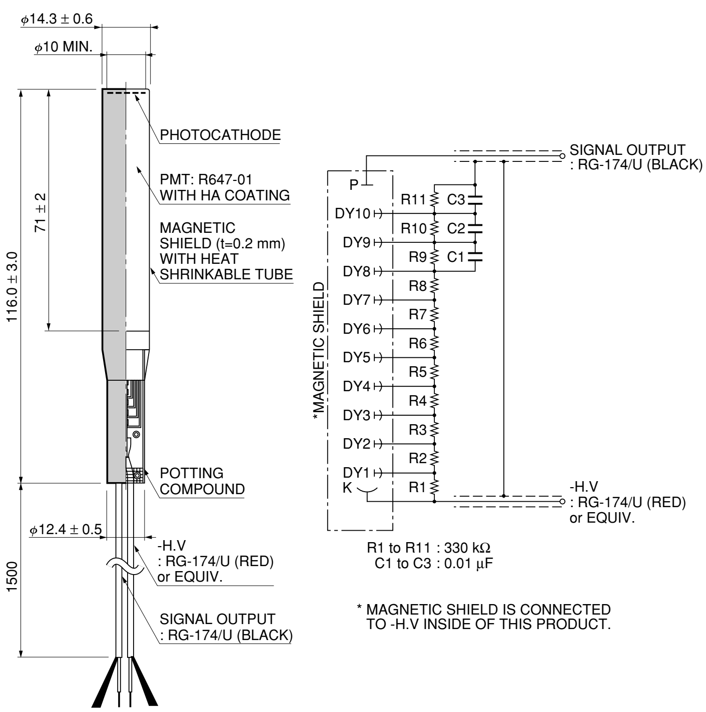
TPMHA0309EC

2 H3695-10



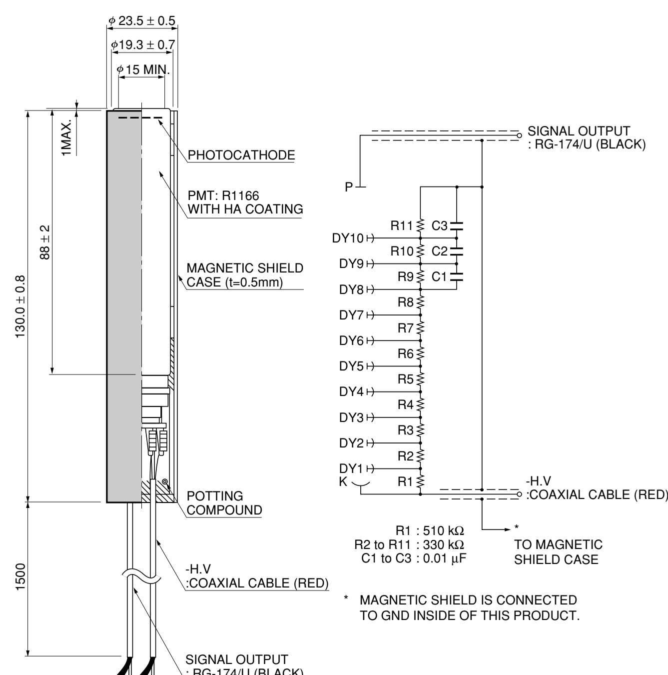
TPMHA0310EC

3 H3165-10



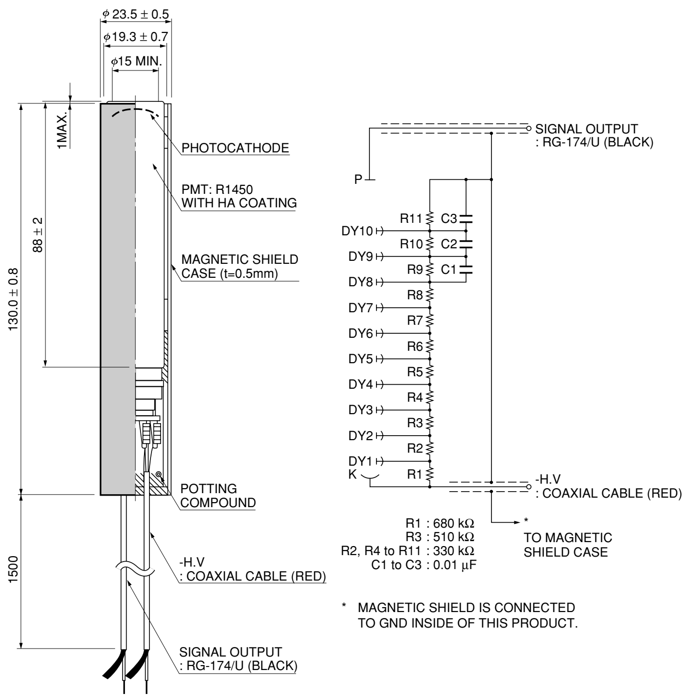
TPMHA0311EC

4 H6520



TPMHA0312EB

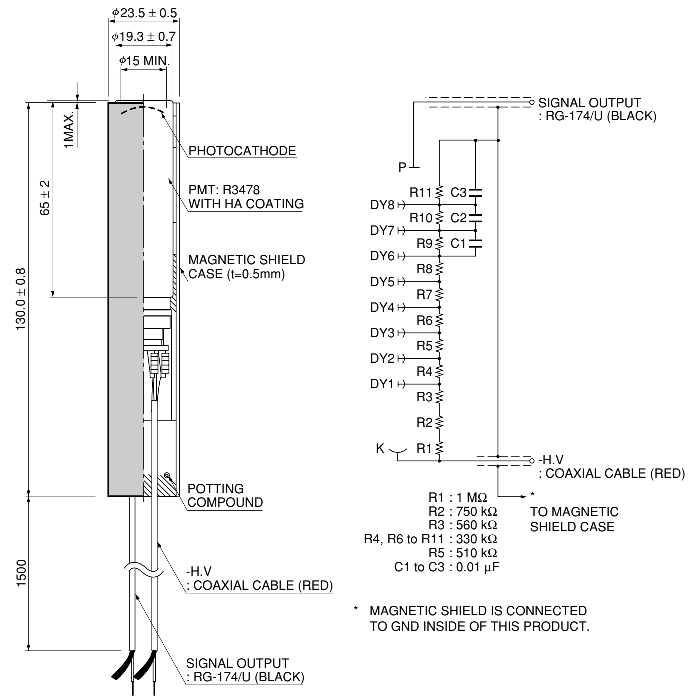
❺ H6524



* MAGNETIC SHIELD IS CONNECTED TO GND INSIDE OF THIS PRODUCT.

TPMHA0313EA

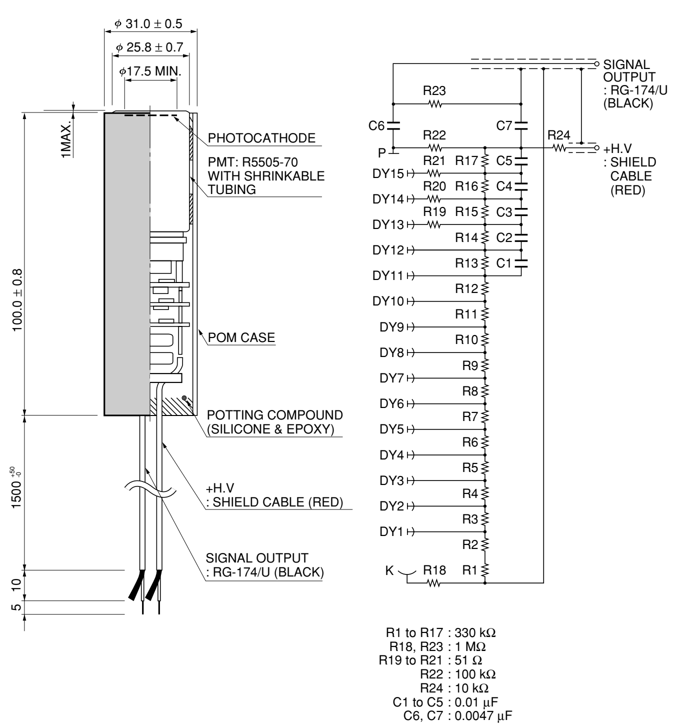
❻ H6612



* MAGNETIC SHIELD IS CONNECTED TO GND INSIDE OF THIS PRODUCT.

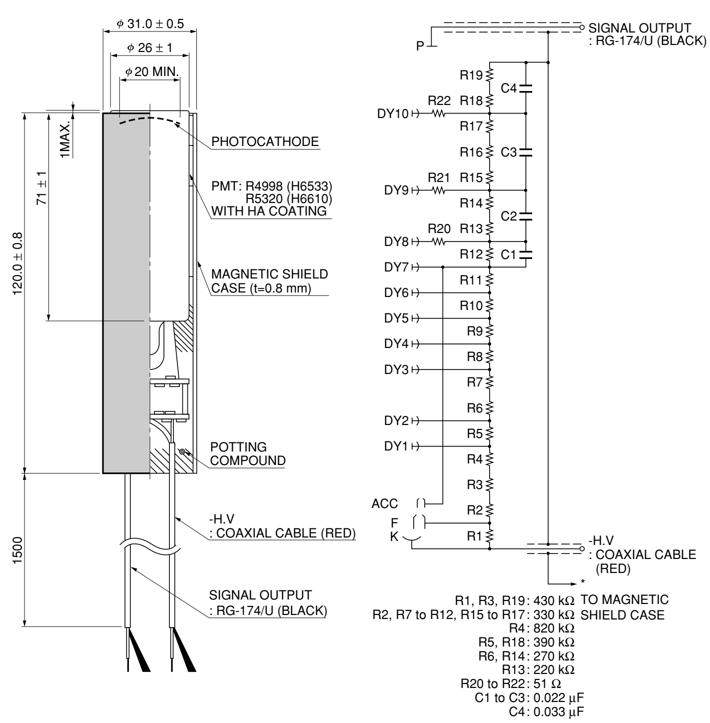
TPMHA0315EA

❼ H6152-70



TPMHA0470EA

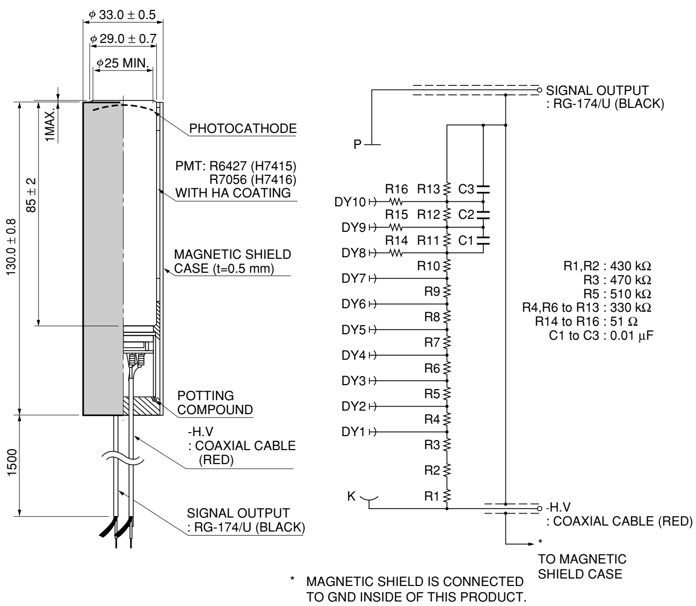
❽ H6533



* MAGNETIC SHIELD IS CONNECTED TO GND INSIDE OF THIS PRODUCT.

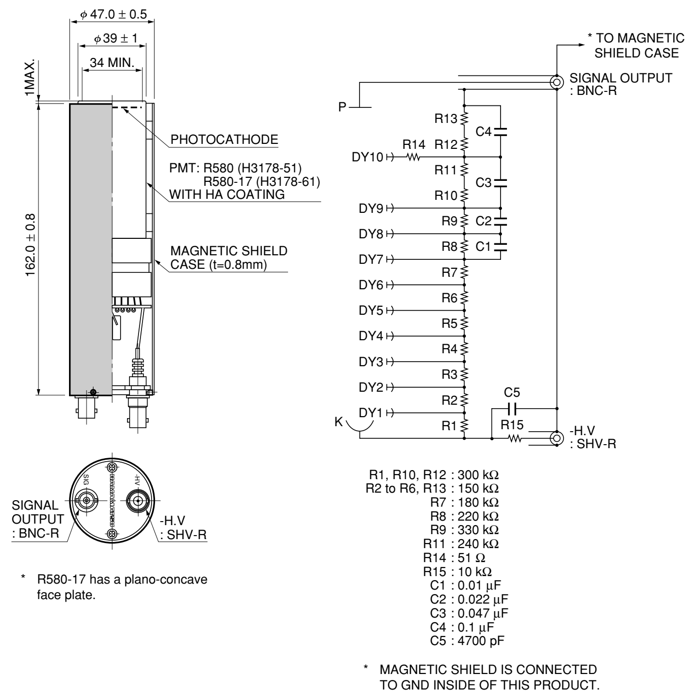
TPMHA0317EB

9 H7415



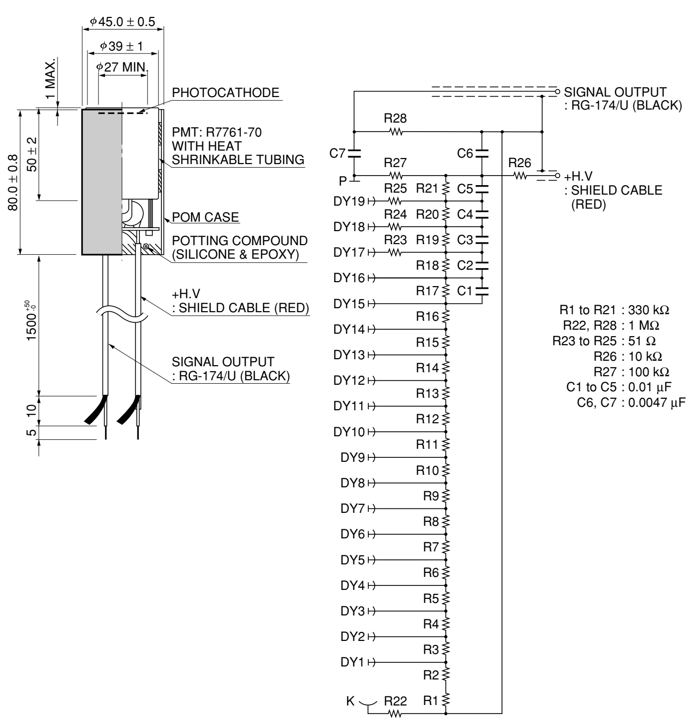
TPMHA0318EB

10 H3178-51



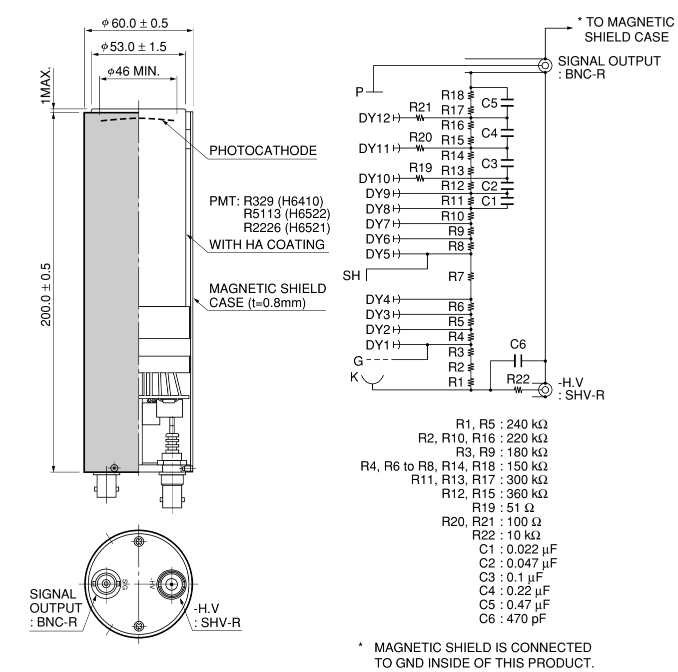
TPMHA0320EB

11 H8409-70



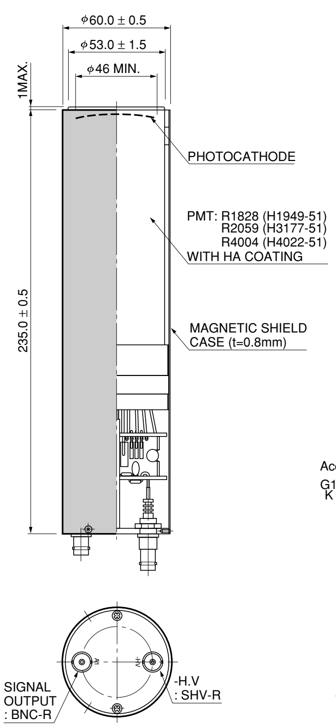
TPMHA0476EA

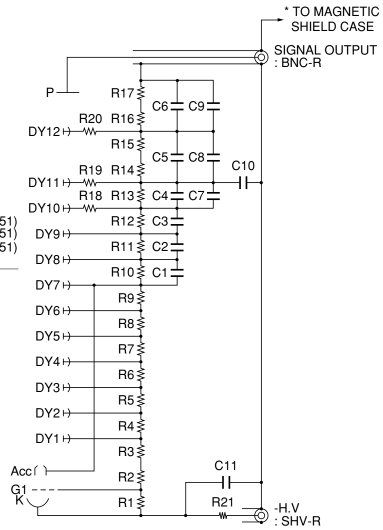
12 H6410



TPMHA0324EB

⑬ H1949-51



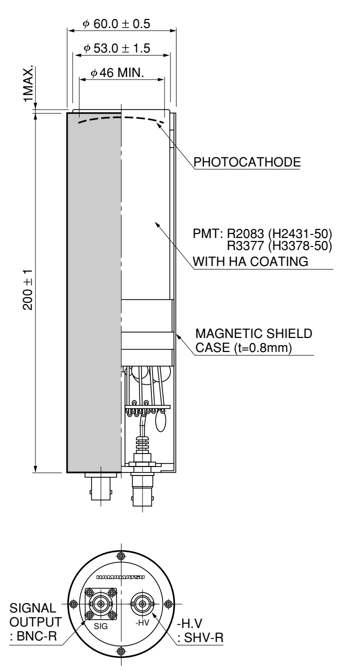


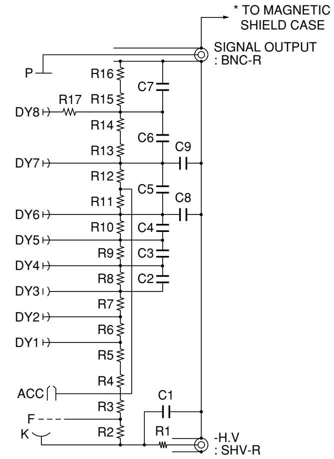
R1, R4 : 240 kΩ
R2, R5 : 360 kΩ
R3, R6 to R11, R17 : 200 kΩ
R12 to R16 : 300 kΩ
R18 to R20 : 51 Ω
R21 : 10 kΩ
C1 to C7 : 0.01 μF
C8 : 0.022 μF
C9 : 0.033 μF
C10 : 0.01 μF
C11 : 470 pF

* MAGNETIC SHIELD IS CONNECTED TO GND INSIDE OF THIS PRODUCT.

TPMHA0326EC

⑭ H2431-50



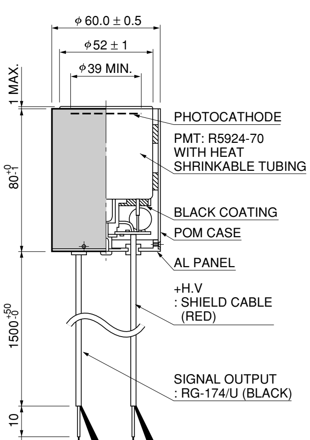


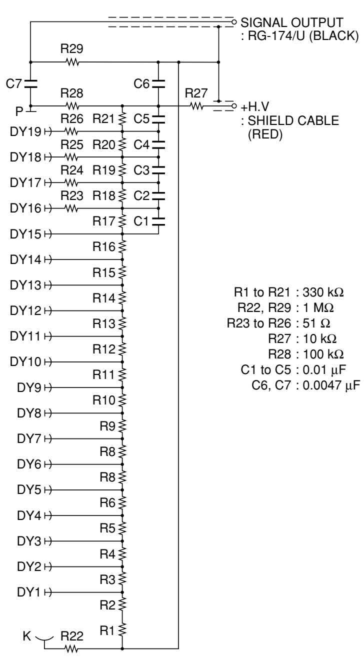
R1 : 33 kΩ
R2, R15 : 390 kΩ
R3, R4, R13 : 470 kΩ
R5 : 499 kΩ
R6, R16 : 360 kΩ
R7 : 536 kΩ
R8 to R11 : 300 kΩ
R12 : 150 kΩ
R14 : 430 kΩ
R17 : 51 Ω
C1 : 2200 pF
C2, C3 : 4700 pF
C4 : 0.01 μF
C5, C6 : 0.022 μF
C7 : 0.047 μF
C8, C9 : 1000 pF

* MAGNETIC SHIELD IS CONNECTED TO GND INSIDE OF THIS PRODUCT.

TPMHA0327EB

⑮ H6614-70

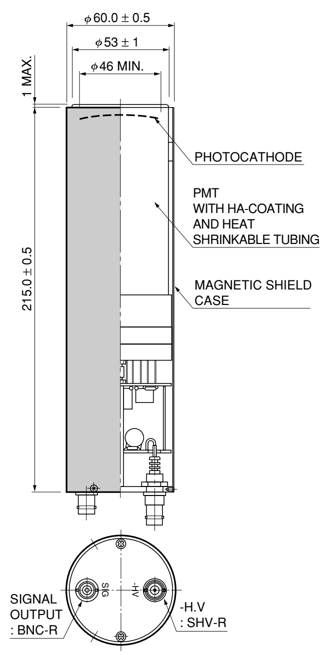


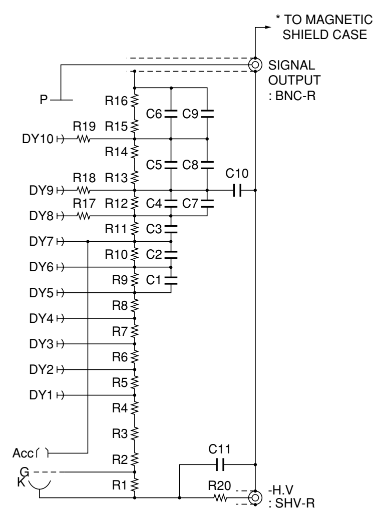


R1 to R21 : 330 kΩ
R22, R29 : 1 MΩ
R23 to R26 : 51 Ω
R27 : 10 kΩ
R28 : 100 kΩ
C1 to C5 : 0.01 μF
C6, C7 : 0.0047 μF

TPMHA0472EA

⑯ H6156-50



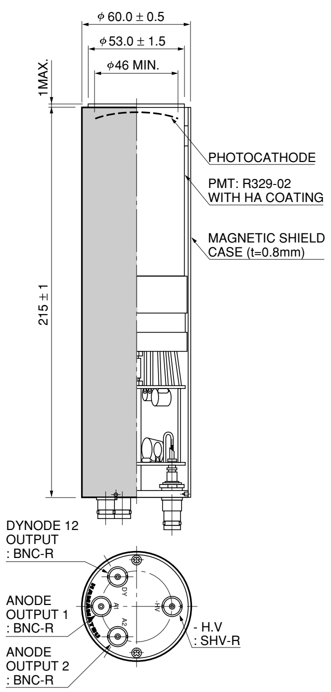


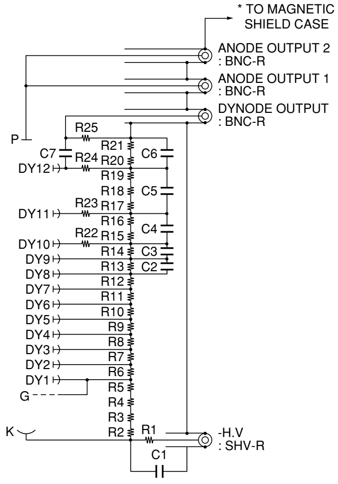
R1 : 270 kΩ
R2, R3, R6 : 360 kΩ
R4, R5 : 240 kΩ
R7 to R11, R16 : 200 kΩ
R12 to R15 : 300 kΩ
R17 to R19 : 51 Ω
R20 : 10 kΩ
C1 to C3, C9 : 0.01 μF
C4, C5 : 0.022 μF
C6 : 0.033 μF
C7, C8 : 4700 pF
C10 : 0.01 μF
C11 : 470 pF

* MAGNETIC SHIELD IS CONNECTED TO GND INSIDE OF THIS PRODUCT.

TPMHA0489EA

⑰ H7195



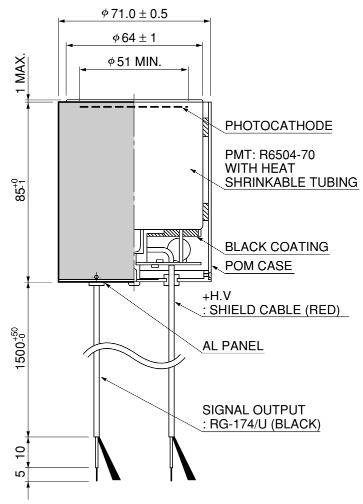


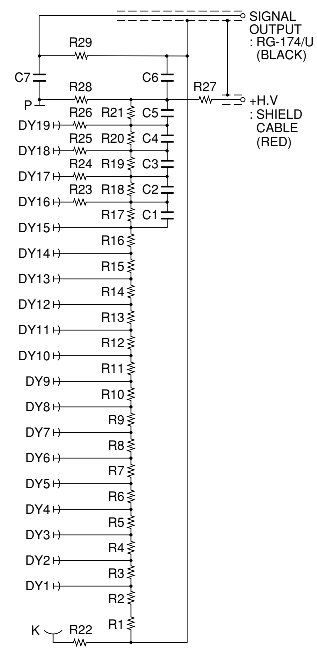
R1, R25 : 10 kΩ
R2 to R4, R17 to R19 : 110 kΩ
R5, R6, R8 to R13, R15
R16, R20, R21 : 100 kΩ
R7, R14 : 160 kΩ
R22 : 51 Ω
R23, R24 : 100 Ω
C1 : 470 pF
C2 : 0.022 μF
C3 : 0.047 μF
C4 : 0.1 μF
C5 : 0.22 μF
C6 : 0.47 μF
C7 : 0.01 μF

* MAGNETIC SHIELD IS CONNECTED TO GND INSIDE OF THIS PRODUCT.

TPMHA0323EB

⑱ H8318-70

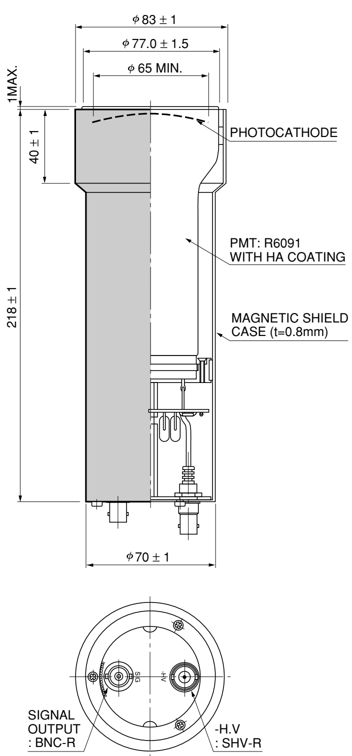


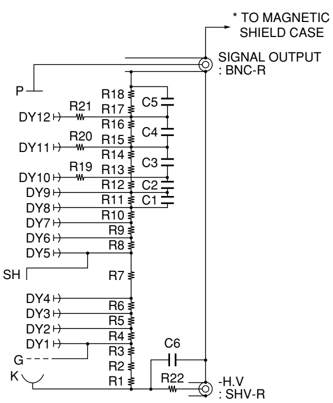


R1 to R21 : 330 kΩ
R22, R29 : 1 MΩ
R23 to R26 : 51 Ω
R27 : 10 kΩ
R28 : 100 kΩ
C1 to C5 : 0.01 μF
C6, C7 : 0.0047 μF

TPMHA0473EA

⑲ H6559



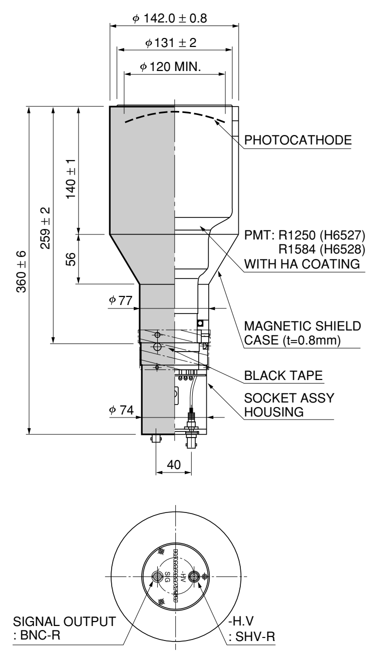


R1, R5 : 240 kΩ
R2, R10, R16 : 220 kΩ
R3, R9 : 180 kΩ
R4, R6 to R8, R14, R18 : 150 kΩ
R11, R13, R17 : 300 kΩ
R12, R15 : 360 kΩ
R19 : 51 Ω
R20, R21 : 100 Ω
R22 : 10 kΩ
C1 : 0.022 μF
C2 : 0.047 μF
C3 : 0.1 μF
C4 : 0.22 μF
C5 : 0.47 μF
C6 : 470 pF

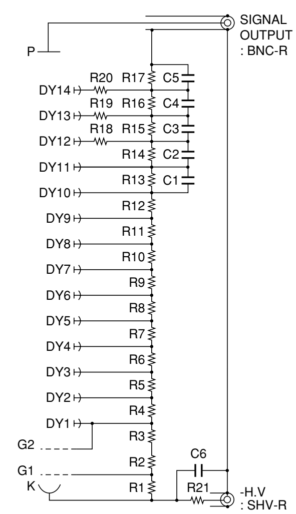
* MAGNETIC SHIELD IS CONNECTED TO GND INSIDE OF THIS PRODUCT.

TPMHA0331EB

⑳ H6527, H6528



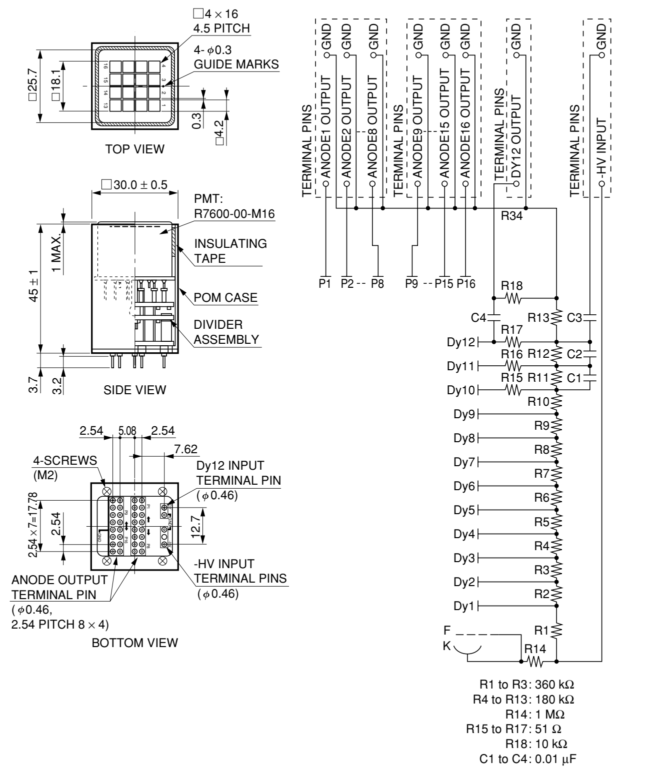
H6527=Flat window, Borosilicate
H6528=Curved window, UV glass



R1, R17 : 240 kΩ
R2 : 360 kΩ
R3 : 390 kΩ
R4 : 120 kΩ
R5 : 180 kΩ
R6 to R13 : 100 kΩ
R14, R15 : 150 kΩ
R16 : 300 kΩ
R18 : 51 Ω
R19, R20 : 100 Ω
R21 : 10 kΩ
C1 : 0.022 μF
C2 : 0.047 μF
C3 : 0.1 μF
C4 : 0.22 μF
C5 : 0.47 μF
C6 : 470 pF

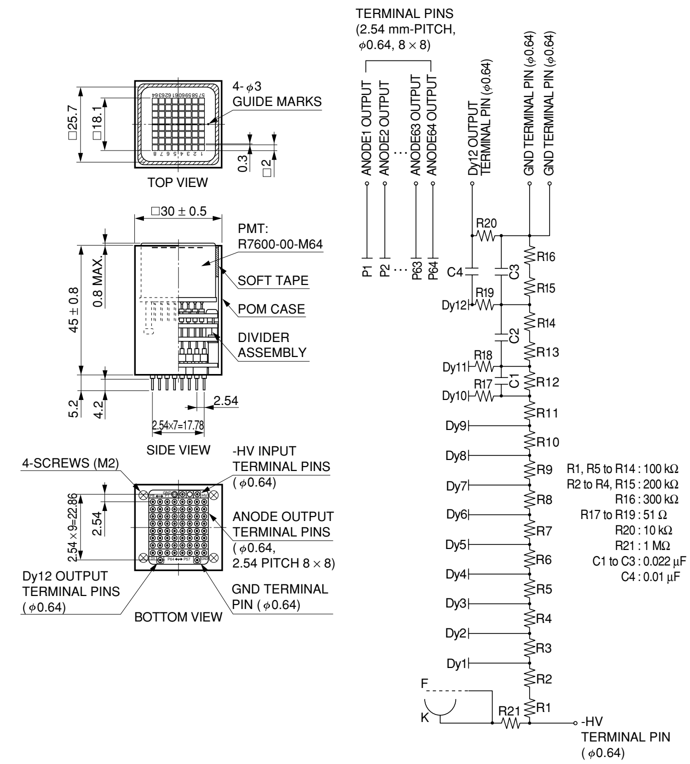
TPMHA0332EC

㉑ H8711



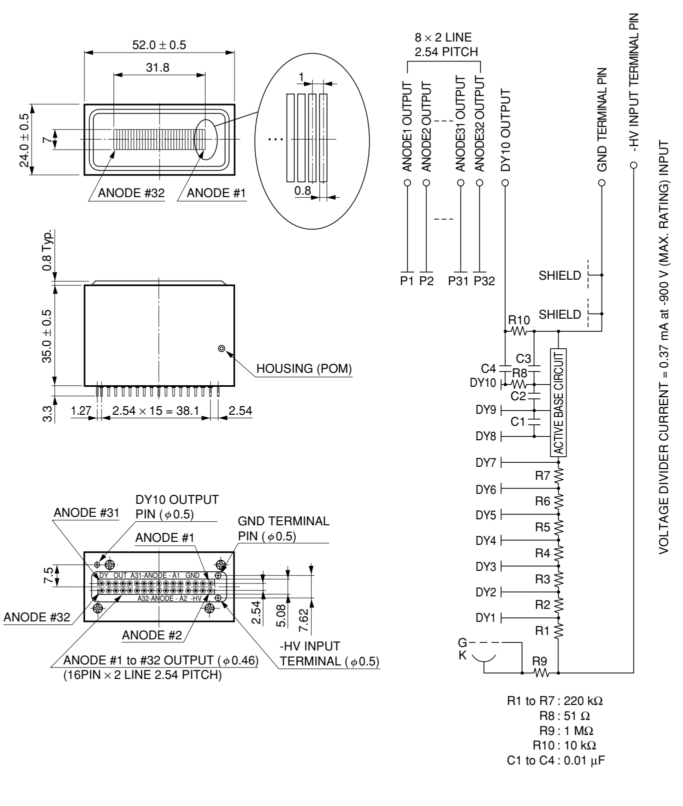
TPMHA0487EB

㉒ H7546B



TPMHA0488EB

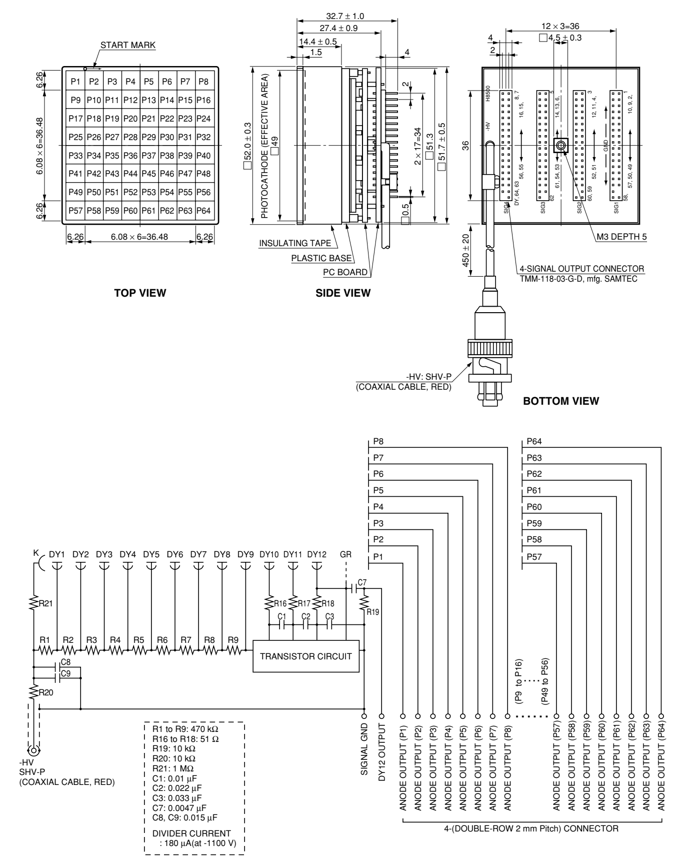
㉓ H7260-20



TPMHA0455EC

TPMHA0192EA

㉔ H8500



TPMHA0498ED

Photomultiplier Tube Socket Assemblies

TACCF0178

Photomultiplier Tube Socket Assemblies

Hamamatsu provides a wide variety of socket assemblies specifically designed for simple and reliable operation of photomultiplier tubes (often abbreviated as PMTs). These socket assemblies consist primarily of a high quality socket and voltage divider circuit integrated into a compact case. Variant types are available with internal current-to-voltage conversion amplifiers, gate circuits and high voltage power supply circuits.

Types of Socket Assemblies

The circuit elements used in Hamamatsu socket assemblies are represented by the three letters below. The socket assembly types are grouped according to the combination of these letters.

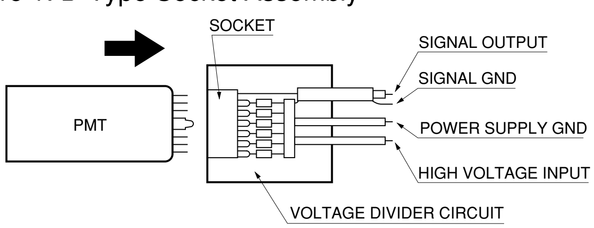
D : Voltage Divider
A : Amplifier
P : High Voltage Power Supply

D-Type Socket Assemblies (E717, E990 Series, etc.)

The D-type socket assemblies contain a voltage divider circuit along with a socket in a compact metallic or plastic case. Plastic case types are potted with silicone compound to ensure high environmental resistance.

Refer to page 78 for the selection guide to D-type socket assemblies.

Figure 1: D-Type Socket Assembly

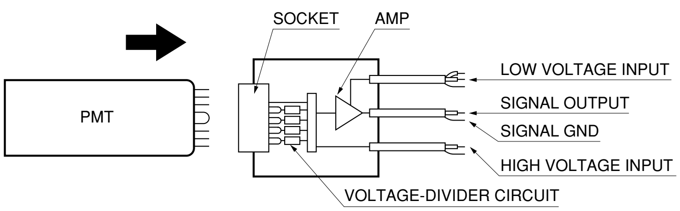


TACCC0001EB

DA-Type Socket Assemblies (C7246, C7247 Series)

In addition to the circuit elements of the D-type socket assemblies, the DA-type socket assemblies include an amplifier that converts the low-level, high-impedance current output of a photomultiplier tube into a low-impedance voltage output. Possible problems from noise induction are eliminated since the high-impedance output of the photomultiplier tube is connected to the amplifier at the minimum distance.

Figure 2: DA-Type Socket Assembly

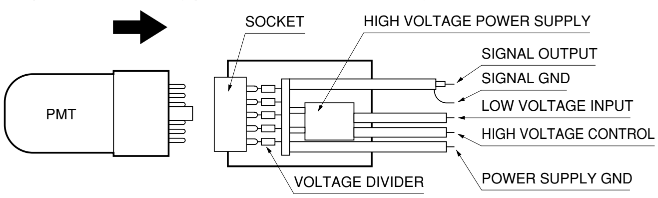


TACCC0002ED

DP-Type Socket Assemblies (C6270)

DP-type socket assemblies comprise a built-in high-voltage power supply circuit added to a D-type socket assembly.
The C6270 uses an active voltage divider circuit and a high voltage power supply.

Figure 3: DP-Type Socket Assembly



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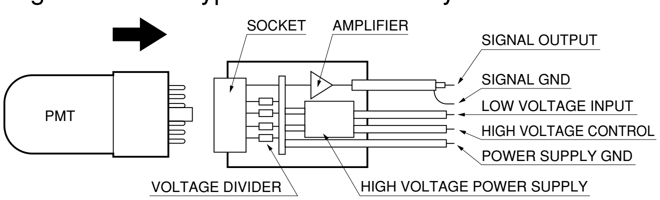
DAP-Type Socket Assemblies (C6271)

This type of socket assembly has a current-to-voltage conversion amplifier and a high voltage power supply, efficiently added to the circuit components of the D-type socket assembly.

Figure 4: DAP-Type Socket Assembly



TACCC0054EA

Basics of Voltage Dividers

The following information describes voltage divider circuits which are basic to all types of socket assemblies. Refer to this section for information on proper use of the socket assemblies.

Voltage Divider Circuits

To operate a photomultiplier tube, a high voltage of 500 volts to 2000 volts is usually supplied between the photocathode (K) and the anode (P), with a proper voltage gradient set up along the photoelectron focusing electrode (F) or grid (G), secondary electron multiplier electrodes or dynodes (Dy) and, depending on photomultiplier tube type, an accelerating electrode (Acc). Figure 5 shows a schematic representation of photomultiplier tube operation using independent multiple power supplies, but this is not a practical method. Instead, a voltage divider circuit is commonly used to divide, by means of resistors, a high voltage supplied from a single power supply.

Figure 5: Schematic Representation of Photomultiplier Tube Operation

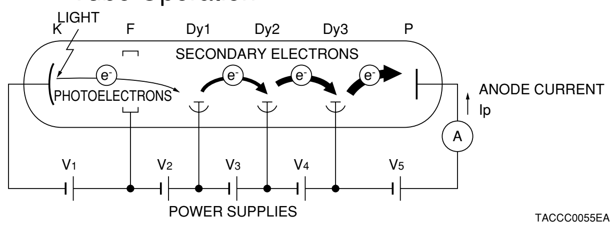
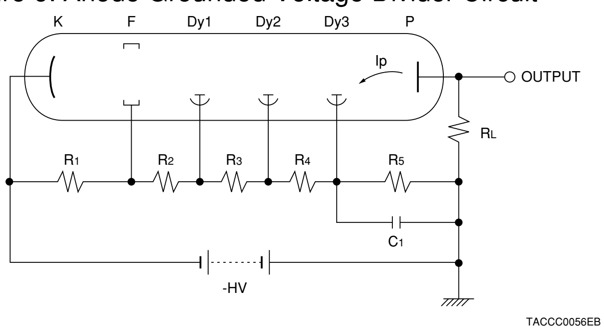


Figure 6 shows a typical voltage divider circuit using resistors, with the anode side grounded. The capacitor C_1 connected in parallel to the resistor R_5 in the circuit is called a storage capacitor and improves the output linearity when the photomultiplier tube is used in pulse operation, and not necessarily used in providing DC output. In some applications, transistors or Zener diodes may be used in place of these resistors.

Figure 6: Anode Grounded Voltage Divider Circuit

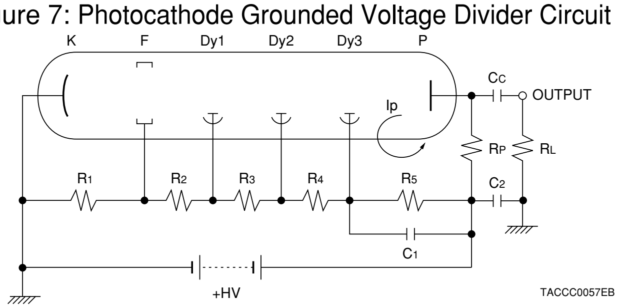


Anode Grounding and Photocathode Grounding

In order to eliminate the potential difference between the photomultiplier tube anode and external circuits such as an ammeter, and to facilitate the connection, the generally used technique for voltage divider circuits is to ground the anode and supply a high negative voltage (-HV) to the photocathode, as shown in Figure 6. This scheme provides the signal output in both DC and pulse operations, and is therefore used in a wide range of applications.

In photon counting and scintillation counting applications, however, the photomultiplier tube is often operated with the photocathode grounded and a high positive voltage (+HV) supplied to the anode mainly for purposes of noise reduction. This photocathode grounding scheme is shown in Figure 7, along with the coupling capacitor C_C for isolating the high voltage from the output circuit. Accordingly, this setup cannot provide a DC signal output and is only used in pulse output applications. The resistor R_P is used to give a proper potential to the anode. The resistor R_L is placed as a load resistor, but the actual load resistance will be the combination of R_P and R_L.

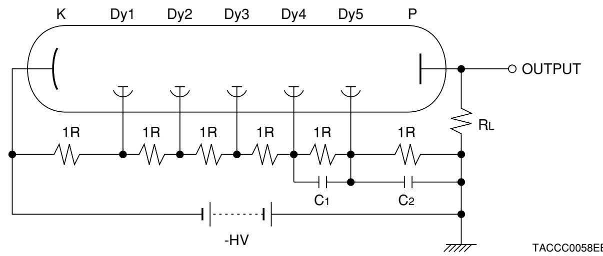
Figure 7: Photocathode Grounded Voltage Divider Circuit



Standard Voltage Divider Circuits

Basically, the voltage divider circuits of socket assemblies listed in this catalog are designed for standard voltage distribution ratios which are suited for constant light measurement. Socket assemblies for side-on photomultiplier tubes in particular mostly use a voltage divider circuit with equal interstage voltages allowing high gain.

Figure 8: Equally Divided Voltage Divider Circuit



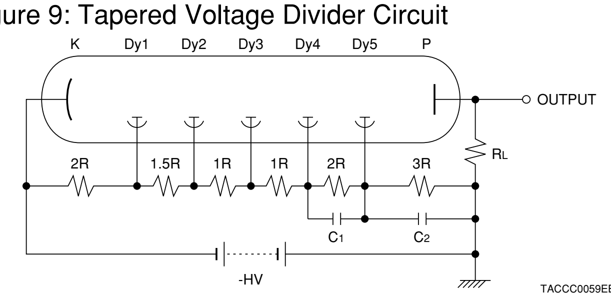
Tapered Voltage Divider Circuits

In most pulsed light measurement applications, it is often necessary to enhance the voltage gradient at the first and/or last few stages of the voltage divider circuit, by using larger resistances as shown in Figure 9. This is called a tapered voltage divider circuit and is effective in improving various characteristics. However it should be noted that the overall gain decreases as the voltage gradient becomes greater. In addition, care is required regarding the interstage voltage tolerance of the photomultiplier tube as higher voltage is supplied. The tapered voltage circuit types and their suitable applications are listed below.

Tapered circuit at the first few stages (resistance: large → small)
- Photon counting (improvement in pulse height distribution)
- Low-light-level detection (S/N ratio enhancement)
- High-speed pulsed light detection (improvement in timing properties)
- Other applications requiring better magnetic characteristics and uniformity

Tapered circuit at the last few stages (resistance: small → large)
- High pulsed light detection (improvement in output linearity)
- High-speed pulsed light detection (improvement in timing properties)
- Other applications requiring high output across the load resistor

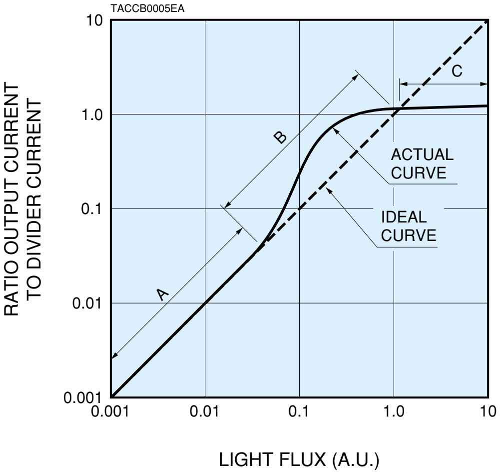
Figure 9: Tapered Voltage Divider Circuit



Voltage Divider Circuit and Photomultiplier Tube Output Linearity

In both DC and pulse operations, when the light incident on the photocathode increases to a certain level, the relationship between the incident light level and the output current begins to deviate from the ideal linearity. As can be seen from Figure 10, region A maintains good linearity, and region B is the so-called overlinearity range in which the output increase is larger than the ideal level. In region C, the output goes into saturation and becomes smaller than the ideal level. When accurate measurement with good linearity is essential, the maximum output current must be within region A. In contrast, the lower limit of the output current is determined by the dark current and noise of the photomultiplier tube as well as the leakage current and noise of the external circuit.

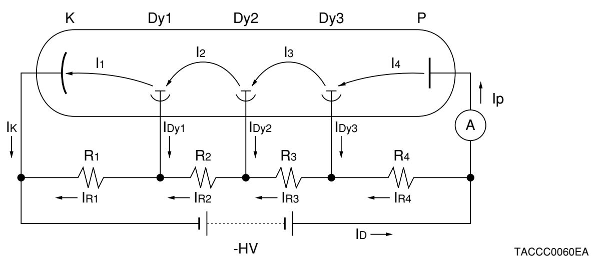
Figure 10: Output Linearity of Photomultiplier Tube



Output Linearity in DC Mode

Figure 11 is a simplified representation showing photomultiplier tube operation in the DC output mode, with three stages of dynodes and four dividing resistors R_1 through R_4 having the same resistance value.

Figure 11: Basic Operation of Photomultiplier Tube and Voltage Divider Circuit



[When light is not incident on the tube]

In dark state operation where a high voltage is supplied to a photomultiplier tube without incident light, the current components flowing through the voltage divider circuit will be similar to those shown in Figure 12 (if we ignore the photomultiplier tube dark current). The relation of current and voltage through each component is given below

Interelectrode current of photomultiplier tube

$I_1=I_2=I_3=I_4$ (= 0 A)

Electrode current of photomultiplier tube

$I_K=I_{Dy1}=I_{Dy2}=I_{Dy3}=I_P$ (= 0 A)

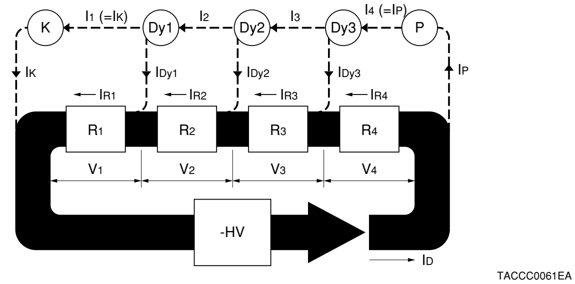
Voltage divider circuit current

$I_{R1}=I_{R2}=I_{R3}=I_{R4}=I_D= (HV/\sum_{n=1}^{4} R_n)$

Voltage divider circuit voltage

$V_1=V_2=V_3=V_4=I_D \cdot R_n$ (= HV/4)

Figure 12: Operation without Light Input



[When light is incident on the tube]

When light is allowed to strike the photomultiplier tube under the conditions in Figure 12, the resulting currents can be considered to flow through the photomultiplier tube and the voltage divider circuit as schematically illustrated in Figure 13. Here, all symbols used to represent the current and voltage are expressed with a prime ('), to distinguish them from those in dark state operation.

The voltage divider circuit current I_D' is the sum of the voltage divider circuit current I_D in dark state operation and the current flowing through the photomultiplier tube ΔI_D (equal to average interelectrode current). The current flowing through each dividing resistor Rn becomes as follows:

$I_{Rn}' = I_D' - I_n'$

Where In' is the interelectrode current which has the following relation:

$I_1' < I_2' < I_3' < I_4'$

Thus, the interstage voltage V_n' (=$I_{Rn}' \cdot R_n$) becomes smaller at the latter stages, as follows:

$V_1' > V_2' > V_3' > V_4'$

Figure 13: Operation with Light Input

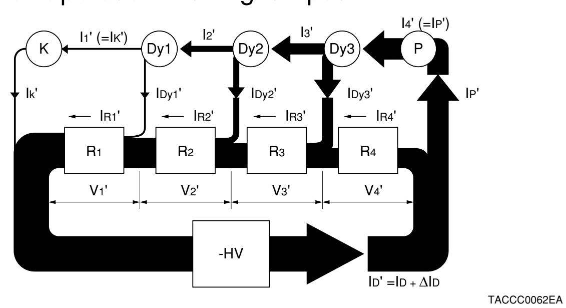
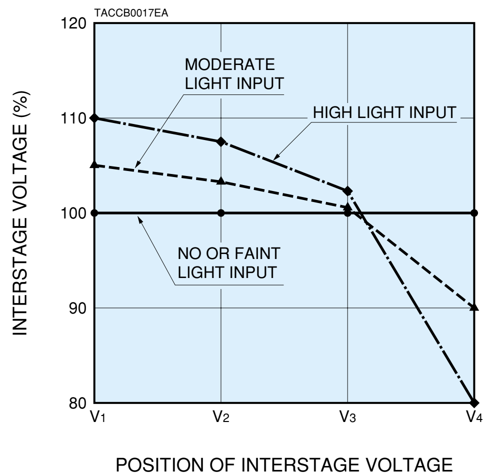


Figure 14 shows changes in the interstage voltages as the incident light level varies. The interstage voltage V_4' with light input drops significantly compared to V_4 in dark state operation. This voltage loss is redistributed to the other stages, resulting an increases in V_1', V_2' and V_3' which are higher than those in dark state operation. The interstage voltage V_4' is only required to collect the secondary electrons emitted from the last dynode to the anode, so it has little effect on the anode current even if dropped to 20 or 30 volts. In contrast, the increases in V_1', V_2' and V_3' directly raise the secondary emission ratios (δ_1, δ_2 and δ_3) at the dynodes Dy1, Dy2 and Dy3, and thus boost the overall gain m (= $\delta_1 \cdot \delta_2 \cdot \delta_3$). This is the cause of overlinearity in region B in Figure 10. As the incident light level further increases so that V4' approaches 0 volts, output saturation occurs in region C.

Figure 14: Changes in Interstage Voltages at Different Incident Light Levels



Linearity Improvement in DC Output Mode

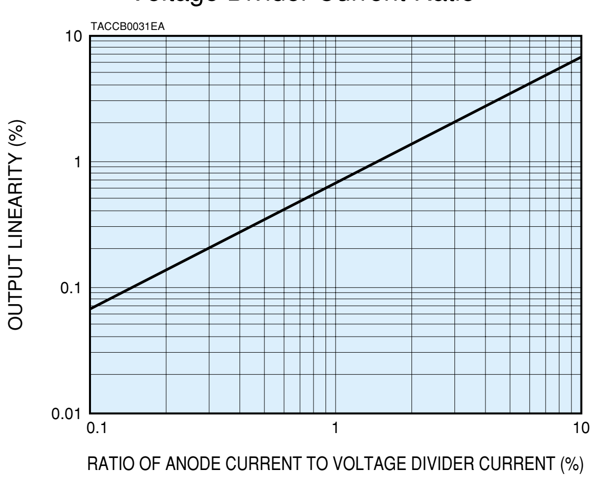
To improve the linearity in DC output mode, it is important to minimize the changes in the interstage voltage when photocurrent flows through the photomultiplier tube. There are several specific methods for improving the linearity, as discussed below.

①Increasing the voltage divider current

Figure 15 shows the relationship between the output linearity of a 28 mm (1-1/8") diameter side-on photomultiplier tube and the ratio of anode current to voltage divider current. This is a sample plot, so actual data may differ from tube to tube even for the same type of photomultiplier tube, depending on the supply voltage and individual dynode gains. To ensure high photometric accuracy, it is recommended that the voltage divider current be maintained at least twice the value obtained from this figure.

The maximum linear output in DC mode listed for the D-type socket assemblies in this catalog indicates the anode current equal to 1/20 of the voltage divider current. The output linearity at this point can be maintained within ±3 % to ±5 %.

Figure 15: Output Linearity vs. Anode Current to Voltage Divider Current Ratio

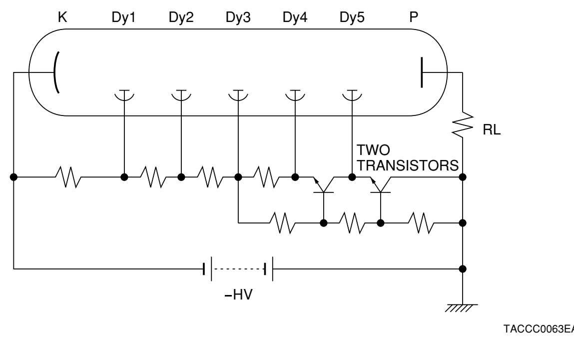


As stated above, good output linearity can be obtained simply by increasing the voltage divider current. However, this is accompanied by heat emanating from the voltage divider. If this heat is conducted to the photomultiplier tube, it may cause problems such as an increase in the dark current, and variation in the output.

②Using the active voltage divider circuit

Use of a voltage divider circuit having transistors in place of the dividing resistors in last few stages (for example, Hamamatsu E6270 series using FETs) is effective in improving the output linearity. This type of voltage divider circuit ensures good linearity up to an output current equal to 60 % to 70 % of the voltage divider current, since the interstage voltage is not affected by the interelectrode current inside the photomultiplier tube. A typical active voltage divider circuit is shown in Figure 16. (See page 93 for DC linearity characteristics examples.)

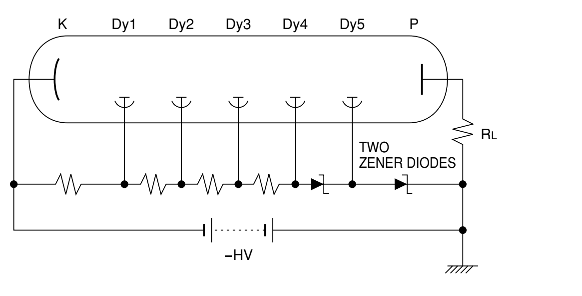
Figure 16: Active Voltage Divider Circuit



③Using Zener Diodes

The output linearity can be improved by using Zener diodes in place of the dividing resistors in the last few stages, because the Zener diodes serve to maintain the interstage voltages at a constant level. However, if the supply voltage is greatly varied, the voltage distribution may be imbalanced compared to other interstage voltages, thus limiting the adjustable range of the voltage with this technique. In addition, if the supply voltage is reduced or if the current flowing through the Zener diodes becomes insufficient due to an increase in the anode current, noise may be generated from the Zener diodes. Precautions should be taken when using this type of voltage divider circuit. Figure 17 shows a typical voltage divider circuit using Zener diodes.

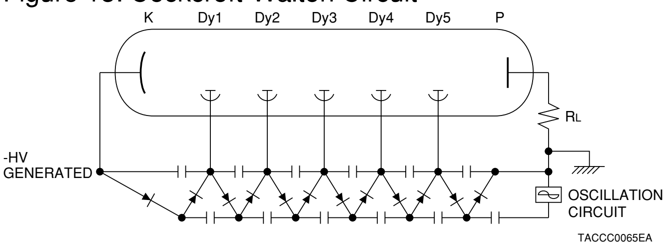
Figure 17: Voltage Divider Circuit Using Zener Diodes



④Using Cockcroft-Walton Circuit

When a Cockcroft-Walton circuit as shown in Figure 18 is used to operate a 28 mm (1-1/8") diameter side-on photomultiplier tube with a supply voltage of 1000 volts, good DC linearity can be obtained up to 200 µA and even higher. Since a high voltage is generated by supplying a low voltage to the oscillator circuit, there is no need for using a high voltage power supply.
This Cockcroft-Walton circuit achieves superior DC output linearity as well as low current consumption.

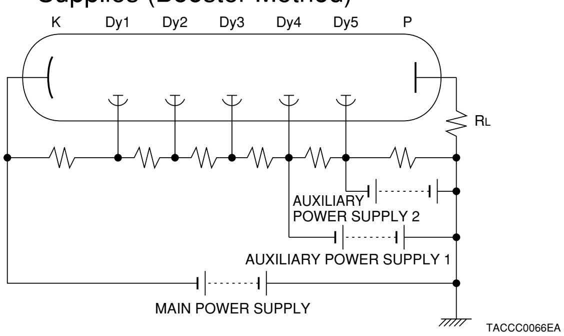
Figure 18: Cockcroft-Walton Circuit



⑤Using multiple high voltage power supplies

As shown in Figure 19, this technique uses multiple power supplies to directly supply voltages to the last few stages near the anode. This is sometimes called the booster method, and is used for high pulse and high count rate applications in high energy physics experiments.

Figure 19: Voltage Divider Circuit Using Multiple Power Supplies (Booster Method)



Output Linearity in Pulsed Mode

In applications such as scintillation counting where the incident light is in the form of pulses, individual pulses may range from a few to over 100 milliamperes even though the average anode current is small at low count rates. In this pulsed output mode, the peak current in extreme cases may reach a level hundreds of times higher than the voltage divider current. If this happens, it is not possible to supply interelectrode currents from the voltage divider circuit to the last few stages of the photomultiplier tube, thus leading to degradation in the output linearity.

Improving Linearity in Pulsed Output Mode

①Using storage capacitors

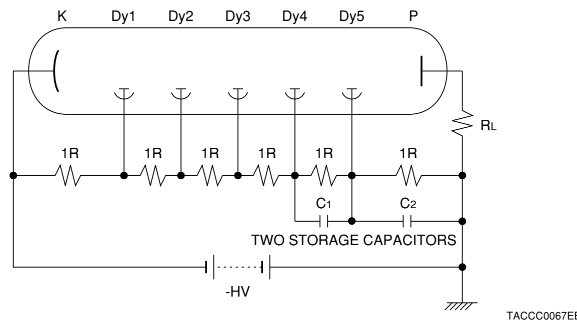
Using multiple power supplies mentioned above is not popular in view of the cost. The most commonly used technique is to supply the interelectrode current by using storage capacitors as shown in Figure 20. There are two methods for connecting these storage capacitors: the serial method and the parallel method. As Figures 20 and 21 show, the serial method is more widely used since it requires lower tolerance voltages of the capacitors. The capacitance value C (farads) of the storage capacitor between the last dynode and the anode should be at least 100 times the output charge as follows:

$$C > 100 \cdot Q/V$$

where Q is the charge of one output pulse (coulombs) and V is the voltage (volts) across the last dynode and the anode.

Since this method directly supplies the pulse current with electrical charges from the capacitors, if the count rate is increased and the resulting duty factor becomes larger, the electrical charge will be insufficient. Therefore, in order to maintain good linearity, the capacitance value obtained from the above equation must be increased according to the duty factor, so that the voltage divider current is kept at least 50 times larger than the average anode current just as with the DC output mode.
The active voltage divider circuit and the booster method using multiple power supplies discussed previously, provide superior pulse output linearity even at a higher duty factor.

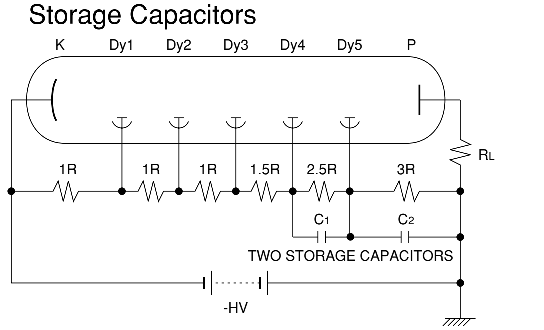
Figure 20: Equally Divided Voltage Divider Circuit and Storage Capacitors



②Using tapered voltage divider circuit with storage capacitors

Use of the above voltage divider circuit having storage capacitors is effective in improving pulse linearity. However, when the pulse current increases further, the electron density also increases, particularly in last stages. This may cause a space charge effect which prevents interelectrode current from flowing adequately and leading to output saturation. A commonly used technique for extracting a higher pulse current is the tapered voltage divider circuit in which the voltage distribution ratios in the latter stages are enhanced as shown in Figure 21. Care should be taken in this case regarding loss of the gain and the breakdown voltages between electrodes.
Since use of a tapered voltage divider circuit allows an increase in the voltage between the last dynode and the anode, it is possible to raise the voltage across the load resistor when it is connected to the anode. It should be noted however, that if the output voltage becomes excessively high, the voltage between the last dynode and the anode may drop, causing a degradation in output linearity.

Figure 21: Tapered Voltage Divider Circuit Using Storage Capacitors



D-Type Socket Assemblies

The D-type socket assemblies are grouped as follows:

(a) For DC output (-HV supply)
Available only upon request

(b) For DC or pulsed output (-HV supply)
e.g. E717-63

(c) For pulsed output (+HV supply)
e.g. E990-08

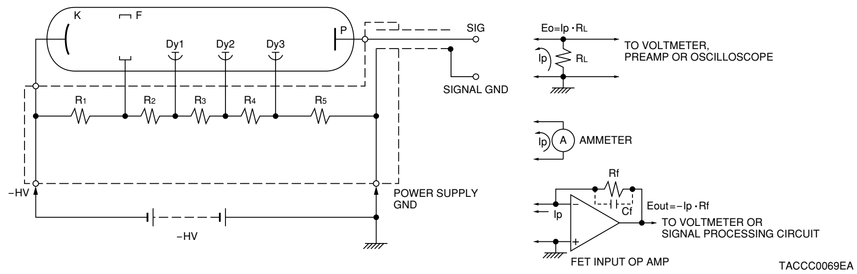
(d) For DC or pulsed output (-HV supply), or pulsed output (+HV supply)
e.g. E717-35

Connection of D-Type Socket Assemblies to External Circuits

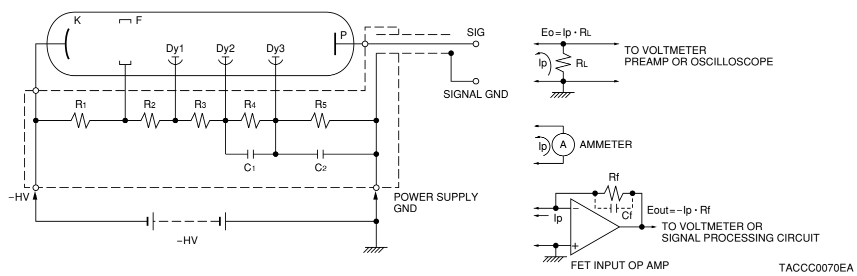
Figure 22 shows typical examples of connecting various D-type socket assemblies to external circuits.

Figure 22: Connection of D-Type Socket Assemblies to Extrernal Circuits

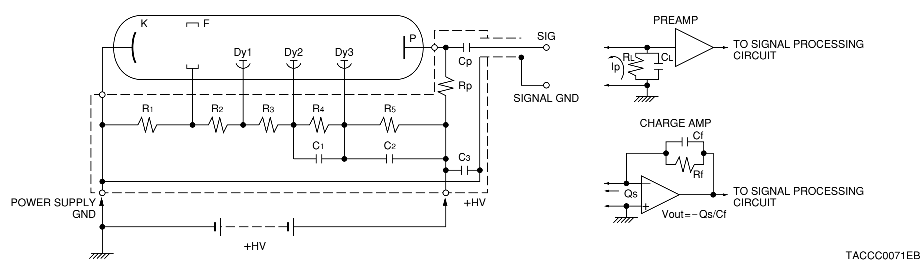
(a) For DC output (-HV supply)



(b) For DC or pulsed output (-HV supply)



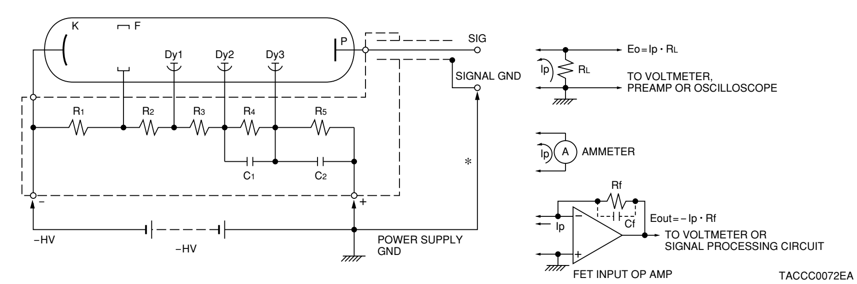
(c) For pulsed output (+HV supply)



(d) For DC or pulsed output (-HV supply),
or pulsed output (+HV supply)

d-1. For DC or pulsed output (-HV supply)

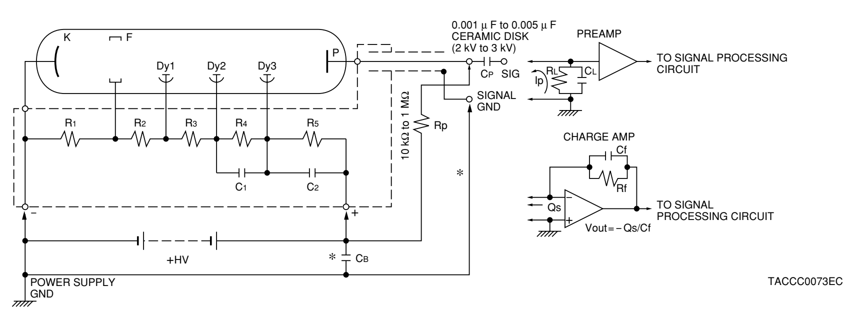
* GND should be connected externaly.



d-2. For pulsed output/+HV supply

For general scintillation counting and photon counting applications, recommended values for C_P and R_P are 0.001 µF to 0.005 µF and 10 kΩ to 1 MΩ. Since a high voltage is supplied to these parts, care must be taken when handling this circuit.

* GND and C_B should be connected externally.



D-Type Socket Assemblies

Socket Assembly Type No.	Applicable PMT Diameter	Outline and Diagram	Grounded Electrode/ Supply Voltage Polarity	Maximum Ratings: Insulation Voltage between Case and Pins (V)	Maximum Ratings: Supply Voltage (V)	Ⓐ Voltage Divider Current (mA)	Ⓑ Leakage Current in Signal Max. (A)	Total Voltage Divider Resistance (MΩ)	Ⓒ Maximum Linear Output in DC Mode (μA)	Signal Output	Note
For Side-on Types											
E850-13	13 mm (1/2")	1	Anode/-	1500	1250	0.38	1×10^{-10}	3.30	18 (at 1250 V)	DC/Pulse	
E850-22		2	Anode/-	1500	1250	0.38	1×10^{-10}	3.30	18 (at 1250 V)	DC/Pulse	E850-13, with connector
E717-63	28 mm (1-1/8")	3	Anode/-	1500	1500	0.45	1×10^{-10}	3.30	22 (at 1500 V)	DC/Pulse	
E717-35		4	Anode·Cathode /+·-	1500	1500	0.45	1×10^{-10}	3.30	22 (at 1500 V)	DC/Pulse	Pin output
E717-500		5	Anode/-	1250	1250	0.38	1×10^{-10}	3.30	18 (at 1250 V)	DC/Pulse	E717-63, with connector
For Head-on Types											
E1761-04	10 mm (3/8")	6	Anode/-	1500	1500	0.41	1×10^{-10}	3.63	20 (at 1500 V)	DC/Pulse	
E1761-22		7	Anode/-	1500	1500	0.37	1×10^{-10}	4.02	19 (at 1500 V)	DC/Pulse	For R2496, with connector
E1761-05		8	Anode/-	1500	1500	0.37	1×10^{-10}	4.02	19 (at 1500 V)	DC/Pulse	For R2496
E849-35	13 mm (1/2")	9	Anode/-	1500	1250	0.34	1×10^{-10}	3.63	17 (at 1250 V)	DC/Pulse	
E849-90		10	Anode/-	1500	1250	0.34	1×10^{-10}	3.63	17 (at 1250 V)	DC/Pulse	E849-35, with connector
E849-68		11	Anode/-	1500	1250	0.27	1×10^{-10}	4.48	13 (at 1250 V)	DC/Pulse	For R4124
E849-52		12	Anode/-	1500	1250	0.31	1×10^{-10}	3.98	15 (at 1250 V)	DC/Pulse	For R2557, with connector
E2183-04	19 mm (3/4")	13	Anode/-	2250	2250	0.59	1×10^{-10}	3.81	29 (at 2250 V)	DC/Pulse	
E974-13		14	Anode/-	1800	1800	0.47	1×10^{-10}	3.81	23 (at 1800 V)	DC/Pulse	
E974-14		15	Cathode/+	1800	1800	0.47	—	3.81	—	Pulse	For Scintillation Counting
E974-17		16	Anode/-	1800	1800	0.47	1×10^{-10}	3.81	23 (at 1800 V)	DC/Pulse	E974-13, with connector
E974-22		17	Anode/-	1800	1800	0.43	1×10^{-10}	4.16	21 (at 1800 V)	DC/Pulse	For R1450, with connector
E2253-05		18	Anode/-	1800	1800	0.35	1×10^{-10}	5.13	17 (at 1800 V)	DC/Pulse	For R3478, with connector
E2253-08		19	Cathode/+	1800	1800	0.35	—	5.13	—	Pulse	For R3478, for Scintillation Counting
E974-18		20	Anode/-	1500	1500	0.37	1×10^{-10}	3.98	18 (at 1500 V)	DC/Pulse	For R1878, with connector
E2924-11	25 mm (1")	21	Anode/-	1800	1800	0.41	1×10^{-10}	4.47	20 (at 1800 V)	DC/Pulse	For R7899
E2924		22	Anode/-	1500	1250	0.29	1×10^{-10}	4.29	14 (at 1250 V)	DC/Pulse	
E2924-500		23	Anode/-	1500	1250	0.29	1×10^{-10}	4.29	14 (at 1250 V)	DC/Pulse	E2924, with connector
E2924-05		24	Cathode/+	1500	1250	0.29	—	4.30	—	Pulse	For Scintillation Counting
E990-07	28 mm (1-1/8")	25	Anode/-	1500	1500	0.38	1×10^{-10}	3.96	18 (at 1500 V)	DC/Pulse	
E990-08		26	Cathode/+	1500	1500	0.38	—	3.96	—	Pulse	For Scintillation Counting
E990-501		27	Anode/-	1500	1500	0.38	1×10^{-10}	3.96	18 (at 1500 V)	DC/Pulse	E990-07, with connector
E2624		28	Anode/-	2500	2500	0.52	1×10^{-10}	4.80	26 (at 2500 V)	DC/Pulse	For R6427,
E2624-05		29	Cathode/+	2500	2500	0.52	—	4.80	—	Pulse	For R6427, for Scintillation Counting
E2624-14		30	Anode/-	2500	2500	0.52	1×10^{-10}	4.80	26 (at 2500 V)	DC/Pulse	E2624, with connector

NOTE: Ⓐ Measured with the maximum supply voltage
Ⓑ Measured with a supply voltage of 1000 V
Ⓒ The current at which the output linearity is kept within ±5 %

Temperature ranges of D-type socket assemblies.
Operating: 0 °C to +50 °C
Storage : -15 °C to +60 °C

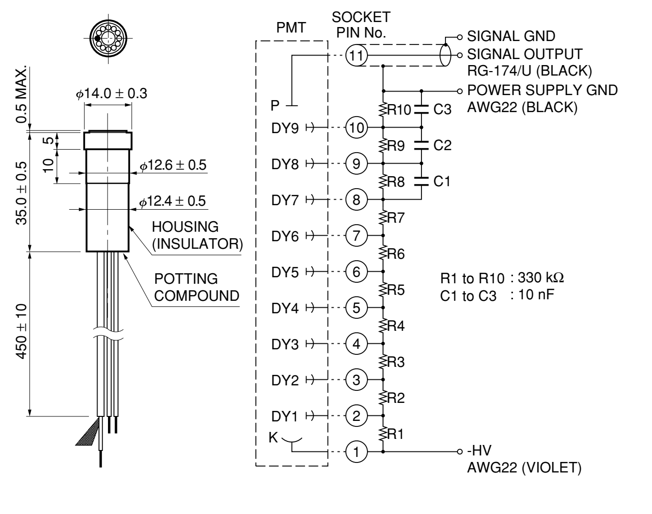
Socket Assembly Type No.	Applicable PMT Diameter	Out-line and Dia-gram	Grounded Electrode/ Supply Voltage Polarity	Maximum Ratings Insulation Voltage between Case and Pins (V)	Maximum Ratings Supply Voltage (V)	Maximum Ratings Ⓐ Voltage Divider Current (mA)	Ⓑ Leakage Current in Signal Max. (A)	Total Voltage Divider Resistance (MΩ)	Ⓒ Maximum Linear Output in DC Mode (μA)	Signal Output	Note
For Head-on Types											
E990-500	28 mm (1-1/8")	31	Anode/-	1500	1500	0.35	1×10^{-10}	4.29	17 (at 1500 V)	DC/Pulse	
E990-29		32	Anode/-	1500	1500	0.34	1×10^{-10}	4.48	16 (at 1500 V)	DC/Pulse	For R3998-02
E2183-500	38 mm (1-1/2")	33	Anode/-	2000	1750	0.45	1×10^{-10}	3.97	22 (at 1750 V)	DC/Pulse	With connector
E2183-502		34	Cathode/+	2000	1750	0.45	—	3.96	—	Pulse	With connector, for scintillation counting
E1198-26	51 mm (2") 76 mm (3")	35	Anode/-	1500	1500	0.38	1×10^{-10}	4.01	18 (at 1500 V)	DC/Pulse	
E1198-27		36	Cathode/+	1500	1500	0.38	—	4.01	—	Pulse	For scintillation counting
E1198-05		37	Anode/-	1500	1500	0.46	1×10^{-10}	3.3	22 (at 1500 V)	DC/Pulse	
E1198-20		38	Cathode/+	1500	1500	0.46	—	3.3	—	Pulse	For scintillation counting
E1198-07	51 mm (2")	39	Anode/-	1750	1750	0.44	1×10^{-10}	3.98	22 (at 1750 V)	DC/Pulse	For R2154-02
E2979-500		40	Anode/-	3000	3000	0.70	1×10^{-10}	4.31	34 (at 3000 V)	DC/Pulse	For R1828-01, with rear panel connector, with magnetic shield
E2979-501		41	Anode/-	2500	2500	0.67	1×10^{-10}	3.75	33 (at 2500 V)	DC/Pulse	For R3234-01, with rear panel connector, with magnetic shield
E1198-23	51 mm (2") 76 mm (3") 127 mm (5")	42	Cathode/+	2200	2000	0.50	—	3.97	—	Pulse	For scintillation counting
E1198-22		43	Anode/-	2200	2000	0.50	1×10^{-10}	3.97	25 (at 2000 V)	DC/Pulse	
E6316		44	Cathode/+	2200	2000	0.50	—	3.97	—	Pulse	For E1198-23, with rear panel connector, for scintillation counting
E6316-01		45	Anode/-	2200	2000	0.50	1×10^{-10}	3.97	25 (at 2000 V)	DC/Pulse	For E1198-22, with rear panel connector
E5859-05	51 mm (2") 76 mm (3")	46	Anode/-	1500	1500	0.38	1×10^{-10}	3.98	18 (at 1500 V)	DC/Pulse	With rear panel connector
E5859		47	Anode/-	2700	2700	0.67	1×10^{-10}	4.06	33 (at 2700 V)	DC/Pulse	With rear panel connector
E5859-01		48	Anode/-	2700	2700	0.75	1×10^{-10}	3.62	37 (at 2700 V)	DC/Pulse	With rear panel connector
E5859-03		49	Cathode/+	2700	2700	0.75	—	3.63	—	Pulse	With rear panel connector, for scintillation counting
E1435-02	51 mm (2")	50	Anode/-	1500	1500	0.38	1×10^{-10}	3.96	18 (at 1500 V)	DC/Pulse	
E7693	127 mm (5")	51	Anode/-	3000	3000	1.02	1×10^{-10}	2.94	51 (at 3000 V)	DC/Pulse	For R1250, for R1584, with rear panel connector
E7694	208 mm (8")	52	Anode/-	1800	1800	0.38	1×10^{-10}	4.71	19 (at 1800 V)	DC/Pulse	For R5912, with rear panel connector
E7694-01		53	Cathode/+	1800	1800	0.38	—	4.71	—	Pulse	For R5912, with rear panel connector
E5780	Metal Package PMT R7400U Series	54	Anode/-	1000	1000	0.36	1×10^{-10}	2.8	17 (at 1000 V)	DC/Pulse	
E5996	Metal Package PMT R7600U Series	55	Anode/-	900	900	0.33	1×10^{-10}	2.75	16 (at 900 V)	DC/Pulse	
E7083	Metal Package PMT R7600U-M4 Series	56	Anode/-	900	900	0.33	1×10^{-10}	2.75	4 Ⓓ (at 900 V)	DC/Pulse	
E6736	Metal Package PMT R5900U-L16	57	Anode/-	900	900	0.38	1×10^{-10}	2.42	1.16 Ⓓ (at 900 V)	DC/Pulse	
E7514	Metal Package PMT R8520U-C12	58	Anode/-	1000	1000	0.34	1×10^{-10}	2.97	1.4 Ⓓ (at 1000 V)	DC/Pulse	
E6133-04	for High Magnetic Environments 25 mm (1")	59	Cathode/+	2500	2500	0.45	—	5.62	—	Pulse	For R5505, with connector

NOTE: Ⓓ Current of one anode

CAUTION: Socket assemblies are not designed to operate in a vacuum.

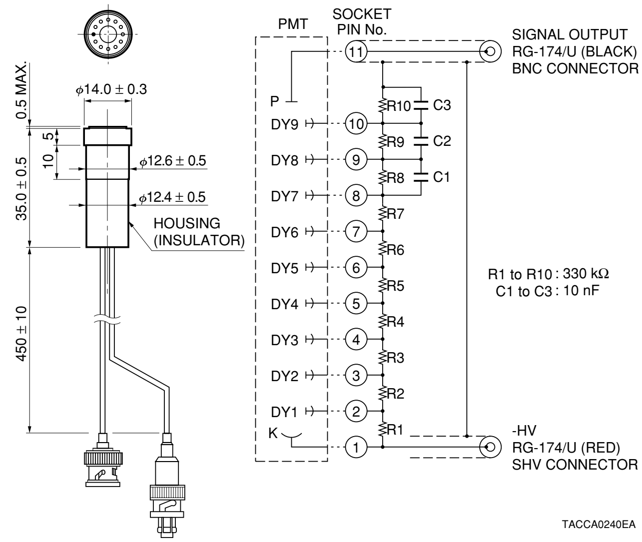
D-Type Socket Assemblies Dimensional Outlines and Diagrams (Unit: mm)

1 E850-13



TACCA0096EC

2 E850-22



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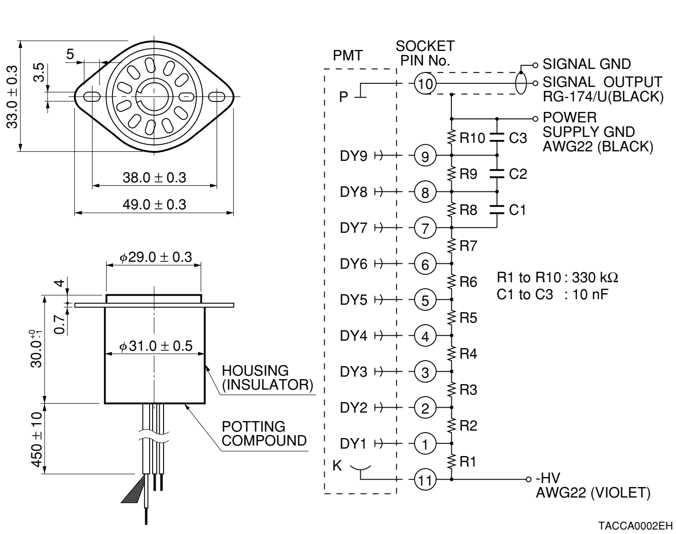
3 E717-63



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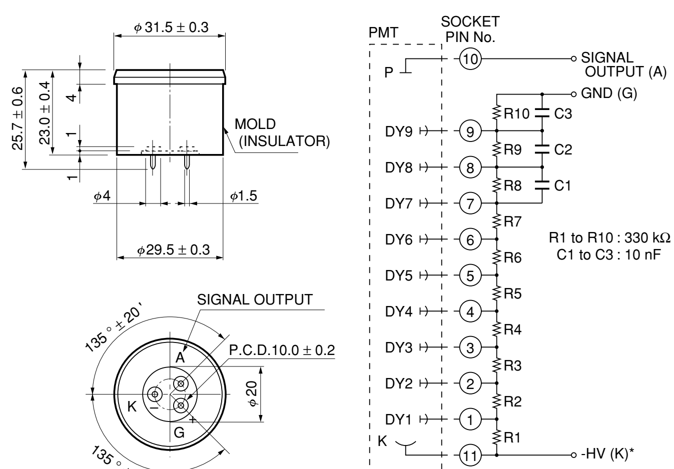
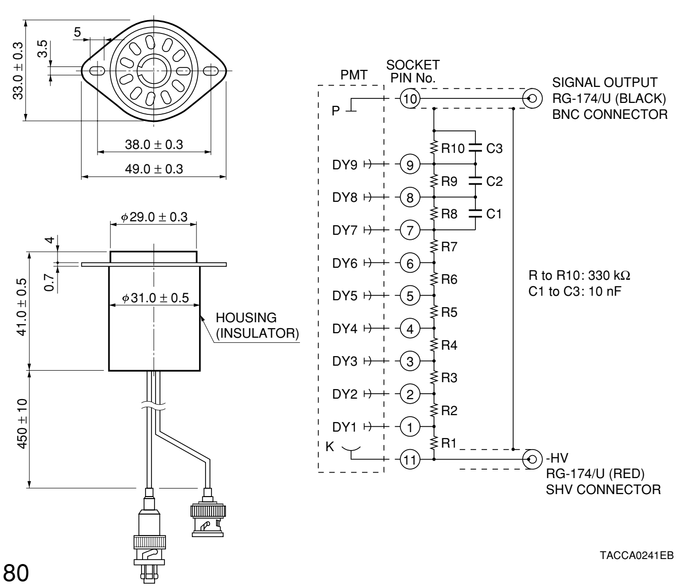
4 E717-35



* "Wiring diagrm at left applies when -HV is supplied." To supply +HV,connect the pin "G" to+HV, and the pin "K" to the GND.

TACCA0098ED

5 E717-500



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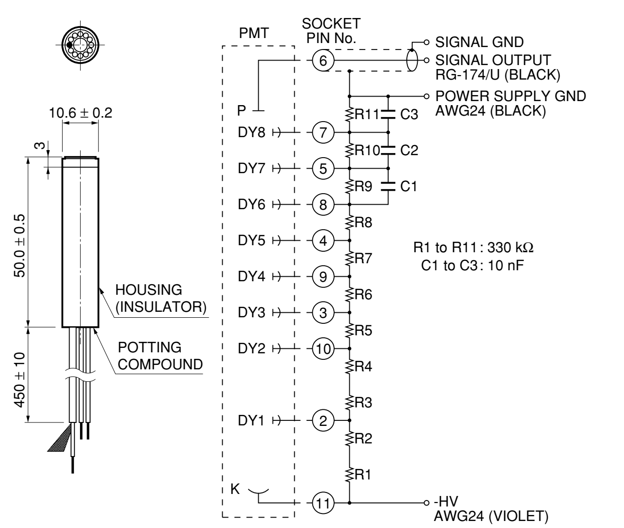
6 E1761-04



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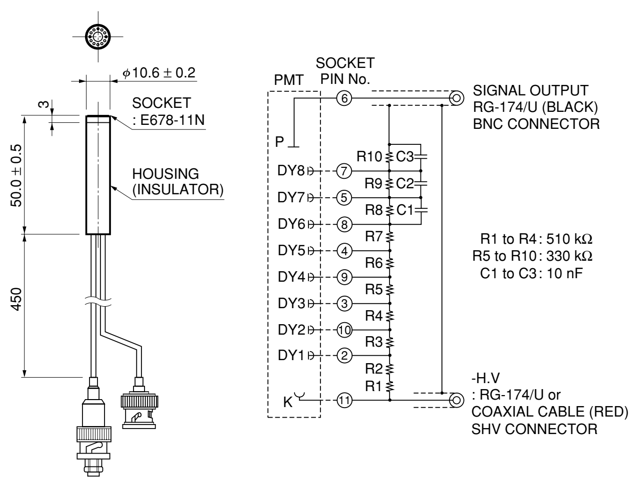
7 E1761-22



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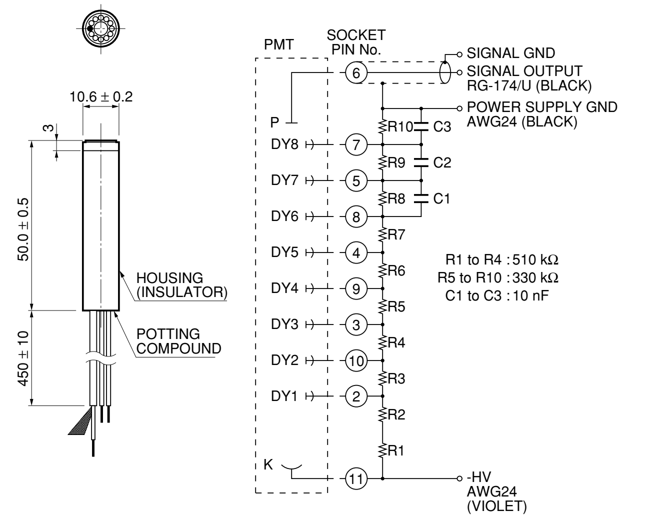
8 E1761-05



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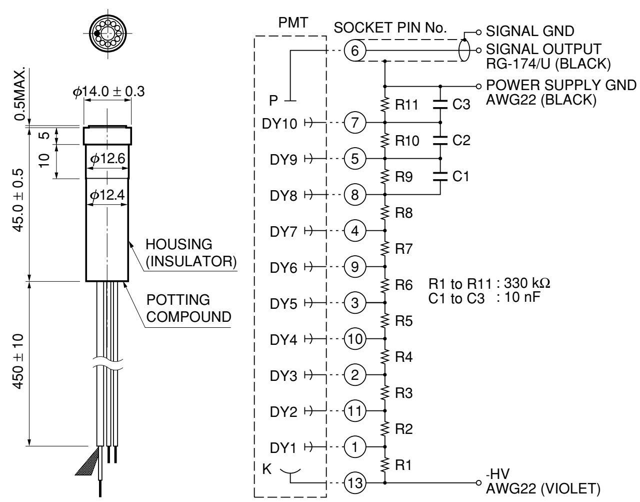
9 E849-35



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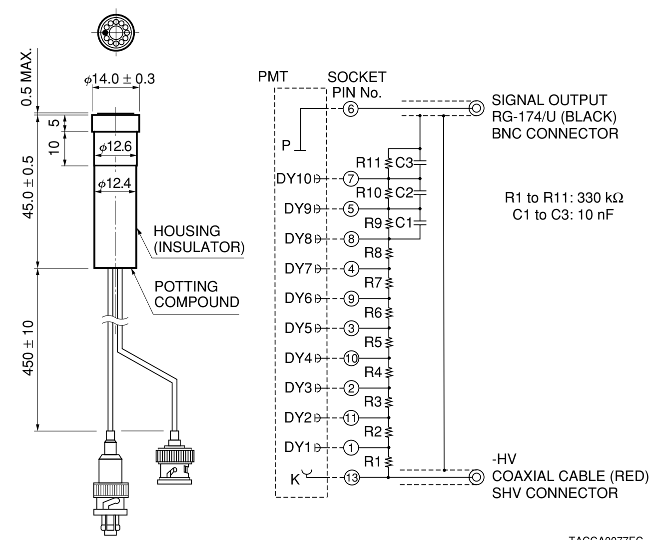
10 E849-90



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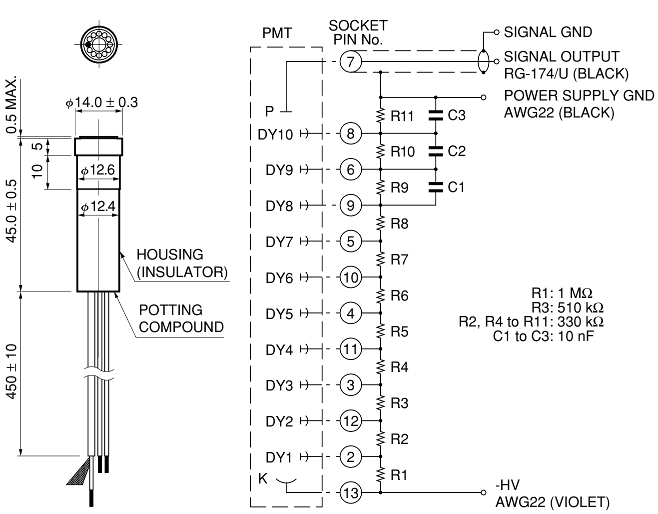
11 E849-68



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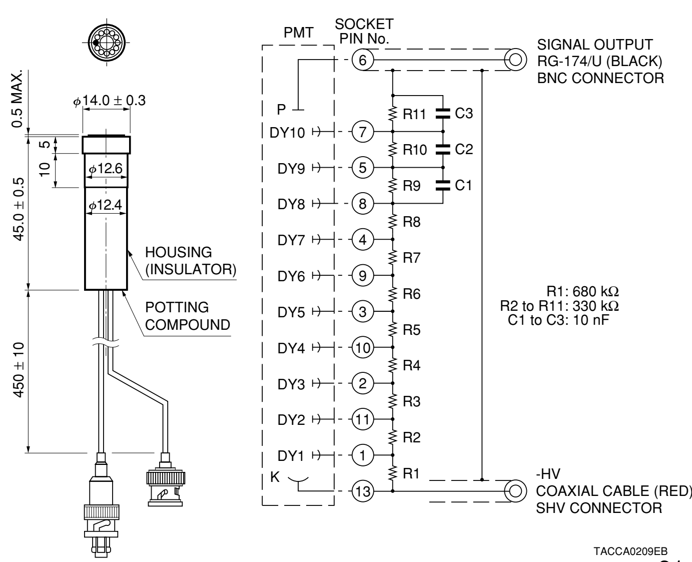
12 E849-52



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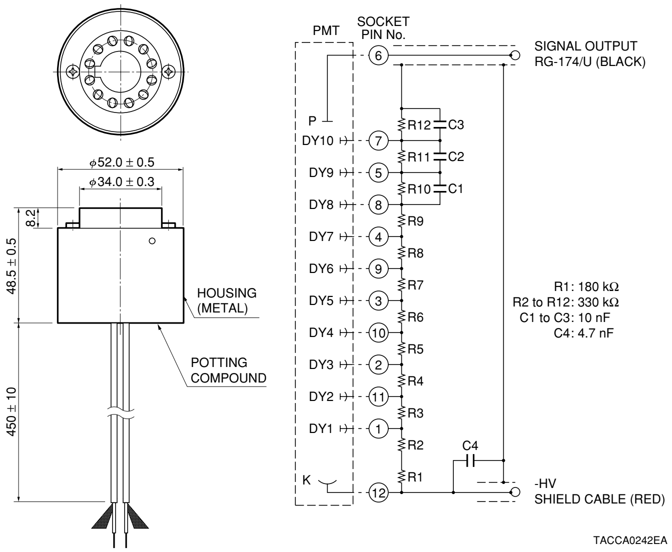
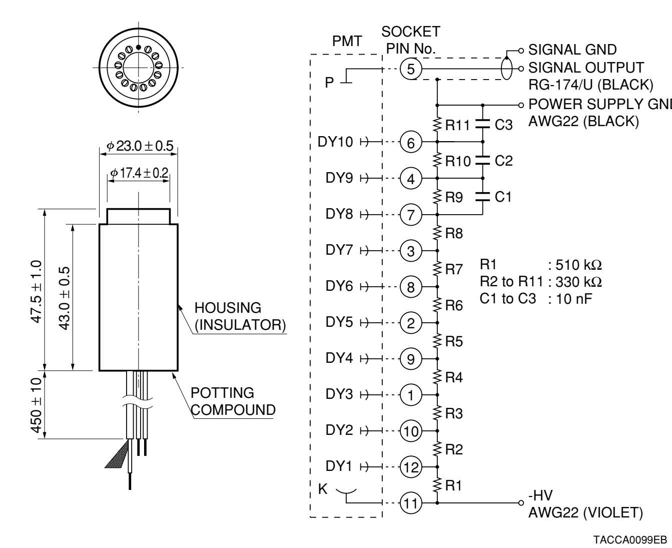
⑬ E2183-04



⑭ E974-13



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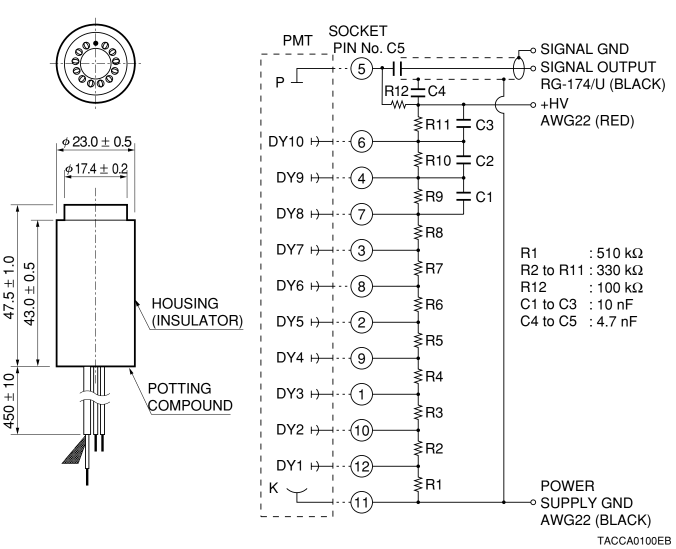
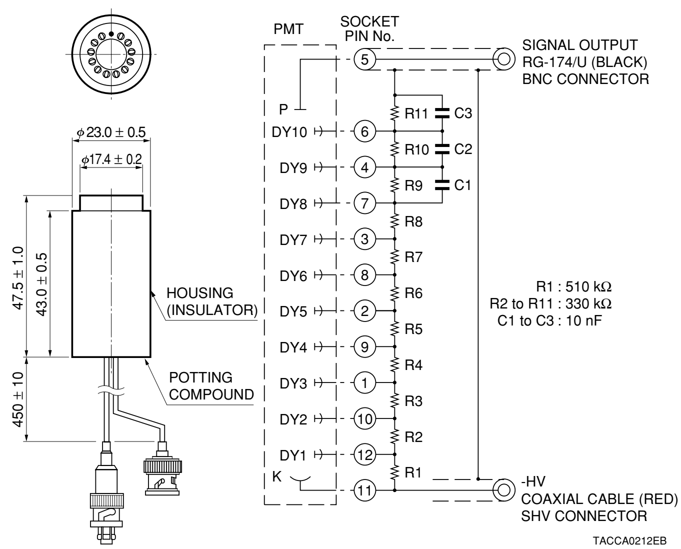
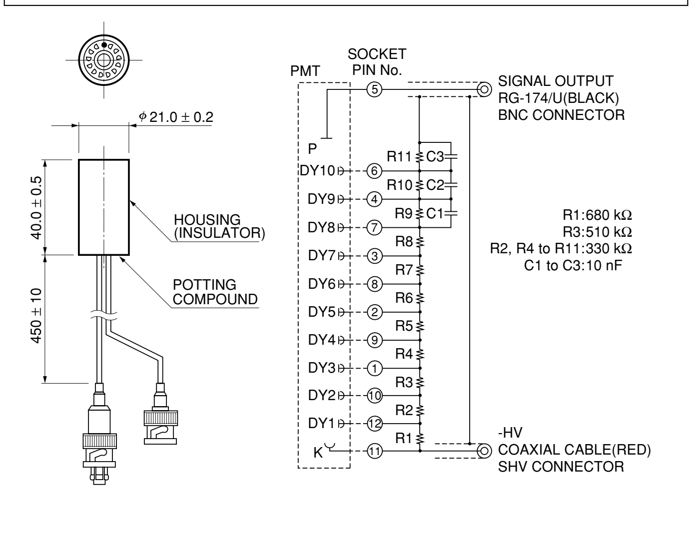


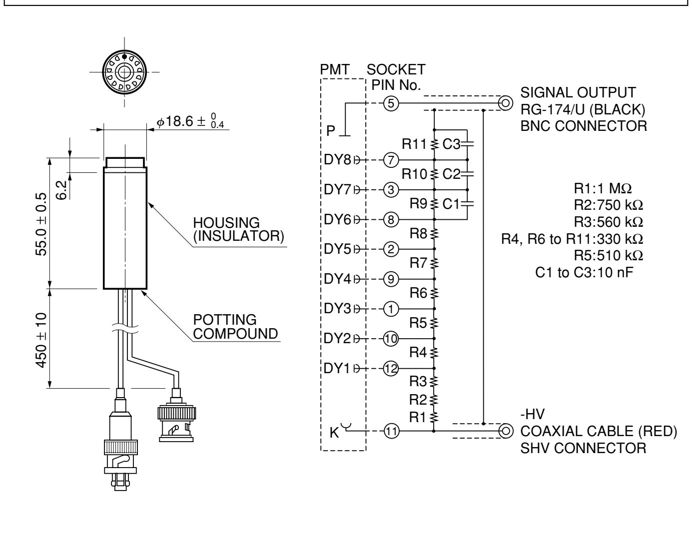
⑯ E974-17



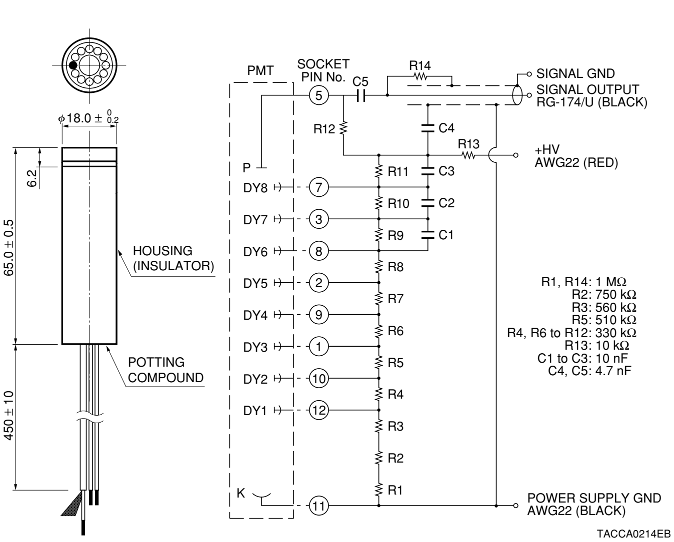
⑰ E974-22



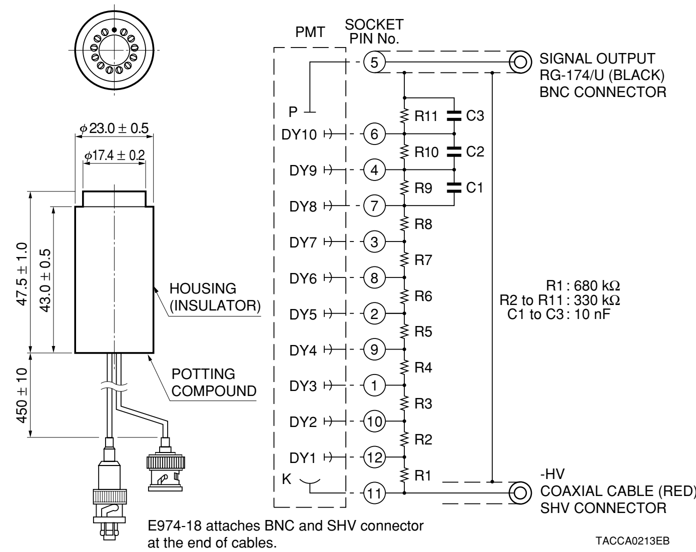
⑱ E2253-05



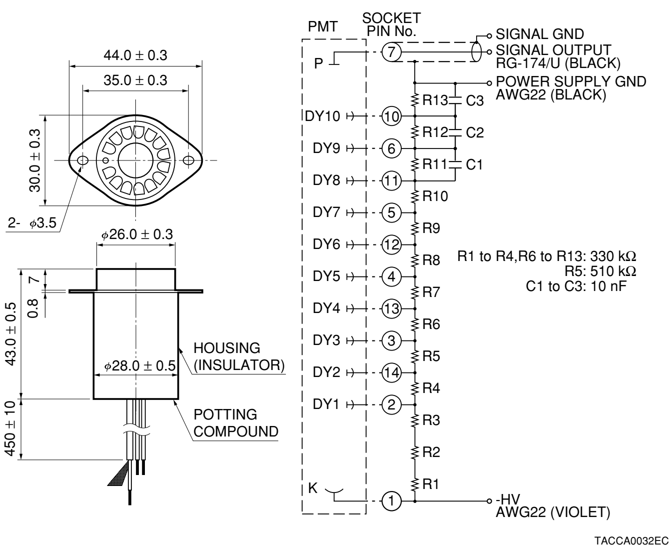
⑲ E2253-08



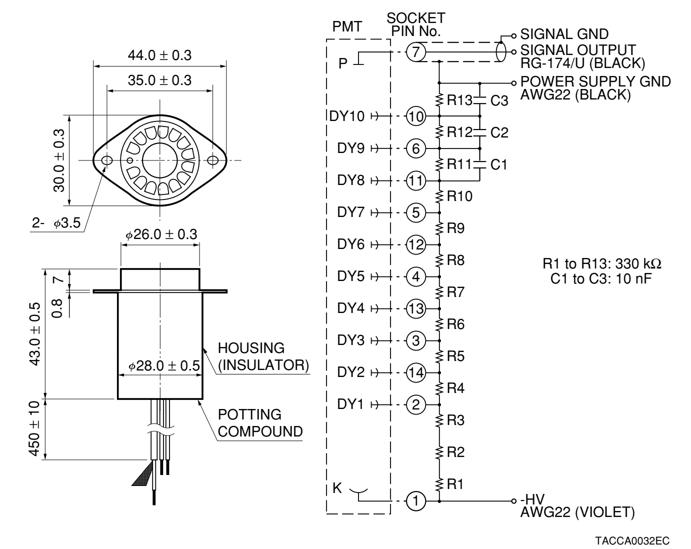
⑳ E974-18



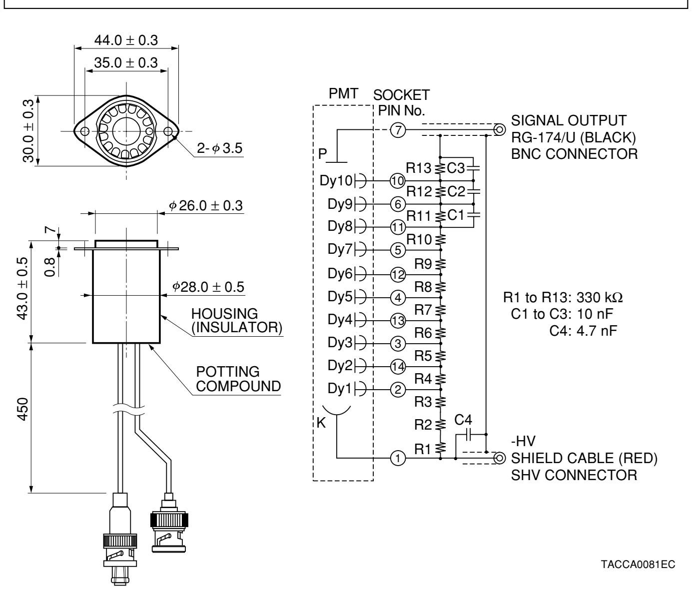
㉑ E2924-11



㉒ E2924



㉓ E2924-500



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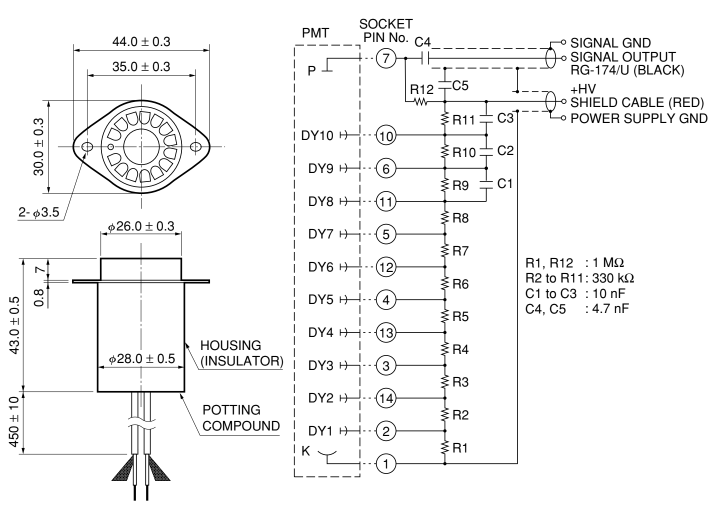
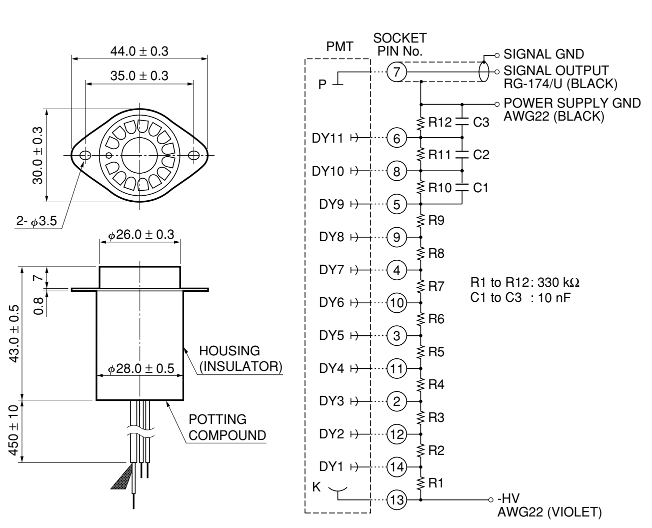
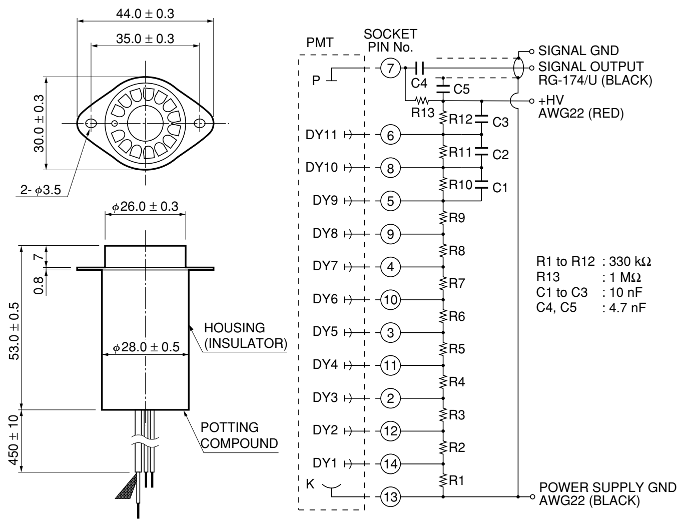


D-Type Socket Assemblies Dimensional Outlines and Diagrams (Unit: mm)

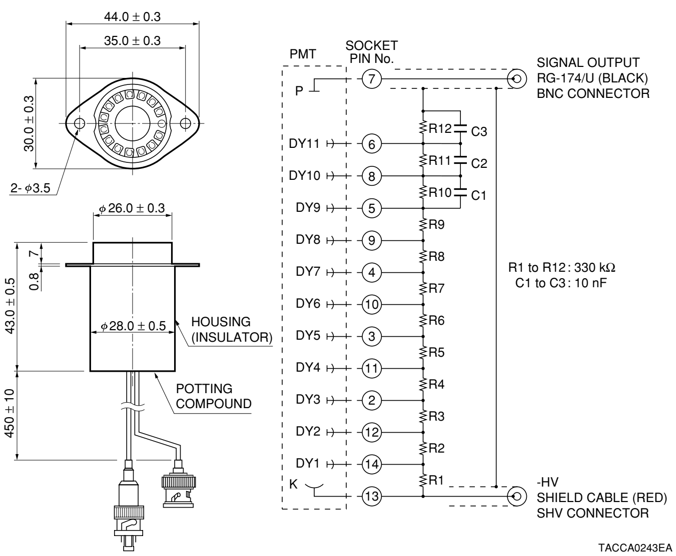
㉕ E990-07



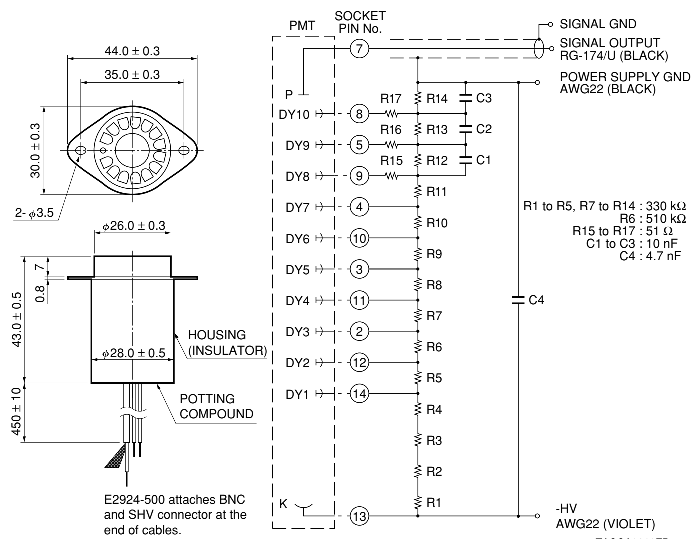
㉖ E990-08



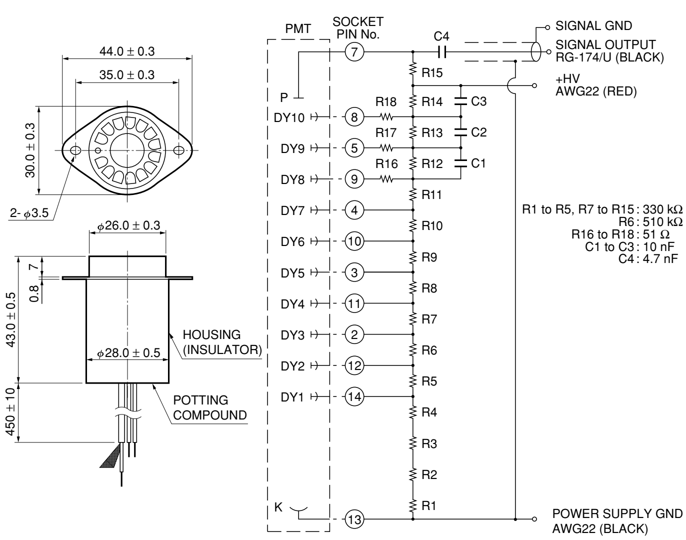
㉗ E990-501



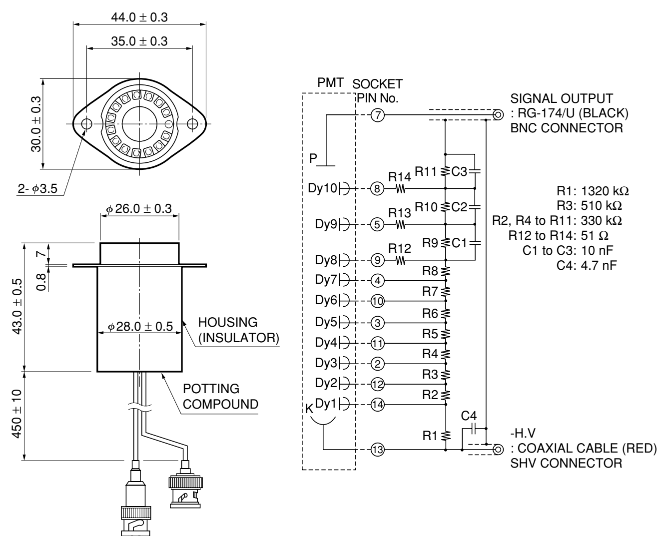
㉘ E2624



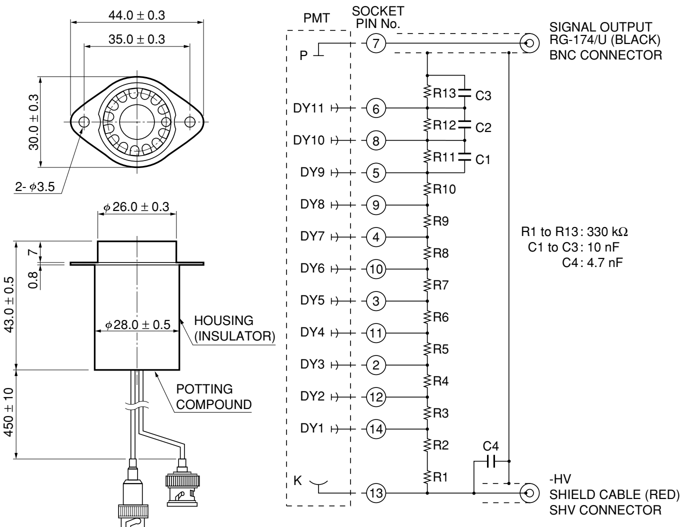
㉙ E2624-05



㉚ E2624-14



㉛ E990-500



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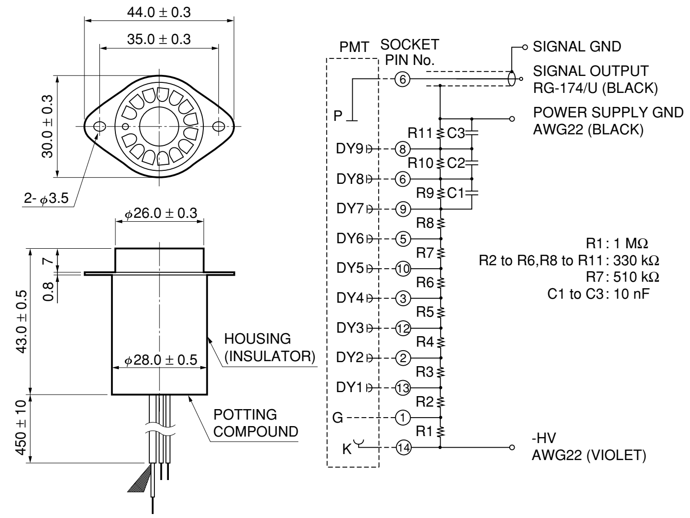
㉜ E990-29



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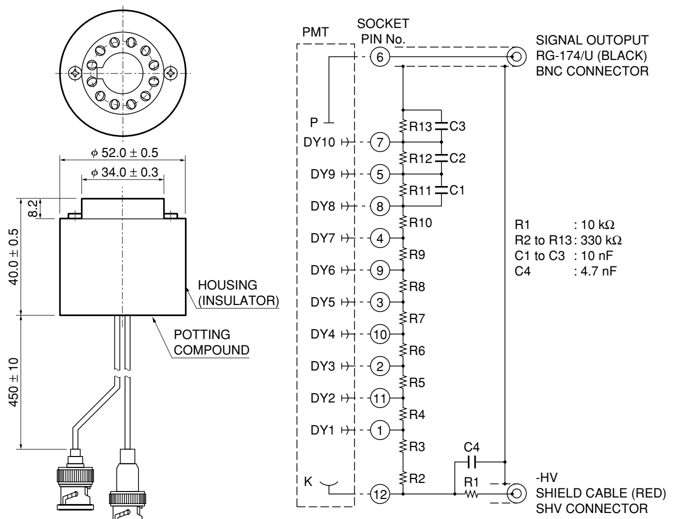
㉝ E2183-500



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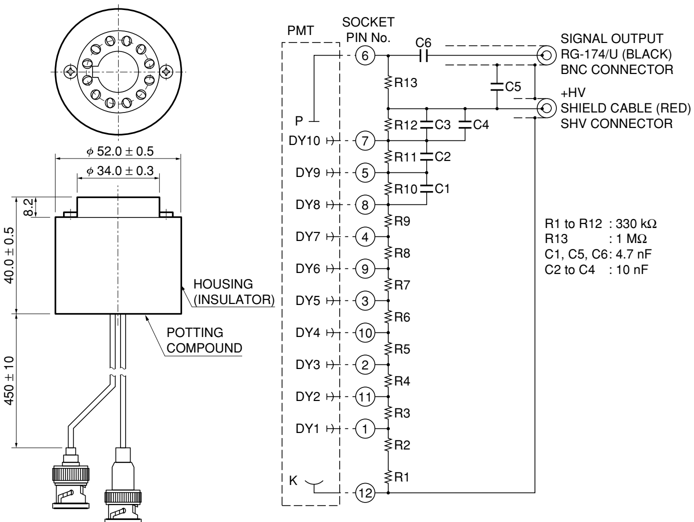
㉞ E2183-502



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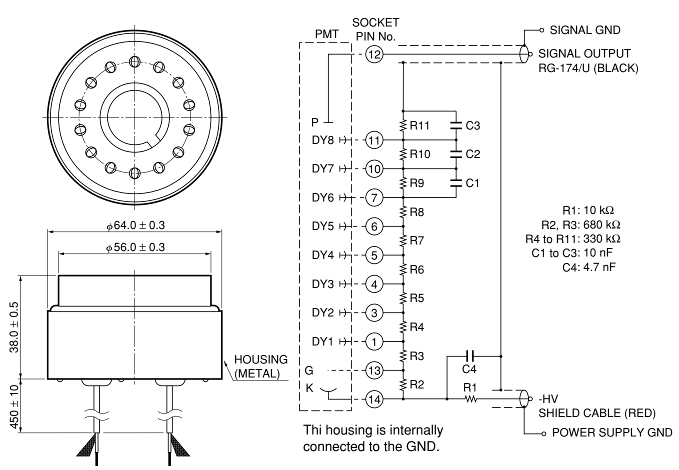
㉟ E1198-26



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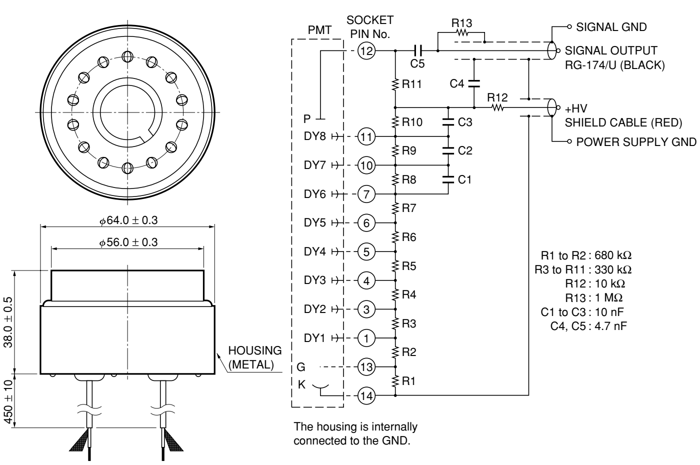
㊱ E1198-27



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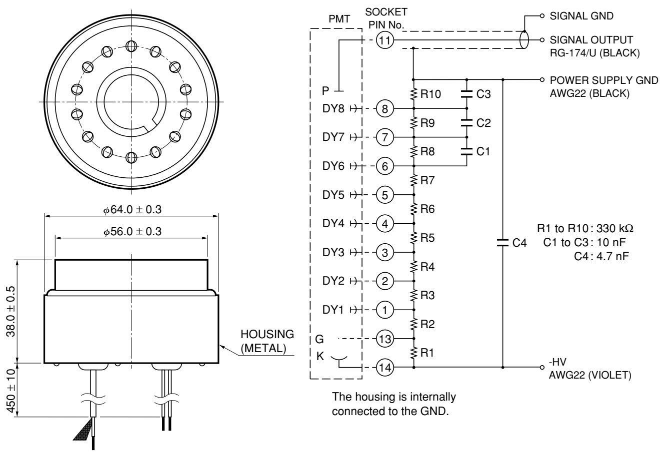
37 E1198-05



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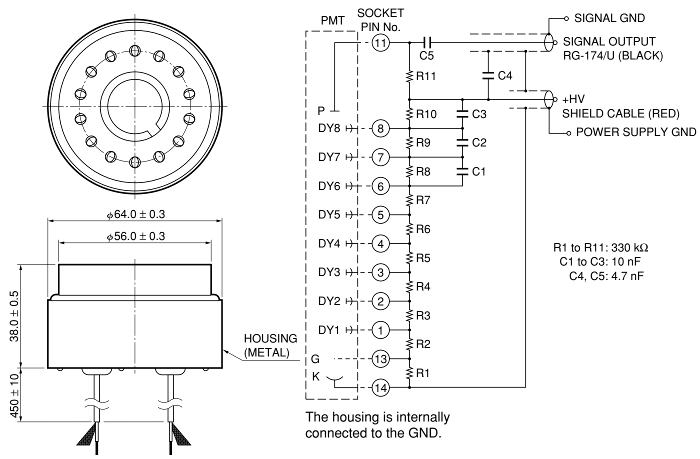

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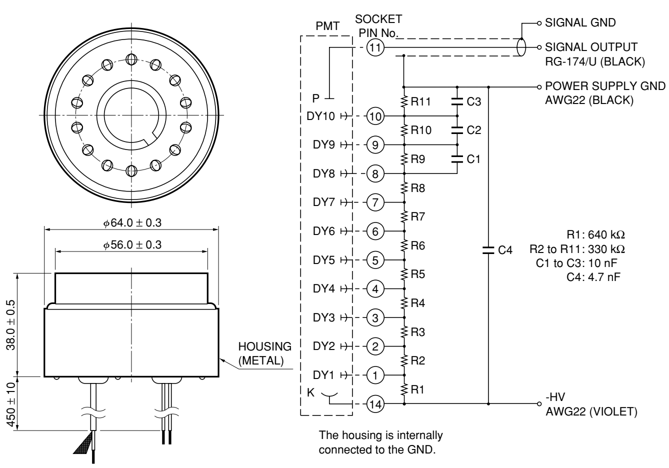

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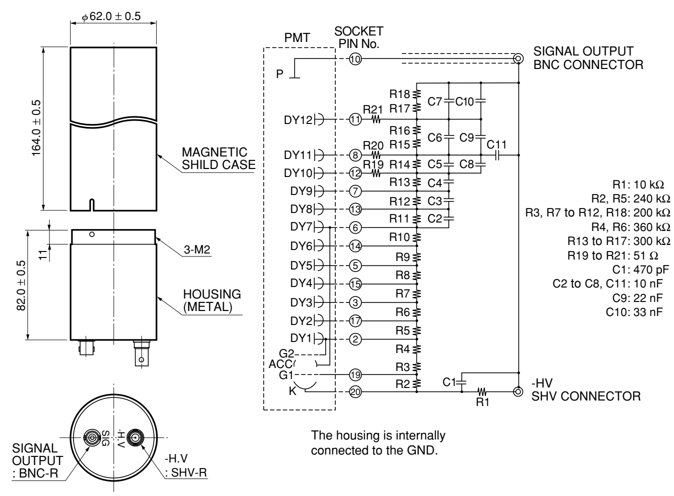

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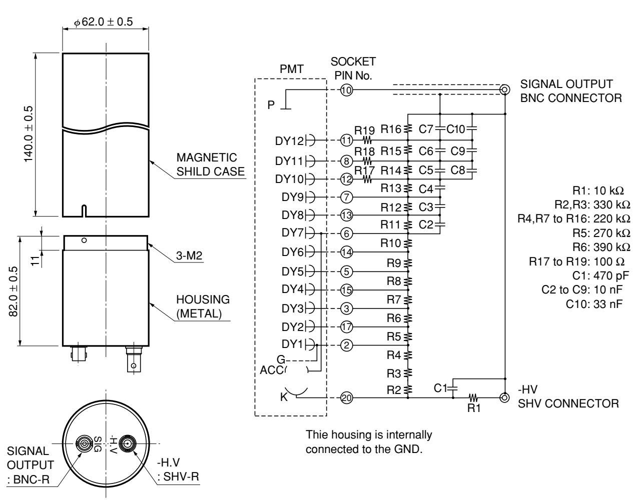

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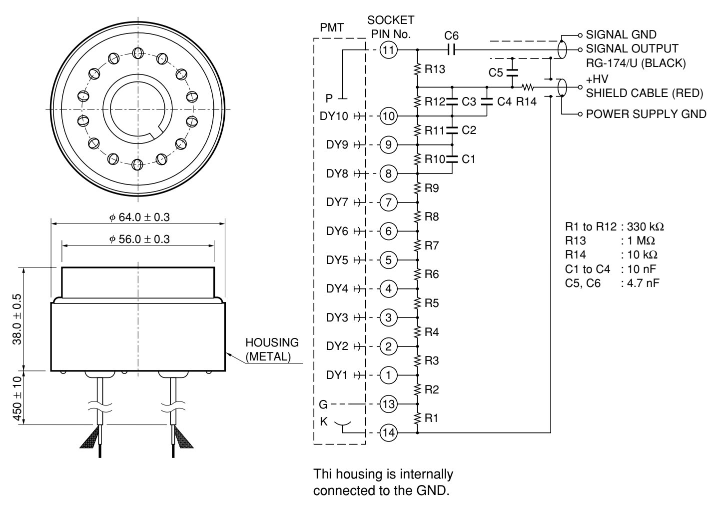

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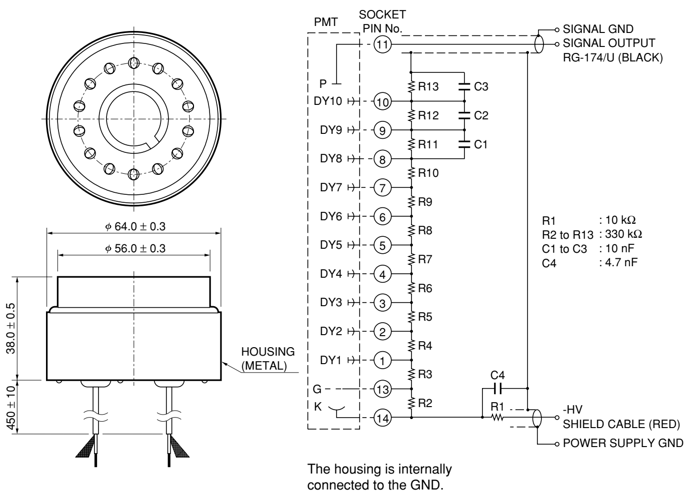
43 E1198-22



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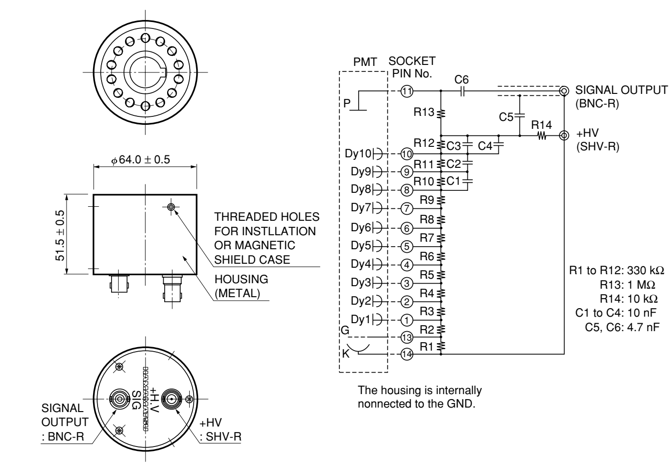
44 E6316



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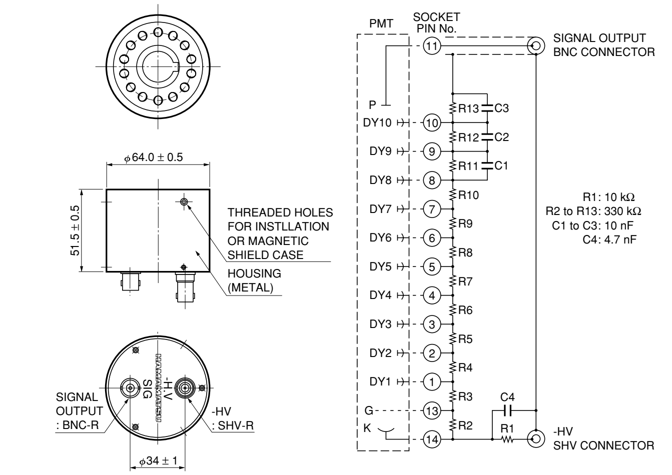
45 E6316-01



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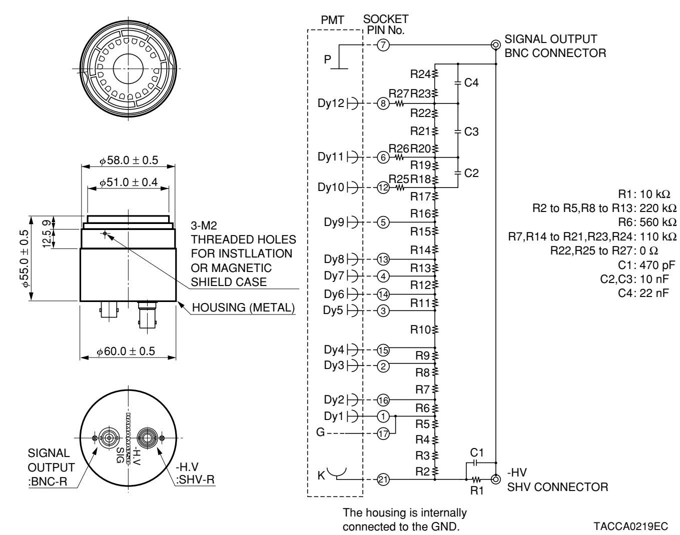
46 E5859-05



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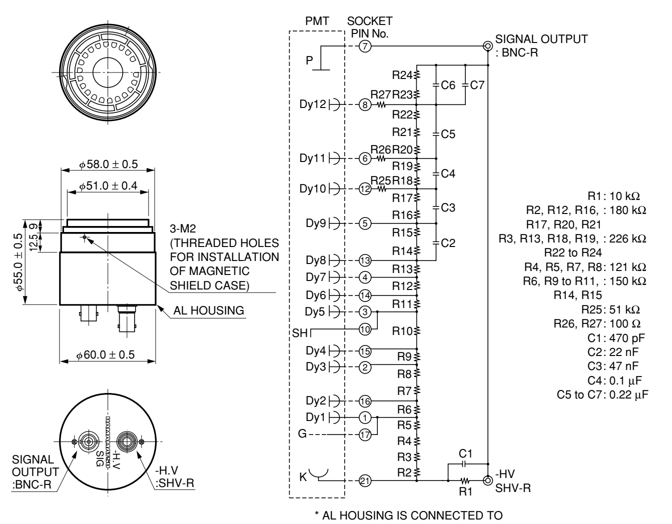
47 E5859



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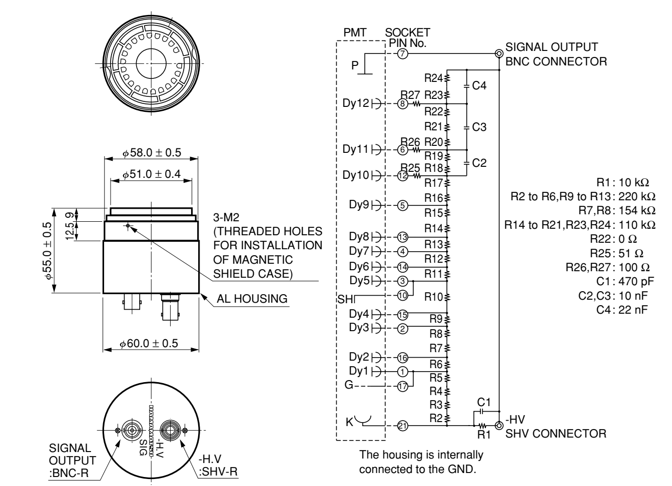
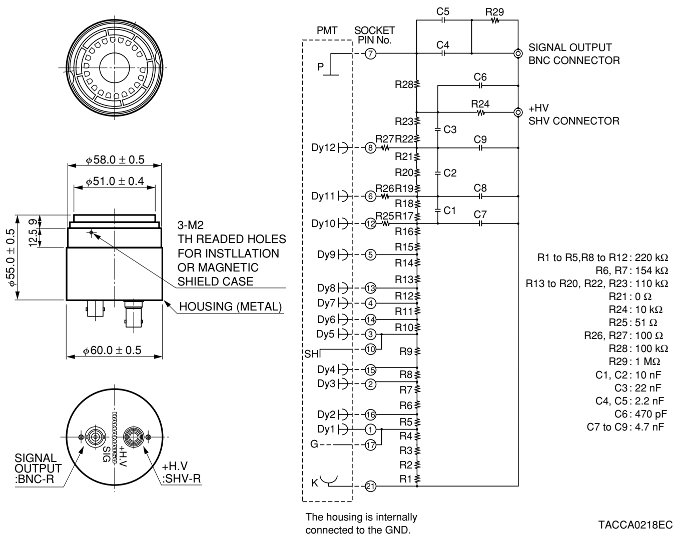


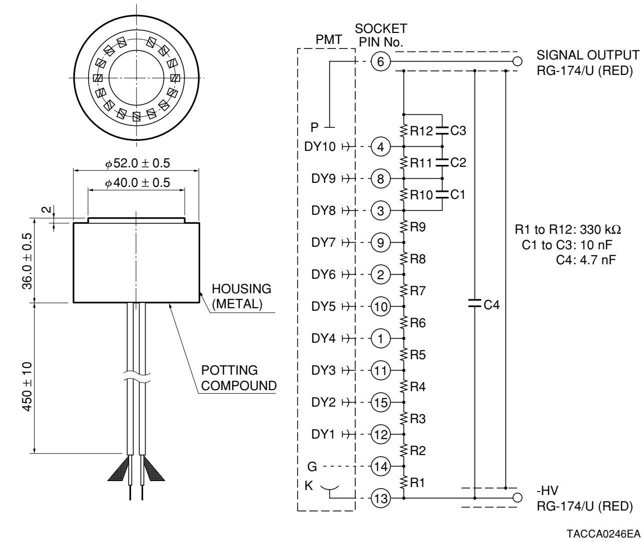
TACCA0178EB

D-Type Socket Assemblies Dimensional Outlines and Diagrams (Unit: mm)

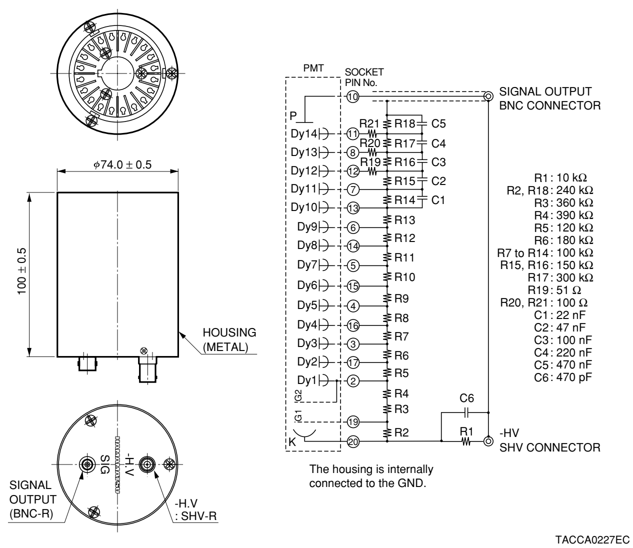
㊾ E5859-03



㊿ E1435-02



㊿① E7693



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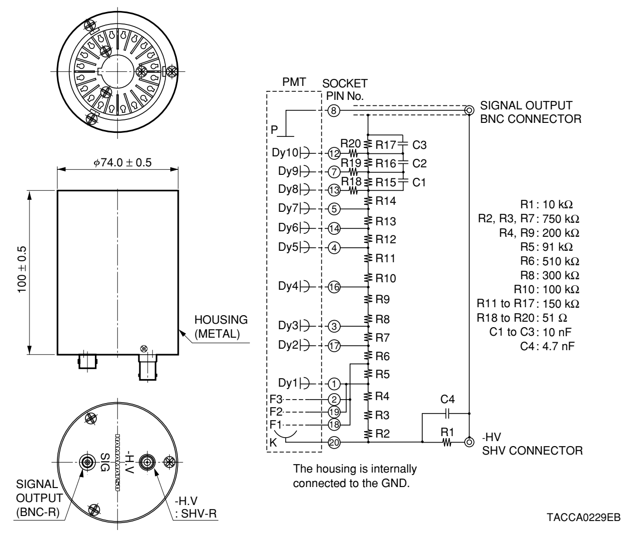
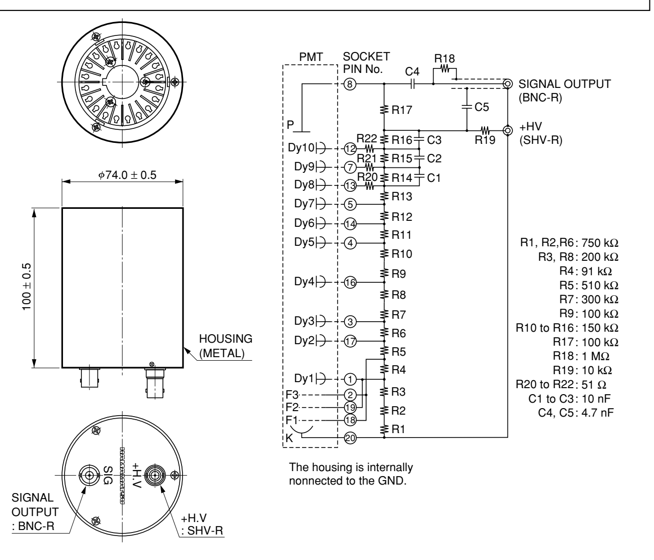
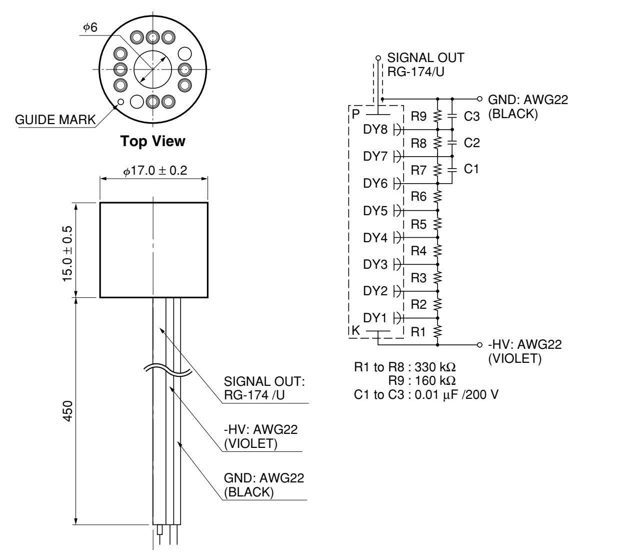


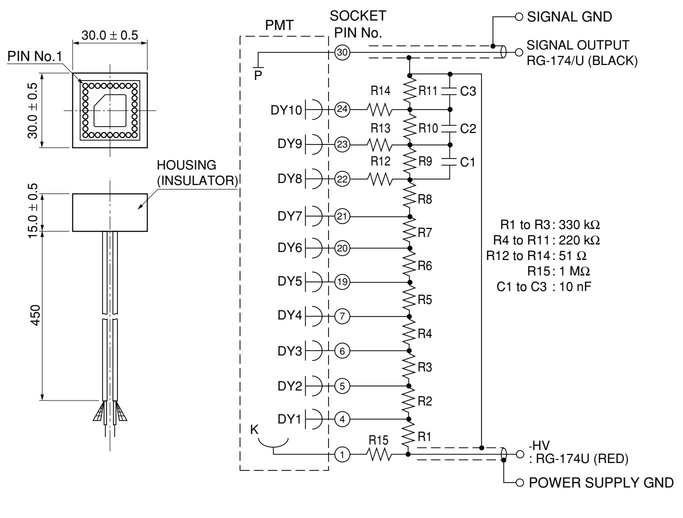
㊿③ E7694-01



㊿④ E5780



55 E5996



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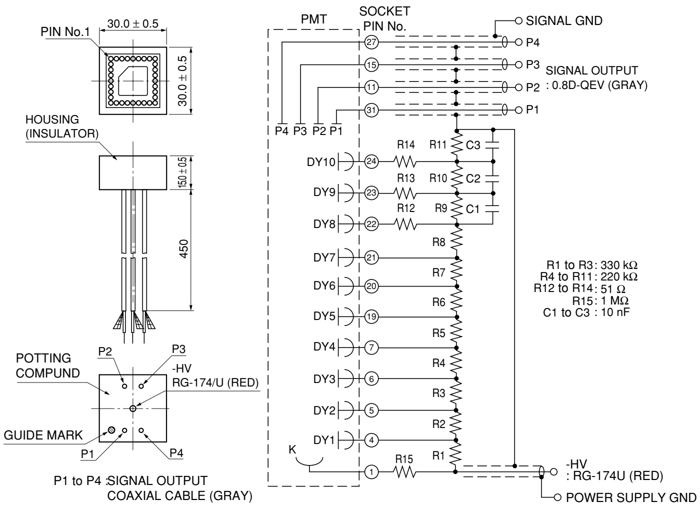
56 E7083



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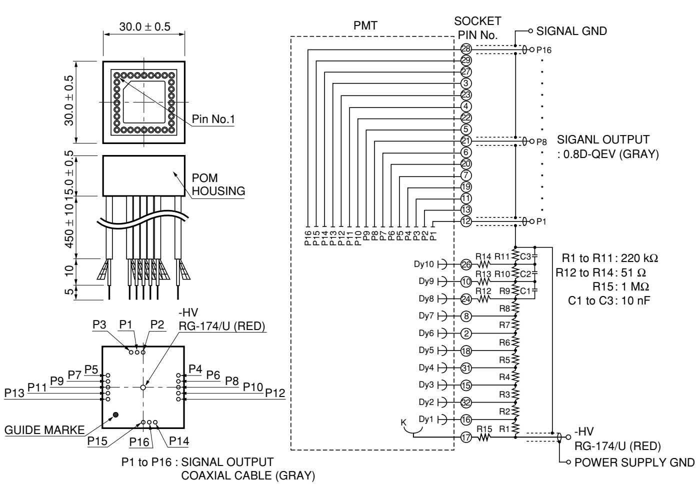
57 E6736



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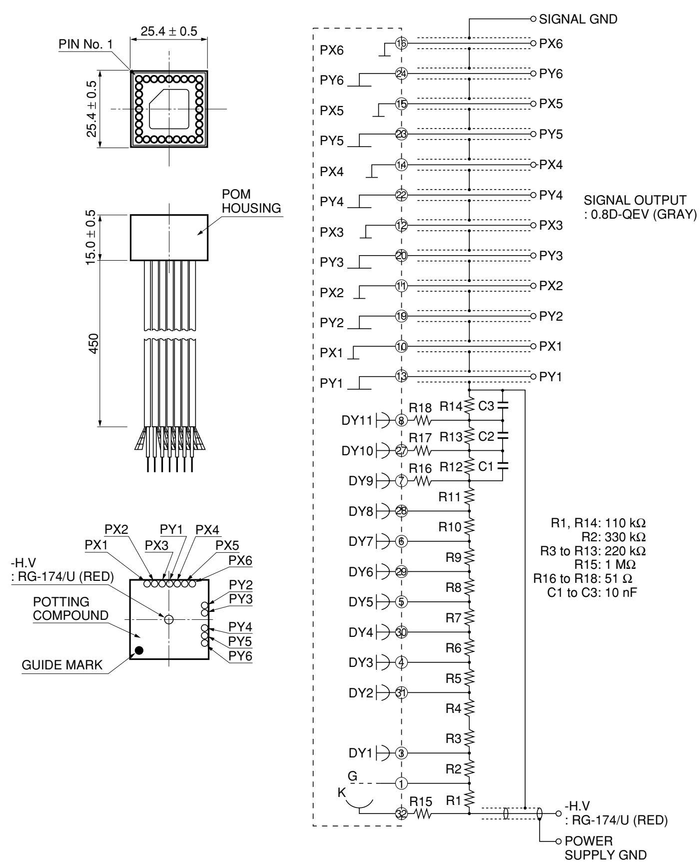
58 E7514



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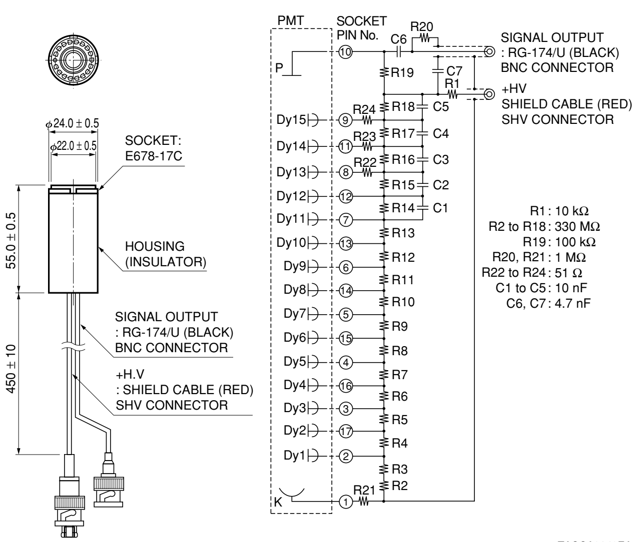


TACCA0248EA

DA-TYPE SOCKET ASSEMBLIES C7246 SERIES, C7247 SERIES

The C7246 and C7247 series are DA type socket assemblies designed for 28 mm (1-1/8 inch) diameter side-on and head-on photomultiplier tubes. A voltage-divider circuit and an amplifier are incorporated in the same package.
The C7247 series uses an amplifier with a wide bandwidth of 0 Hz to 5 MHz, while the C7246 uses an amplifier with a practical bandwidth of 0 Hz to 20 kHz to improve the effective S/N ratio. The photomultiplier tube low-level, high-impedance current can be converted into a low-impedance voltage output by a factor of 0.3 V/µA.
Both the C7246 and C7247 series use an active voltage-divider circuit that ensures excellent DC linearity at low power consumption. The C7246 series also has a gain adjustment function that does not affect amplifier frequency bandwidth.

Specifications

Parameter	C7246	C7246-01	C7247	C7247-01	Unit
Applicable PMTs	28 mm Dia. Head-on R316-02, R374, R2228 R5929, R6094, R6095, R6834	28 mm Dia. Side-on	28 mm Dia. Head-on R316-02, R374, R2228 R5929, R6094, R6095, R6834	28 mm Dia. Side-on	—

MAXIMUM RATINGS

Parameter	C7246	C7246-01	C7247	C7247-01	Unit
Input Voltage for Amplifier	±18		±18		V
Supply Voltage for Divider	-1500		-1500		V
Operating Temperature	0 to +40		0 to +40		°C
Storage Temperature	-15 to +60		-15 to +60		°C

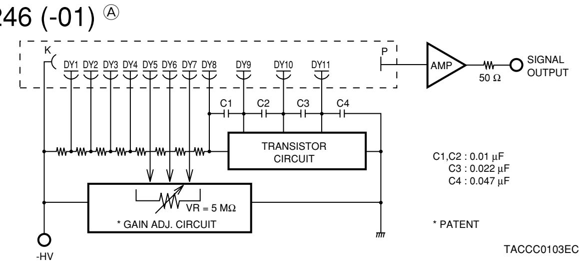
GENERAL

Parameter		C7246	C7246-01	C7247	C7247-01	Unit
Input Voltage for Amplifier		±12 to ±15		±12 to ±15		V
Input Current for Amplifier (at ±15 V)	Typ.	0.53		12		mA
Recommended Supply Voltage for Divider		-400 to -1000 *	-300 to -1000 *	-400 to -900	-300 to -600	V
Divider Current	Typ.	174 (at HV = -1000 V)	211 (at HV = -1000 V)	219 (at HV = -900 V)	166 (at HV = -600 V)	µA
Current to Voltage Conversion Factor (with no load resistor)		0.3		0.3		V/µA
Maximum Output Voltage (with no load resistor)		10		10		V
Output Voltage (with 50 Ω load resistor)		0.9		3		V
Maximum input Signal Current (with no load resister)	DC	33		33		µA
	Pulse	33		33		µA
Frequency Bandwidth (-3 dB)		0 Hz to 20 kHz		0 Hz to 5 MHz		—
Output Impedance		50		50		Ω
Offset Voltage	Max.	±1		±3		mV
Output Noise Voltage (rms)	Typ.	0.09		9		mV
Adjustable Gain Range	Min.	10	30	—	—	dB
Total Power Consumption (at ±15 V)	Typ.	190 (at HV = -1000 V)	227 (at HV = -1000 V)	558 (at HV = -900 V)	460 (at HV = -600 V)	mW
Weight	Typ.	55	50	55	50	g

* Keep more than 600 V at -HV input when input signal gives more than 10 µA. (C7246, -01)

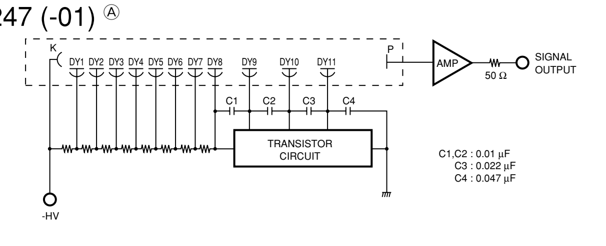
Circuit Diagrams

C7246 (-01) Ⓐ



NOTE: ⒶC7246-01 is for 28 mm side-on PMT so that the last dynode number is "DY9"

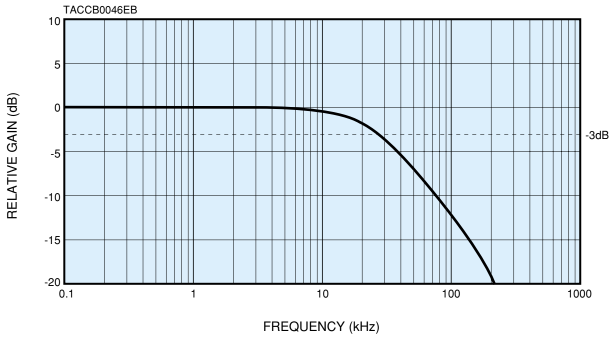
C7247 (-01) Ⓐ



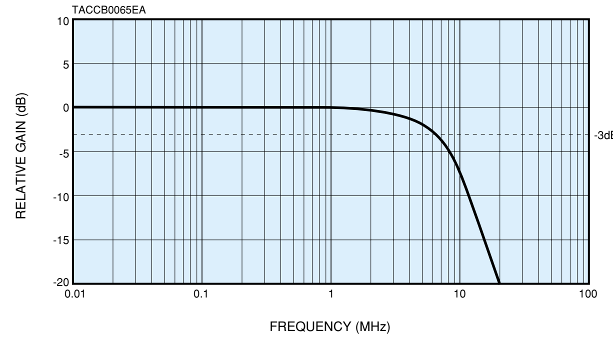
NOTE: ⒶC7247-01 is for 28 mm side-on PMT so that the last dynode number is "DY9"

Frequency Response of Built-in Amplifier

C7246, -01

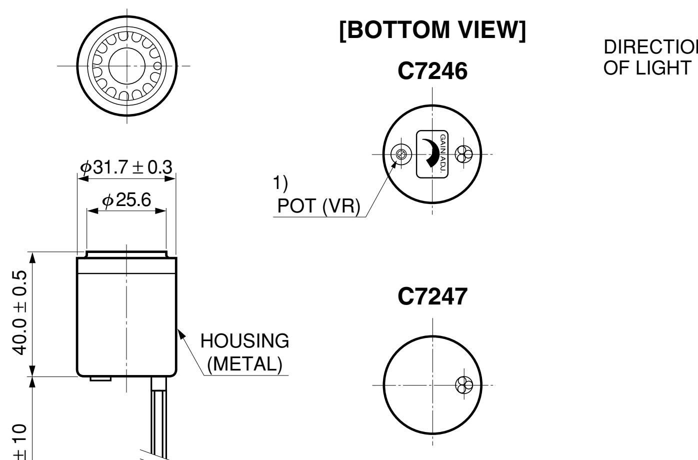


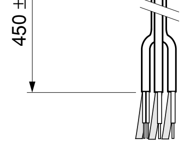
C7247, -01



Dimensional Outlines (Unit : mm)

C7246, C7247





-HV	SHIELD CABLE 2)	RED
SIGNAL OUTPUT	COAX CABLE RG-174/U	BLACK
±15 V	SHIELDED CABLE (COVERING TWISTED PAIR) 3)	GRAY

NOTES: 1) Turning this pot clockwise increases the PMT gain. (25 turns max.)
2) At the end of HV cable, it's possible to attach SHV connector fitting RG-174/U.
3) Connect as follow.
WHITE········ -15 V
ORANGE···· +15 V
SHIELD······· GND

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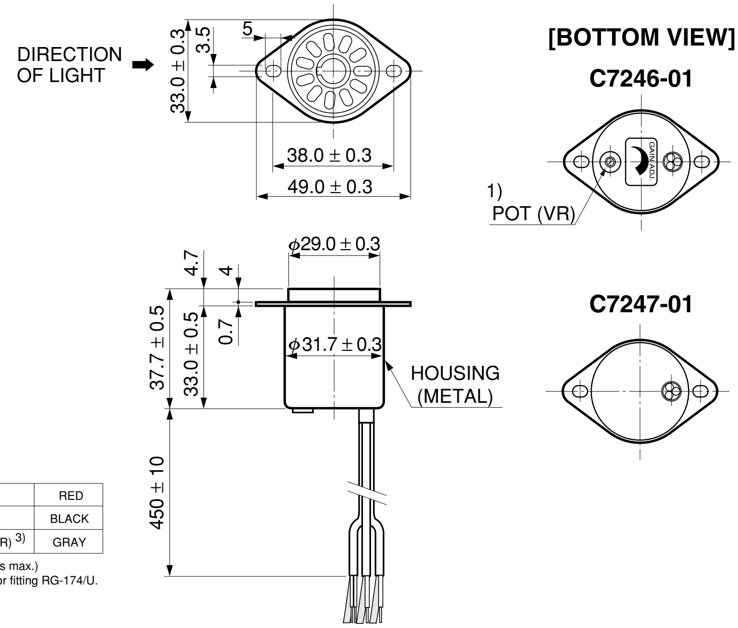
C7246-01, C7247-01



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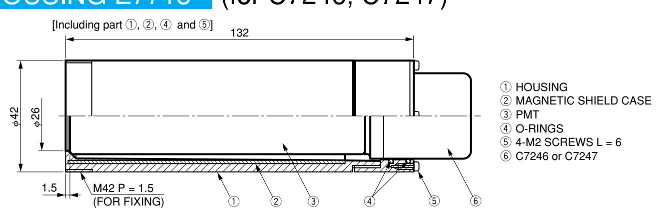
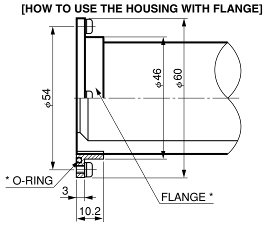
Options (Sold separately)

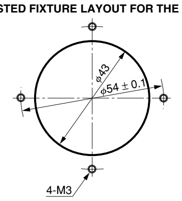
HOUSING E7718 (for C7246, C7247)



[HOW TO USE THE HOUSING WITH FLANGE]



[SUGGESTED FIXTURE LAYOUT FOR THE FLANGE]



* THE FLANGE AND O-RING ARE AVAILABLE TO ORDER SEPARATELY AS P/N; A7719.

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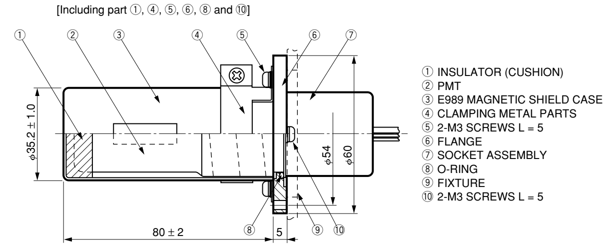
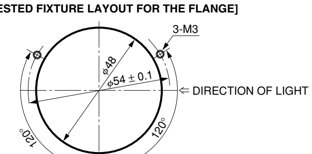
FLANGE A7709 (for C7246-01, C7247-01)



[SUGGESTED FIXTURE LAYOUT FOR THE FLANGE]



TACCA0199EB

DP / DAP-Type Socket Assemblies

HIGH VOLTAGE POWER SUPPLY SOCKET ASSEMBLY C6270 (DP Type)
HIGH VOLTAGE POWER SUPPLY SOCKET ASSEMBLY WITH TRANSIMPEDANCE AMPLIFIER C6271 (DAP Type)

C6270 is a high voltage power supply socket assembly for 28 mm (1-1/8 inch) diameter side-on photomultiplier tubes (PMTs), incorporating a regulated high voltage power supply and an active voltage divider. It enables simple yet stable photomultiplier tube operations with extended DC output linearity by only supplying +15 V and connectiong to a potentiometer or a 0 V to +5 V for high voltage adjustments.
C6271 further incorporates a transimpedance amplifier which converts the photomultiplier tubes high impedance current signal to low impedance voltage signal.

Features (C6270)

- **Superior DC Output Linearity**
- **Fast High Voltage Programming Response**
- **Wide High Voltage Output Range**
- **Low Ripple/Noise**
- **Low Power Consumption**

Features (C6271)

- **With Transimpedance Amplifier**
- **Superior DC Output Linearity**
- **Fast High Voltage Programming Response**
- **Wide High Voltage Output Range**
- **Low Ripple / Noise**
- **Low Power Consumption**

Common Specifications

GENERAL

Parameter			C6270	C6271	Unit
Applicable PMTs			28 mm (1-1/8 inch) Dia. side-on types		—
Input Voltage			+15 ± 1		V
Input Current		Typ.	45	55	mA
Linear DC Output Current of PMT Ⓐ	at -1000 V	Typ.	100	43	µA
	at -500 V	Typ.	50	43	µA
Operating Temperature			0 to +40		°C
Storage Temperature			-15 to +60		°C
Weight		Typ.	50	53	g

NOTE: Ⓐ Within: ±2 % linearity

HIGH VOLTAGE POWER SUPPLY

Parameter		Value/Description	Unit
Output Voltage Range		0 to -1250	V
Line Regulation Against ±1 V Input Change	Typ.	±0.01	%
Ripple/Noise (p-p) in High Voltage Output	Typ.	0.008	%
High Voltage Control		0 V to +5 V or external 50 kΩ potentiometer	—
High Voltage Programming Response Ⓑ	Typ.	80	ms
Temperature Coefficient of High Voltage Output	Typ.	±0.01	%/°C

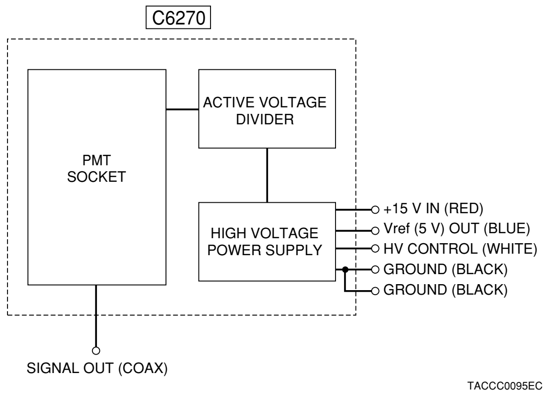
NOTE: Ⓑ for 0 %→99 % HV change

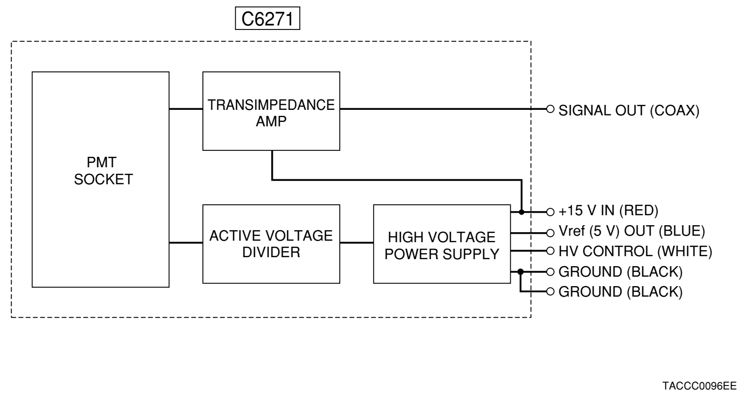
C6271 Specifications

TRANSIMPEDANCE AMPLIFIER SECTION

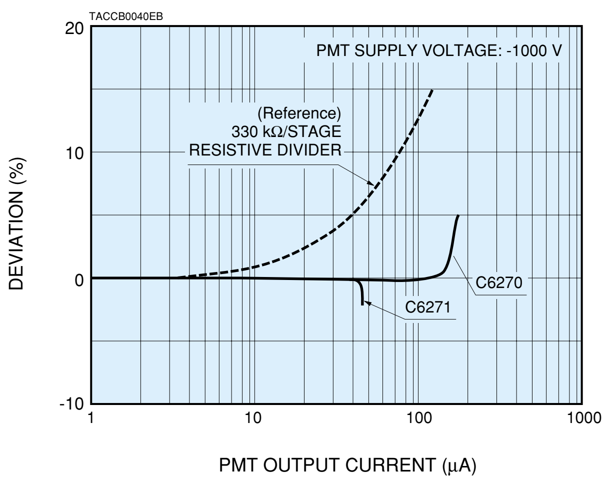
Parameter		Value	Unit
Current to Voltage Conversion Factor		0.3	V/µA
Maximum Linear Signal Output Voltage	Typ.	+13 (Anode Current=43 µA)	V
Bandwidth (-3 dB)		0 Hz to 10 kHz	—
Signal Output Offset Voltage	Typ.	-0.3 to +0.3	mV
Induced Ripple (p-p) on Signal Output	Typ.	2	mV

Schematic Diagrams

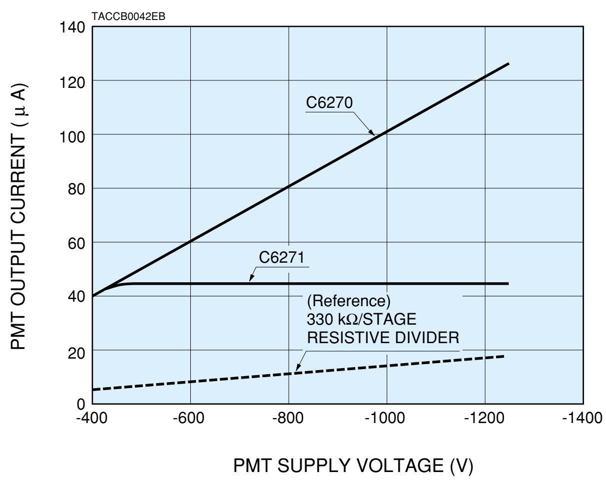




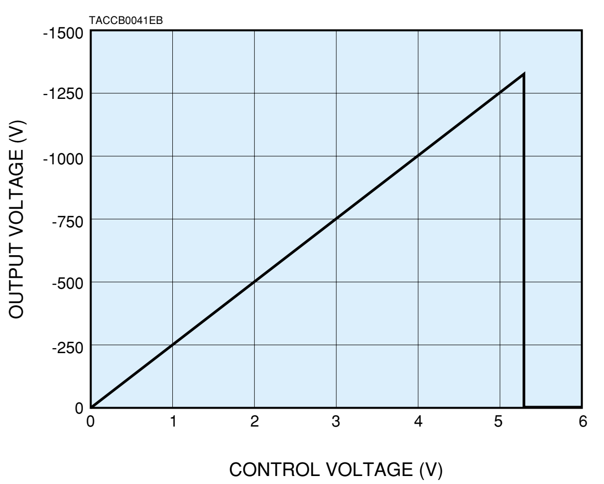
DC Linearity Characteristics



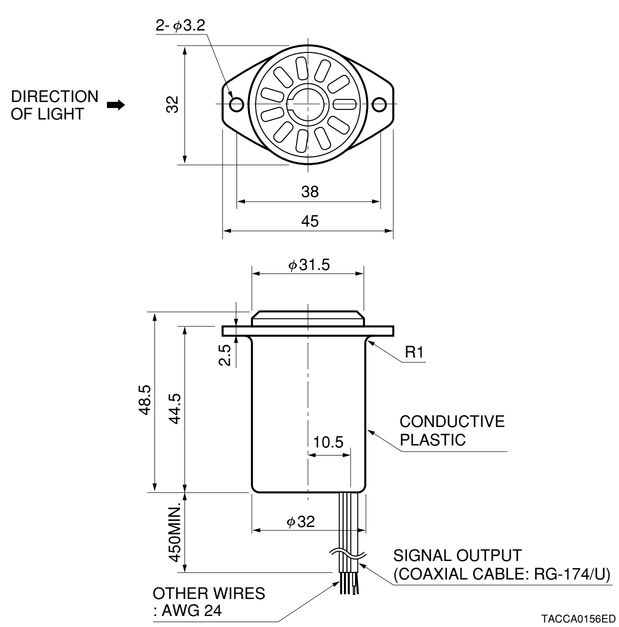
Practical PMT DC Output Limits



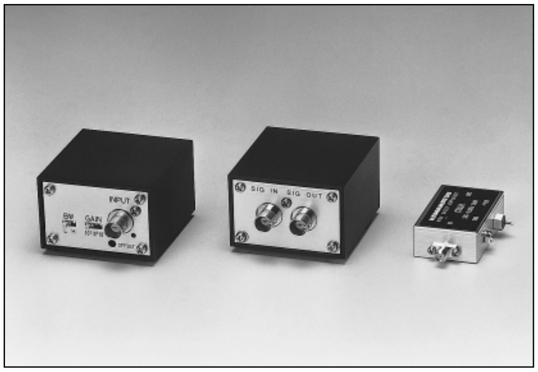
High Voltage Controlling Characteristics



Dimensional Outlines (Unit: mm)



Preamplifier Units C7319, C6438, C5594


Left: C7319, Center: C6438, Right: C5594 TACCF0176

Hamamatsu provides three types of preamplifier units for photomultiplier tubes. Features of each type are as follows.
Select the one that best matches your application.

Features

● **C7319**
- Switchable frequency bandwidth (2 ranges) and current-to-voltage conversion factor (3 ranges)
- Ideal for applications requiring low noise and high gain

● **C6438**
- Wide bandwidth from 0 Hz up to 50 MHz

● **C5594**
- 1.5 GHz cutoff frequency for reliable amplification of high-speed output pulse from PMT
- Ideal for single photon fluorescence lifetime measurement using MCP-PMT and time characteristics measurements using various PMTs
- Choice of SMA or BNC input and output connector

Characteristics

Parameter	C7319	C6438	C5594	Unit
Input Voltage	±5 to ±15	±5	+12 to +16	V
Input Current Typ.	±8 Ⓐ	±20	95 Ⓔ	mA
Frequency Bandwidth (-3 dB)	0 Hz to 20 kHz or 0 Hz to 200 kHz (selectable)Ⓑ	0 Hz to 50 MHz	50 kHz to 1.5 GHz	—
Current-to-Voltage Conversion Factor	0.1 V/μA, 1 V/μA or 10 V/μA (selectable)	0.5 mV/μA Ⓓ	3.15 mV/μA Ⓓ	—
Amplifier Input	±Current	±Voltage	±Voltage	—
Output Polarity	Inverted	Non-inverted	Non-inverted	—
Voltage Gain	— Ⓒ	20 ± 3 Ⓓ (Approx. 10 times)	36 Ⓓ (Approx. 63 times)	dB
Input Impedance	— Ⓒ	50	50	Ω
Output Impedance	50	50	50	Ω
Operating Ambient Temperature	0 to +40	0 to +40	0 to +40	°C
Storage Temperature	-20 to +60	-10 to +60	-15 to +60	°C
Weight	170	160	80	g

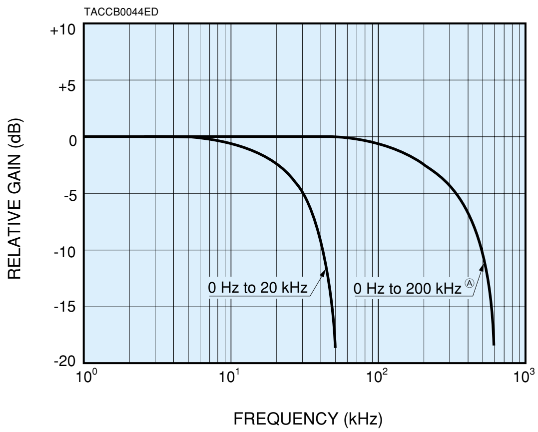
NOTE: Ⓐat ±15 V
Ⓑ10 V/μA conversion ratio, to be limited to 0 Hz to 100 kHz frequency bandwidth.
ⒸC7319 is current to voltage conversion amplifier unit.
Ⓓat 50 Ω Load resistor
Ⓔat +15 V

C5594 Input connector and type No.

Input	Output	
	SMA jack (female)	BNC jack (female)
SMA plug (male)	**C5594-12**	**C5594-14**
SMA jack (female)	**C5594-22**	**C5594-24**
BNC plug (male)	**C5594-32**	**C5594-34**
BNC jack (female)	**C5594-42**	**C5594-44**

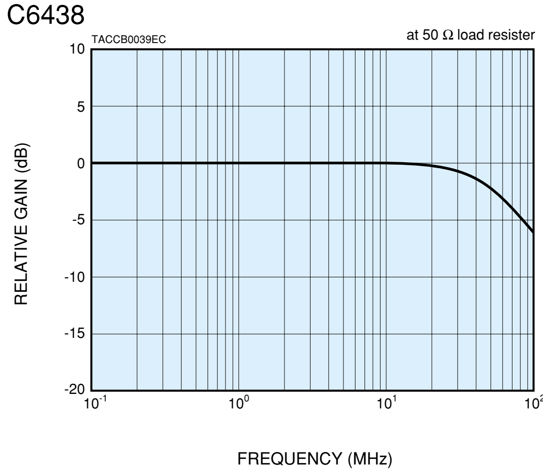
Frequency Response

C7319

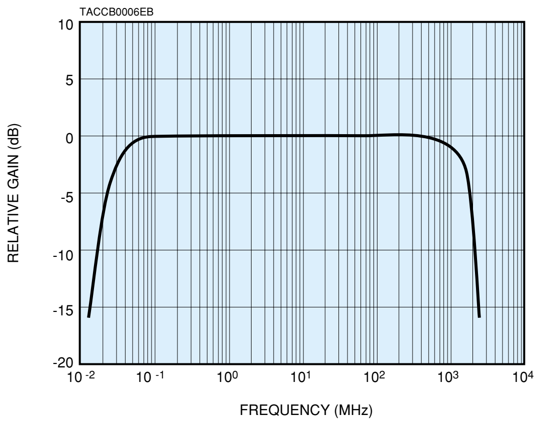


Ⓐ To be limited to 0 Hz to 100 kHz at 10 V/μA
(Current to voltage conversion factor)

C6438

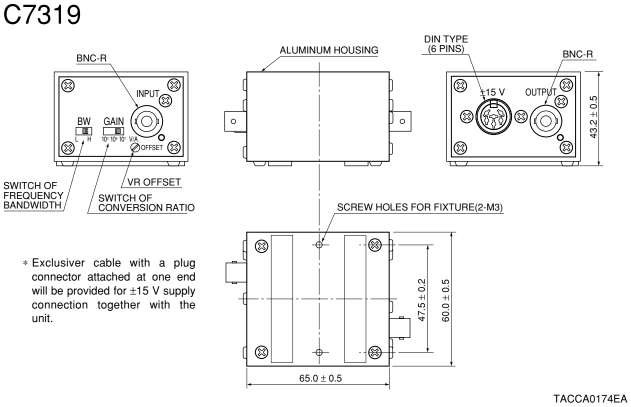


C5594



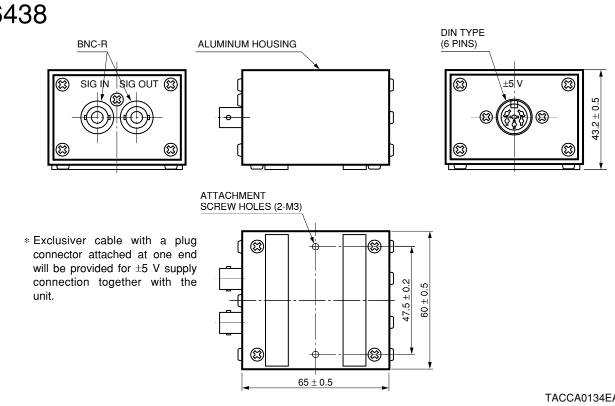
Dimensional Outlines (Unit: mm)

C7319



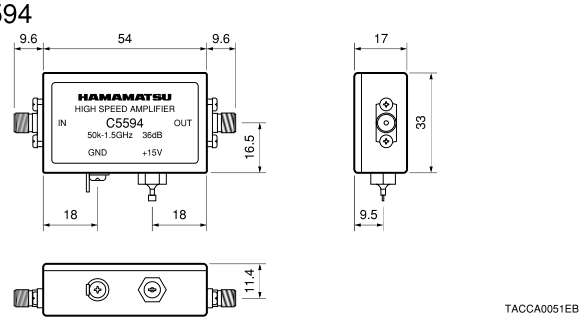
∗ Exclusiver cable with a plug connector attached at one end will be provided for ±15 V supply connection together with the unit.

C6438



∗ Exclusiver cable with a plug connector attached at one end will be provided for ±5 V supply connection together with the unit.

C5594



Voltage Dependence of Photomultiplier Tube Gain

The photoelectrons emitted from the photocathode of a photomultiplier tube are channeled by the electron lens to impinge on the first dynode where several times the number of secondary electrons are then emitted. This multiplicative increase of secondary electrons is repeated at the latter dynodes and as a result, the number of electrons reaching the anode is approximately 10^5 to 10^7 times the original number of photoelectrons emitted from the photocathode.
The relationship of the secondary electron emission δ for each dynode to the supplied voltage is expressed as follows:

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

where A is a constant, E is the interstage voltage, and α is another constant determined by the dynode material and geometric structure. The value of α is usually in the range 0.7 to 0.8. When a voltage V is supplied between the anode and the photocathode of a photomultiplier tube having n dynode stages, the overall gain μ is given by

$$\mu = (A \cdot E^{\alpha})^n = \{A \cdot [V/n+1]^{\alpha}\}^n = \{A^n / (n+1)^{\alpha n}\} V^{\alpha n}$$

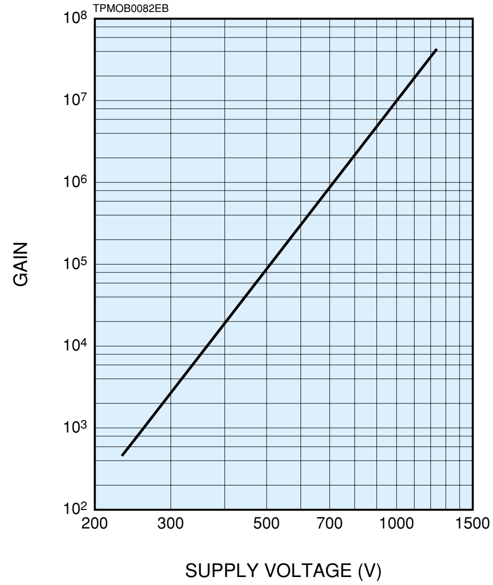
Here, if $\{A^n / (n+1)^{\alpha n}\}$ is substituted for K, μ becomes

$$\mu = K \cdot V^{\alpha n}$$

Typical photomultiplier tubes have 9 to 12 dynode stages and as shown in Figure 23, the gain is proportional to the 6th to 10th power of the voltage supplied between the photocathode and the anode. This essentially means that the output of a photomultiplier tube is extremely sensitive to variations in the supplied voltage. Thus the power supply stability such as drift, ripple, temperature regulation, input regulation and load regulation must be at least 10 times as stable as the output stability required of the photomultiplier tube.

Hamamatsu regulated high voltage power supplies are products developed based on our years of experience as a photomultiplier tube manufacturer and our leading edge technology. All models are designed to conform to stability requirements demanded of photomultiplier tube operations. Various models are provided, ranging from on-board unit types to general-purpose bench-top types, allowing you to choose the desired power supply that suits your application.

Gain vs. Supply Voltage

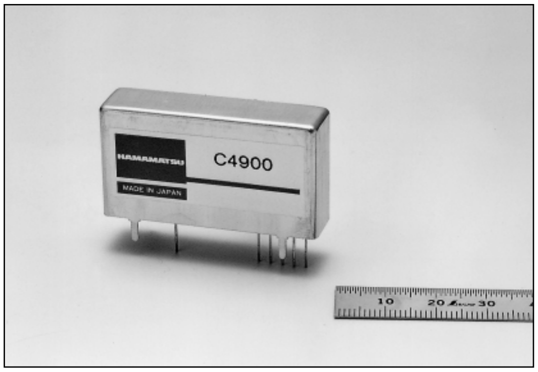


Selection Guide to High Voltage Power Supplies

Type	Type No.		Max. Output Voltage (V)	Output Current (mA)	Input Voltage	Dimensions (W × H × D) (mm)**	Weight
Unit Type	C4900	—	-1250	0.6	+15 V	46 × 24 × 12	31 g
		-01		0.5	+12 V		
		-50	+1250	0.6	+15 V		
		-51		0.5	+12 V		
	C4710	—	-1500	1	+15 V	65 × 27.5 × 45	105 g
		-01			+12 V		
		-02			+24 V		
		-50*	+1500		+15 V		
		-51*			+12 V		
		-52*			+24 V		
Bench-top Type	C3830		-1500	1	AC 100 V	255 × 54 × 230	2.8 kg
	C4720		+1500				
	C3350		±3000	10	AC 100 V	220 × 120 × 350	8 kg
	C3360		-5000	1	AC 100 V	210 × 99 × 273	3.5 kg

* Order made products
** Excluding projecting parts

Compact High Voltage Power Supply Units C4900 Series



TACCF0154

CE EN61010-1: 1993 + A2: 1995

The C4900 series is an on-board type high voltage power supply unit, with a design that aims at providing both "compactness and high performance". The newly developed circuit achieves high performance and low power consumption. The C4900 series in addition provides enhanced protective functions yet is offered at lower costs.
The C4900 and -01 are designed for negative output, while the C4900-50 and -51 have positive output.

Features

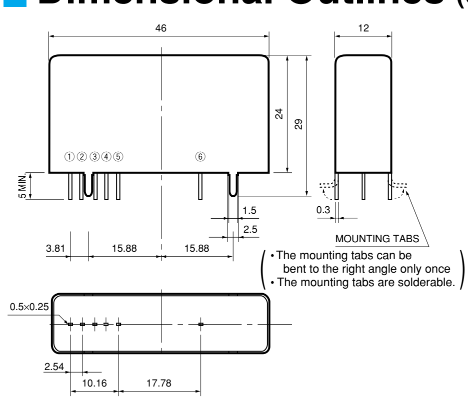
- **Very compact and lightweight**
- **Low power consumption**
- **Variable output voltage range from 0 V**
- **High stability**
- **Quick response**
- **Ample protective functions**

Specifications

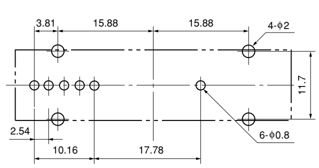
Parameter		C4900	C4900-01	C4900-50	C4900-51	Unit
Input Voltage Range		+15 ± 1	+12 ± 0.5	+15 ± 1	+12 ± 0.5	V
Input Current Ⓐ with no load	Typ.	14	15	14	15	mA
Input Current Ⓐ with full load	Typ.	90	95	90	95	mA
Variable Output Range		0 to -1250		0 to +1250		V
Specification Guaranteed Output Voltage Range		-200 to -1250		+200 to +1250		V
Output Current	Max.	0.6	0.5	0.6	0.5	mA
Line Regulation Against ±1 V/0.5 V Input Change Ⓑ	Typ.	±0.01				%
Load Regulation Against 0 % to 100 % Load Change Ⓐ	Typ.	±0.01				%
Ripple/Noise (p-p) Ⓑ	Typ.	0.007				%
Output Voltage Control		By external controlling voltage (0 V to +5 V) or external potentiometer (50 kΩ ±2.5 kΩ)				—
Controlling Voltage Input Impedance	Typ.	80				kΩ
Output Voltage Setting (Absolute Value)	Typ.	(Controlling Voltage × 250) ± 0.5 %				V
Output Voltage Rise Time (0 % → 99 %) Ⓑ	Typ.	50				ms
Temperature Coefficient Ⓑ	Typ.	±0.01				%/°C
Operating Ambient Temperature Ⓑ		0 to +50				°C
Storage Temperature		-20 to +70				°C
Weight		31				g
Protective Functions		Units protected against reversed power input, reversed/excessive controlling voltage input, continuous overloading/short circuit in output				—

NOTE: ⒶAt maximum output voltage.
ⒷAt maximum output voltage and current.

Dimensional Outlines (Unit: mm)



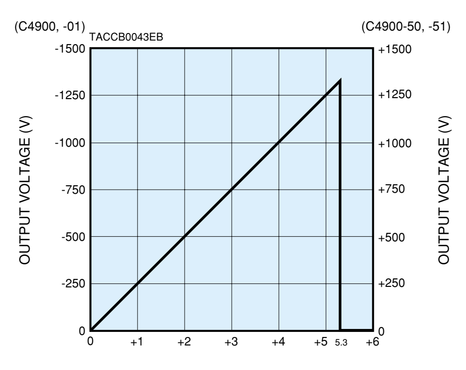
TACCA0157EC



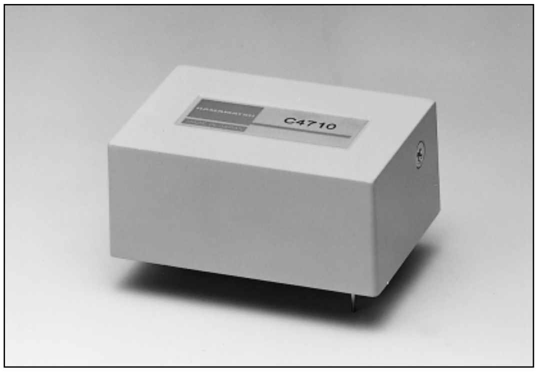
PIN ASSIGNMENT
①+15 V /+12 V IN
②GND 1 (INPUT/OUTPUT GND)
③GND 2 (CONTROLLING VOLTAGE GND)
④HV ADJ (CONTROLLING VOLTAGE INPUT)
⑤Vref OUT
⑥HV OUT
*The housing is internally connected to pin ②.
Pins ② and ③ are internally connected.

TACCA0159EB

Output Voltage Controlling Characteristic



Compact High Voltage Power Supply Units C4710 Series



TACCF0113

The C4710 series comprises on-board type high voltage power supply units, designed specifically for photomultiplier tube operations. The C4710 series is designed for ease of use and high performance, and can be selected from among 6 models to meet your various needs.

Features

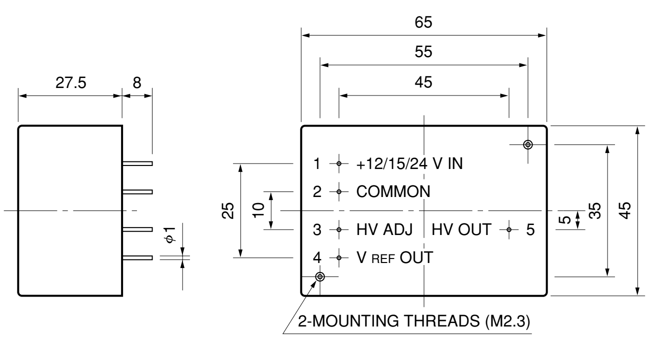
- Compact and lightweight
- High stability
- High output voltage up to 1500 V
- Ample protective functions
- Fully enclosed metal-shielded package

Specifications

Parameter			C4710	C4710-01	C4710-02	C4710-50**	C4710-51**	C4710-52**	Unit
Input Voltage			+15 ± 1	+12 ± 1	+24 ± 1	+15 ± 1	+12 ± 1	+24 ± 1	V
Input Current Ⓐ	with no load	Typ.	95	120	65	95	120	65	mA
(at maximum output voltage)	with full load	Typ.	260	340	145	260	340	145	mA
Specification Guaranteed Output Voltage Range			-240 to -1500			+240 to +1500			V
Output Current		Max.	1						mA
Line Regulation Against ±1 V Input Change *		Typ.	±0.01	±0.015	±0.015	±0.02	±0.02	±0.015	%
Load Regulation Against 0 % to 100 % Load Change Ⓐ		Typ.	±0.01	±0.015	±0.01	±0.01	±0.01	±0.01	%
Ripple/Noise (p-p) *		Typ.	0.005						%
Output Voltage Control			By external controlling voltage (+0.8 V to +5 V) or external potentiometer (10 kΩ)						—
Controlling Voltage Input Impedance		Typ.	40			56			kΩ
Output Voltage Setting (Absolute Value)		Typ.	(Controlling Voltage × 300) ± 0.5 %						V
Output Voltage Rise Time (0 % → 99 %) *		Typ.	100						ms
Temperature Coefficient *		Typ.	±0.01						%/°C
Operating Ambient Temperature *			0 to +40						°C
Storage Temperature			-20 to +60						°C
Weight			105						g
Protective Functions			Units protected against reversed power input, reversed/excessive controlling voltage input, continuous overloading/short circuit in output						—

NOTE: ⒶAt maximum output voltage.
* At maximum output voltage and current.
** Order made products

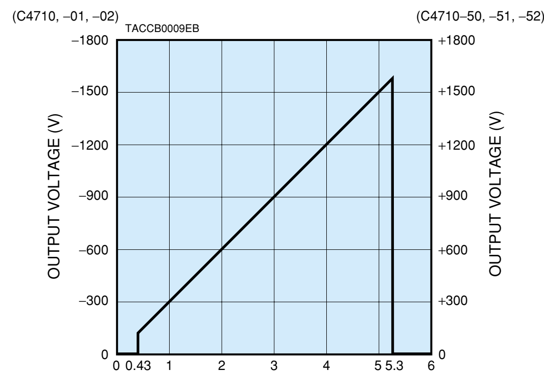
Dimensional Outlines (Unit: mm)



(SIDE VIEW) (BOTTOM VIEW)

TACCA0124EA

Output Voltage Controlling Characteristic



Compact Bench-Top Regulated DC Power Supplies C3830 Series, C4720 Series

TACCF0080

The C3830 series and C4720 series are multipurpose power supplies designed to provide a high voltage output for photomultiplier tube operation and low voltage outputs (±5 V, ±15 V) for peripheral devices such as Hamamatsu preamplifiers and photon counting units. The C3830 series provides a negative high voltage of -200 V to -1500 V, and the C4720 series a positive high voltage of +200 V to +1500 V. In either model, the high voltage output is accurately displayed in four digits on the digital panel meter.

Specifications

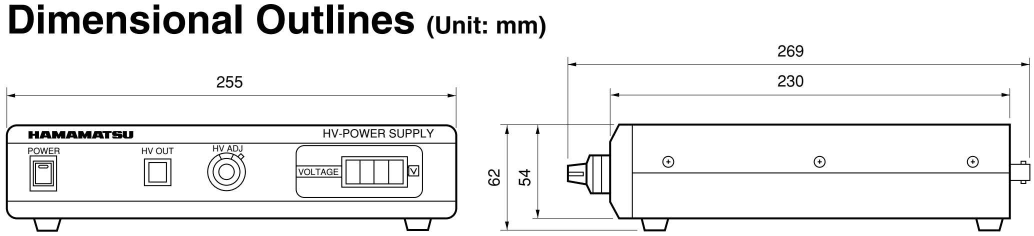
Parameter		High Voltage Power Supply Section	Low Voltage Power Supply Section	
			±5 V Power Supply Section	±15 V Power Supply Section
Output Voltage	C3830/C3830-22	-200 V to -1500 V (Variable)	±4.75 V to ±5.25 V (fixed)	±14.25 V to ±15.75 V (fixed)
	C4720/C4720-22	+200 V to +1500 V (Variable)		
Maximum Output Current		1 mA	500 mA	200 mA
Line Regulation Against ±10 % Line Voltage Change*	Typ.	±0.005 %	±0.005 %	±0.015 %
Load Regulation Against 0 % to 100 % Load Change Ⓐ	Typ.	±0.01 %	±0.5 %	±0.5 %
Ripple/Noise (p-p) *	Typ.	0.005 %	0.16 %	0.06 %
Drift *Ⓑ	Typ.	±0.03 %/h	±0.05 %/h	±0.05 %/h
Temperature Coefficient *	Typ.	±0.03 %/°C	±0.03 %/°C	±0.03 %/°C
High Voltage Output Monitor		4-digit display	—	—
High Voltage Output Monitoring Accuracy Ⓐ	Typ.	±0.5 %	—	—
Output Receptacle	C3830/C4720	One SHV receptacle	Two 4-pin receptacles (HIROSE SR30-10R-4S)	One 4-pin receptacle (MIYAMA MC-032)
	C3830-22/C4720-22	One SHV receptacle	Two 6-pin DIN connectors (HOSHIDEN TCS0260-01-1201)	
AC Input Voltage	C3830/C4720	100 V / 120 V (±10 %) (50/60 Hz)		
	C3830-22/C4720-22	230 V (±10 %) (50/60 Hz)		
Power Consumption *Ⓑ	Max.	Approx. 40 V·A		
Operating Ambient Temperature/Humidity *Ⓒ		0 °C to +40 °C / 90 % RH Max.		
Specification Guaranteed Temperature/Humidity *Ⓒ		+5 °C to +35 °C / 85 % RH Max.		
Storage Temperature/Humidity Ⓒ		-20 °C to +50 °C / 95 % RH Max.		
Weight		Approx. 2.8 kg		
CE Marking	C3830/C4720	—		
	C3830-22/C4720-22	Conforms to ECM directive (89/336/EEC)/EN61326: 1997 + A1: 1998 + A2: 2001 Class B Conforms to low voltage directive (73/223/EEC)/EN61010-1: 2001		

NOTE: ⒶAt maximum output voltage. ⒷAfter 30 minutes warm-up. ⒸNo condensation.
* At maximum output voltage and current.

Accessories

①High voltage output cable (1.5 m long) terminated with SHV-P plugs E1168-17 1
②Spare fuses 2
③Low voltage power supply section mating plugs
C3830/C4720; ±5 V mating plugs (HIROSE SR30-10PE-4P) 2
±5 V mating plugs (MIYAMA MC-032) 1
C3830-22/C4720-22; ±5 V, ±15 V mating plugs (6-pin DIN plgus, HOSIDEN TCP0566-71-5201) 2
④AC line Cable (2 m) 1

Dimensional Outlines (Unit: mm)



TACCA0016EC

Bench-Top High Voltage Power Supply C4840 Series (±3 kV Output)

TACCF0188

The C4840 series are highly regulated, bench-top power supply that provides high output voltage up to ±3 kV/10 mA. The LED panel meter on the front panel allows easy and precise voltage monitoring. The C4840 is ideally suited for operating photomultiplier tubes or proportional counter tubes.

Specifications

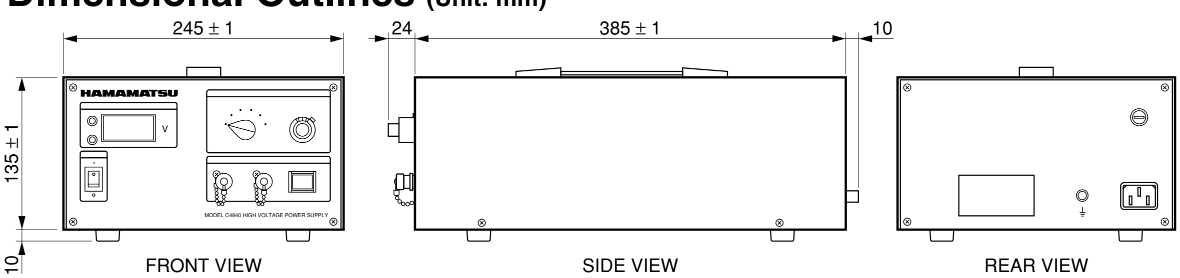
Parameter		Value/Description
Output Voltage		0 V to ±3000 V
Specification Guaranteed Output Voltage		±250 V to ±3000 V
Maximum Output Current		10 mA
Line Regulation Against ±10 % Line Voltage Change *	Max.	±(0.005 % + 10 mV)
Load Regulation Against 0 % to 100 % Load Change Ⓐ	Max.	±(0.01 % + 50 mV)
Ripple/Noise (p-p) *	Max.	0.0007 %
Drift (after 1 h Warm-up) *	Max.	±(0.02 % + 10 mV)/8 h
Temperature Coefficient *	Max.	±0.01 %/°C
Output Voltage Monitor		4-digit digital meter
Output Voltage Monitoring Accuracy Ⓐ	Max.	±(0.1 % ± 3 V)
Protection Circuit		For short circuit and excess output current
AC Input Voltage	C4840-01	120 V (±10 %) (50/60 Hz)
AC Input Voltage	C4840-02	230 V (±10 %) (50/60 Hz)
Power Consumption *		Approx. 100 V·A
Operating Ambient Temperature/Humidity Ⓑ		0 °C to +40 °C / 80 % RH Max.
Specification Guaranteed Temperature/Humidity *Ⓑ		+5 °C to +35 °C / 80 % RH Max.
Storage Temperature/Humidity Ⓑ		-20 °C to +50 °C / 85 % RH Max.
Output Receptacles		Two SHV receptacles
Weight		10 kg
CE Marking		Conforms to ECM directive (89/336/EEC)/EN61326: 1997 + A1: 1998 + A2: 2001 Class B Conforms to low voltage directive (73/223/EEC)/EN61010-1: 2001

NOTE: ⒶAt maximum output voltage. ⒷWithout moisture condensation. * At maximum output voltage and current.

Accessories

①AC line cable (2.4 m long)..1
②High voltage output cable (1.5 m long) terminated with SHV-P plugs E1168-19 1
③Spare fuses..2
④3P/2P connector AC adapter (C4840-01 only) 1

Dimensional Outlines (Unit: mm)



TACCA0256EA

Photomultiplier Tube Dark Current and Cooling Effect

Causes of Dark Current

A small amount of current flows in a photomultiplier tube operated at a high voltage even when no light enters it. This output current is called the dark current. Since the dark current degrades the S/N ratio, it is the factor that determines the lower limit of detection when the output current is extremely low such as in low-level-light measurement. Major causes of the dark current can be classified into the seven described below. The extent to which each of these causes affects the dark current depends on the type of photomultiplier tube and varies from tube to tube or according to operating conditions.

Specific Causes

① Thermionic emission of electrons from the photocathode and dynode surfaces

② Leakage current between electrodes and lead pins (Mainly due to impurities on the electrode supporting materials, glass stem, plastic base surfaces and on the socket surface)

③ Ion current flowing as a result of ionization of residual gases inside the bulb

④ Photoelectron emission caused by internal electrons and ions colliding with the electrode support materials and glass

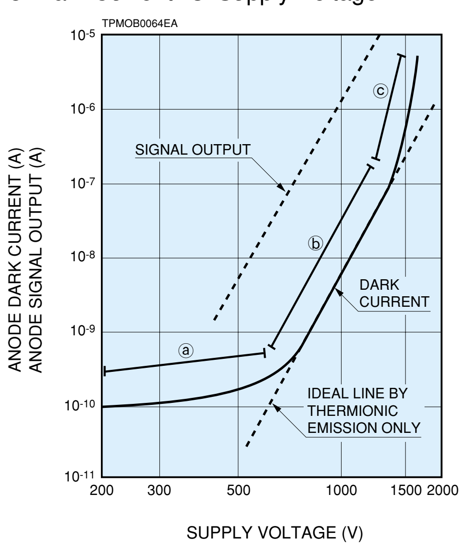
⑤ Photoelectron emission by the glass scintillation as a result of gamma rays emitted from radioactive elements (chiefly ^{40}K) inside the bulb

⑥ Photoelectron emission caused by Cherenkov radiation due to cosmic ray passing through the glass

⑦ Field emission of electrons from the photocathode and dynode surfaces

Figure 23 shows the relationship between the voltage supplied across the photomultiplier tube cathode and anode, and the anode dark current. This characteristic curve can be divided into three regions. In the low-voltage region ⓐ, the major cause of dark current is the leakage current ② and in the high-voltage region ⓒ, ③, ④, and ⑦ become the governing factors that determine the dark current. In contrast, in region ⓑ which approximates actual operating conditions, thermal electron emission is predominant. From this behavior, it can be seen that cooling the photocathode and dynodes would be very effective in reducing the dark current when the photomultiplier tube is operated at the normal voltage range.

Figure 23: Dark Current vs. Supply Voltage

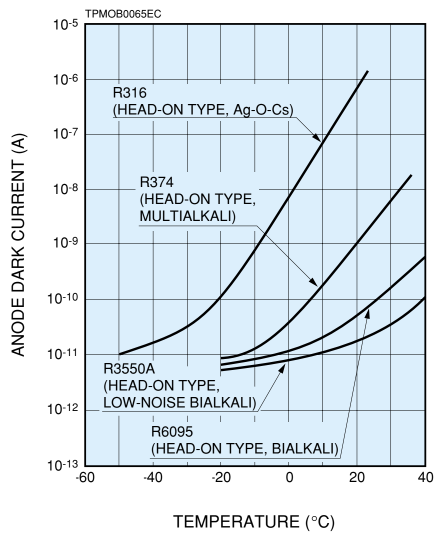


Thermal electron Emission and Cooling Effect

Figure 24 shows a comparison of the temperature characteristics of dark current for various photocathode materials used in photomultiplier tubes of the same configuration and dynode structure. From this figure, it is clear that photocathodes with higher sensitivity at longer wavelengths (multialkali and Ag-O-Cs) exhibit larger dark currents as the temperature increases. In other words, the cooling effect on the dark current and S/N ratio is more remarkable in such photocathodes. In this figure, the cooling effect is limited in the region below -20 °C to -30 °C, due to the fact that contribution of factors other than thermionic emission becomes relatively large in this region. In photon counting applications, since the leakage current can be ignored, greater cooling effect can be achieved.

Thermal electrons are emitted not only from the photocathode but also from the dynodes. However, thermal electrons emitted from the latter dynodes multiply less, and therefore the real problems are electrons from the photocathode and the first or second dynode. Cooling these portions can considerably reduce the dark current.

Figure 24: Dark Current vs. Temperature for Various photocathodes



Selection Guide

Type No.	Applicable PMTs
C4877 Series	ϕ38 mm (1-1/2") and ϕ51 mm (2") Head-on
C4878 Series	MCP-PMT (R3809U-50 series)
C9143	ϕ28 mm (1-1/8") Side-on
C9144	ϕ28 mm (1-1/8") Side-on

High Performance Thermoelectric Coolers C4877, C4878 Series

TACCF0161

Left: C4877 Power Supply
Right: C4877 Cooled PMT Housing

The C4877 series and C4878 series are thermoelectric coolers constructed with enhanced electrostatic and magnetic shielding (C4877 Series). This minimizes the influence of external noise on the photomultiplier tube and thus significantly improves photometric accuracy. These coolers offer user-friendly functions such as easy temperature control and pilot lamp blanking. The C4877 series is designed for use with 51 mm (2") or 38 mm (1-1/2") diameter head-on photomultiplier tubes, and the C4878 series for MCP-PMTs.

Features

- **Thermoelectric cooling using Peltier elements**
- **About -30 °C cooling temperature (with +20 °C cooling water)**
- **Evacuated, double-pane window with heater for frost prevention**
- **Built-in electrostatic and magnetic shielding (C4877 Series)**
- **Water shut-off protection to guard the Peltier elements**
- **Stable operation due to a regulated power supply**

Specifications

[Cooled PMT Housing]

Parameter		Value/Description
Cooling		Thermoelectric cooling using Peltier elements
Heat Exchange Medium		Water
Amount of Cooling Water		1 L/min to 3 L/min
Cooling Temperature (with cooling water at +20 °C)		Approx. -30 °C
Temperature Controllable Range (with cooling water at +20 °C)		-30 °C to 0 °C (continuously adjustable)
Cooling Time		Approx. 120 min
Optical Window Material		Evacuated double-pane fused silica window with heater
Applicable PMTs (Optional)	C4877 Series	28 mm (1-1/8") Dia. and 38 mm (1-1/2") Dia. and 51 mm (2") Dia. Head-on
	C4878 Series	MCP-PMT (R3809U-50 Series)
Applicable Socket Assembly or PMT Holder (Optional)	C4877 Series	E2762 Series Ⓐ
	C4878 Series	E3059-500 (R3809U-50 Series)
Operating Ambient Temperature Ⓑ		0 °C to +40 °C
Storage Temperature Ⓑ		0 °C to +40 °C
Weight		C4877 5.8 kg / C4878 5.5 kg

NOTE: ⒷNo condensation

[Power Supply]

Parameter		Value/Description
AC Input Voltage	C4877, C4878	100 V ± 10 V (50 Hz/60 Hz)
	C4877-01, C4878-01	120 V ± 12 V (50 Hz/60 Hz)
	C4877-02, C4878-02	230 V ± 23 V (50 Hz/60 Hz)
Power Consumption		270 V·A
Output Voltage		28 V
Output Current		4.3 A
Protection Circuit		Functions against cooling water suspension and over current/short circuit
Operating Ambient Temperature Ⓑ		0 °C to +40 °C
Storage Temperature Ⓑ		0 °C to +40 °C
Weight		8.5 kg

NOTE: ⒷNo condensation

[Components and Accessories]

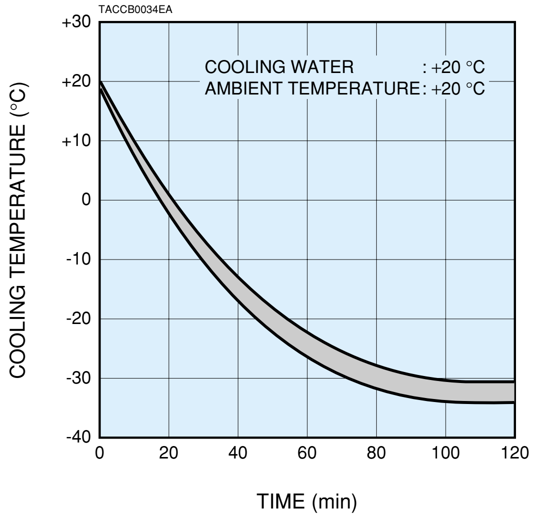
●Cooled PMT Housing (Including an input window) ●Power Supply ●Light Shield Cap
●Spare Fuse ●Water Hose Clamps ●Connection Cable (1.5 m) ●AC Line Cable (2 m)
To operate C4877 and C4878, water hoses with an inner diameter of 15 mm are required.

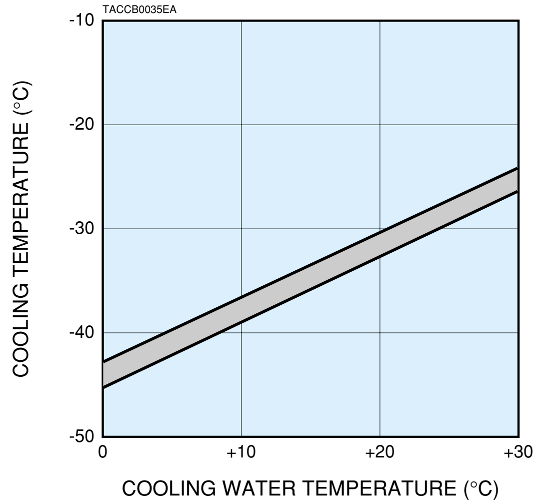
NOTE: Ⓐ

E2762 Series	PMT
E2762-502	R1767, R980, R1387, R2066
E2762-506	R943-02, R3310-02
E2762-509	R464, R585, R649
E2762-510	R329-02, R331-05, R2257
E2762-511	R316-02, R374, R2228, R5929, R6249
E2762-513	R375, R669

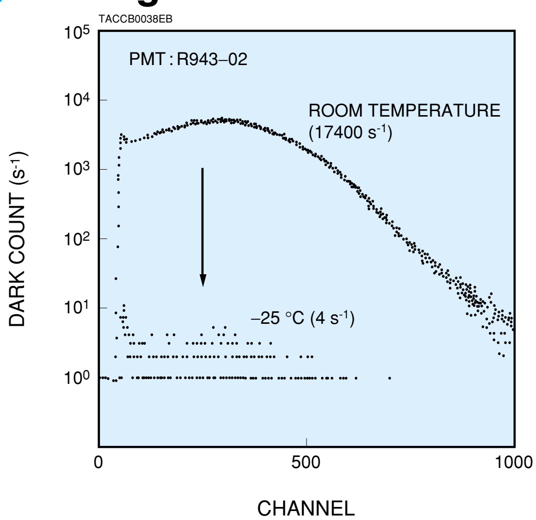
All 6 models E2762 series listed here are
SHV high voltage input and BNC current output type.

Cooling Characteristics

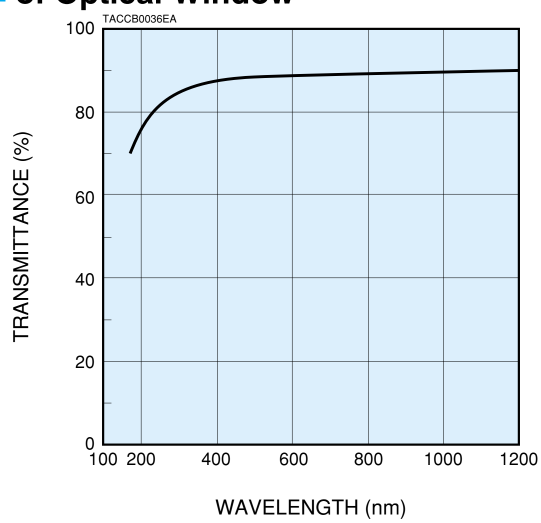




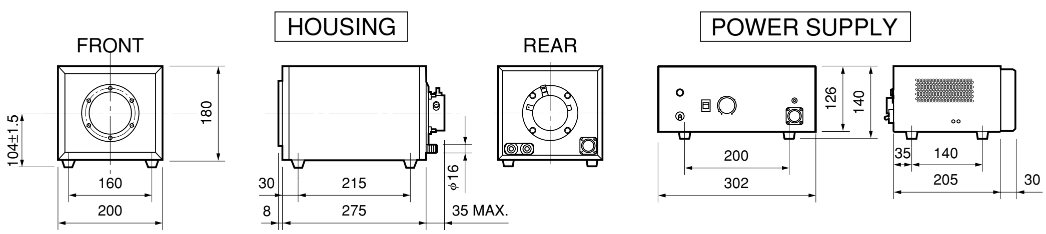
Cooling Effect on Dark Count (C4877)

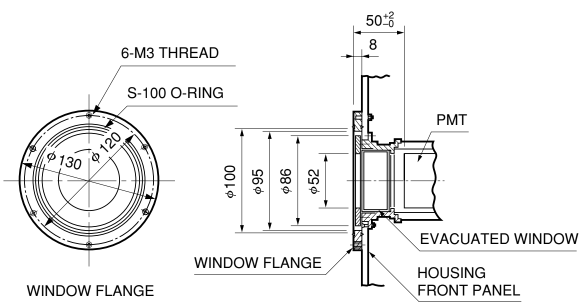


Spectral Transmission Characteristics of Optical Window



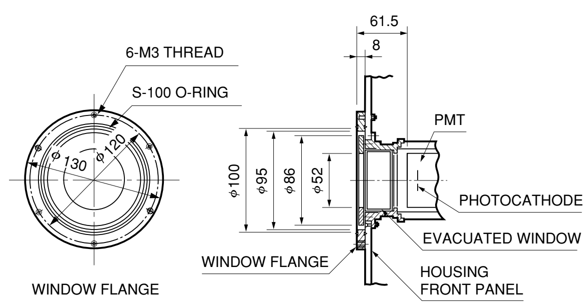
Dimensional Outlines (Unit: mm)





(C4877 Series)

TACCA0172EB



(C4878 Series)

TACCA0173EB

* CE C4877-02 and C4878-02 conform to the EMC directive (89/336/EEC) and the LVD (73/223/EEC) of the European Union.

Thermoelectric Coolers

High Performance Thermoelectric Coolers for 28 mm Dia. Side-on PMTs C9143, C9144

▲Left : C9144 and socket assembly C9145
Right : C9143 and socket assembly E9146

The C9143 and the C9144 are thermoelectric cooling units designed for 28mm diameter side-on photomultiplier tubes (PMT). The C9143 and the C9144 improve S/N (signal to noise ratio) of PMT measurement because of reduction of thermal electrons, which are emitted from PMT photocathode, and minimization of external noise by a built-in electrostatic and magnetic shield. The C9143 and the C9144 can communicate with a PC via an RS-232C serial interface. It enables the PC to control the cooling temperature, high voltage output of C9145 (optionally available socket assembly with a built in Cockcloft-Wolton high voltage power supply) and ±5 V power supply for external equipment. The C9143 and the C9144 use water and forced air respectively to exchange heat of the thermoelectric cooler (Peltier elements).

Features

- **Thermoelectric cooling using Peltier elements**
- **Built-in electrostatic and magnetic shield**
- **Protective function for Peltier elements in case of suspension of water flow or fan operation**
- **Low voltage output for driving C9145 (sold separately)**
- **Control and monitor function of high voltage output of C9145**
- **±5 V output for external equipment**
- **Built-in interface for controlling external equipment**
- **PMT temperature control by PC**

Specifications

[Cooled PMT Housing]

Parameter	C9143	C9144	Unit
Cooling Method	Thermoelectric cooling using Peltier elements		—
Heat Exchange Medium	Water	Forced air	—
Cooling Temperature	Approx. -30 Ⓐ (with cooling water of +20 °C)	Approx. -25 Ⓑ (with ambient temperature of +25 °C)	°C
Lowest Cooling Temperature	-30		°C
Time to Stable Cooling Temperature	Approx. 70	Approx. 80	min
Optical Window Material	Synthetic silica		—
Light Input Aperture Dimension	8 × 24		mm
Applicable PMTs (sold separately)	28 mm Dia. Side-on Type		—
Applicable Socket Assembly (sold separately)	C9145 (DP-type), E9146 (D-type)		—
Operating Ambient Temperature/Humidity Ⓒ	+5 °C to +40 °C / 75 % RH Max.	+5 °C to +35 °C / 75 % RH Max.	—
Storage Temperature/Humidity Ⓒ	-20 °C to +50 °C / 85 % RH Max.		—
Weight	Approx. 1	Approx. 1.6	kg
Feature	Law infuluence by ambient temperature	Easy operation	—

NOTE: ⒶC9143 achieves cooling temperature of approx. -30 °C with water temperature of +20 °C. If the water temperature is higher, the possible lowest cooling temperature becomes higher (Note: lowest cooling temperature is -30 °C). ⒷC9144 achieves cooling temperature of approx. -25 °C with ambient temperature of +25 °C. If the ambient temperature is higher, the possible lowest cooling temperature becomes higher. If the ambient temperature is lower, the possible lowest cooling temperature becomes lower (Note: lowest cooling temperature is -30 °C). ⒸNo condensation

[Controller]

Parameter		Value/Description	Unit
AC Input Voltage		100 to 240 ±10 % (50 Hz / 60Hz)	V
Maximum Power Consumption		120	V·A
Temperature Controllable Range		-30 to -5 (0.5 °C step) Ⓓ	°C
Protective Functions		Protection for Peltier elements in case of suspension of water flow or Fan operation, protection in case of over current / short circuit	—
Power Supply Unit for External Equipment	Output Voltage	±5 (±0.25)	V
	Output Current	0.5	A
	Connector	HIROSE SR30-10R-4S	—
Control Interface	DI (Input)	4 bit (TTL input)	—
	DO (Output)	4 bit (TTL open collector output)	
Serial Interface		RS-232C, 9600 bps	—
Operating Temperature / Humidiy Ⓒ		+5 °C to +40°C / 75 % RH Max.	—
Storage Temperature / Humidity Ⓒ		-20 °C to +50°C / 85 % RH Max.	—
Weight		Approx. 4	kg

NOTE: ⒸNo condensation ⒹPMT temperature may not achieve set up cooling temperature controlled by the operator if ambient temperature and/or water temperature is high. The cooling temperature is controlled on PC.

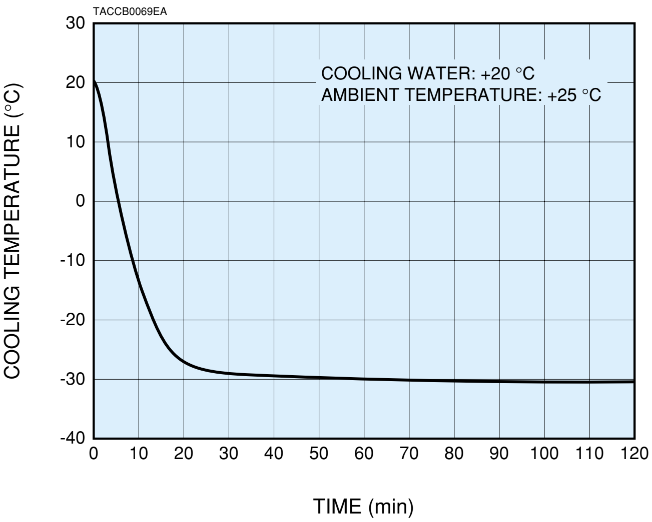
[Components and Accessories]

●Cooled PMT housing ●Controller ●Light shield cap ●Spare fuses (2 pcs) ●AC line cable (2 m)
●Connection cable (1.5 m) between cooled PMT housing and controller ●Instruction manual
●RS-232C communication cable (1.5 m) ●Software for cooling temperature control, voltage control of C9145

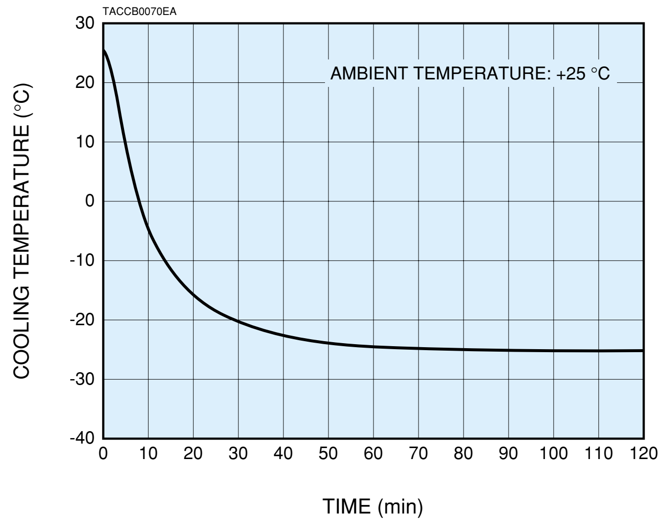
* To operate C9143, water hoses with an outer diameter of 6 mm and an inner diameter of 4 mm are required.

Cooling Characteristics (C659-50 Series)

●C9143

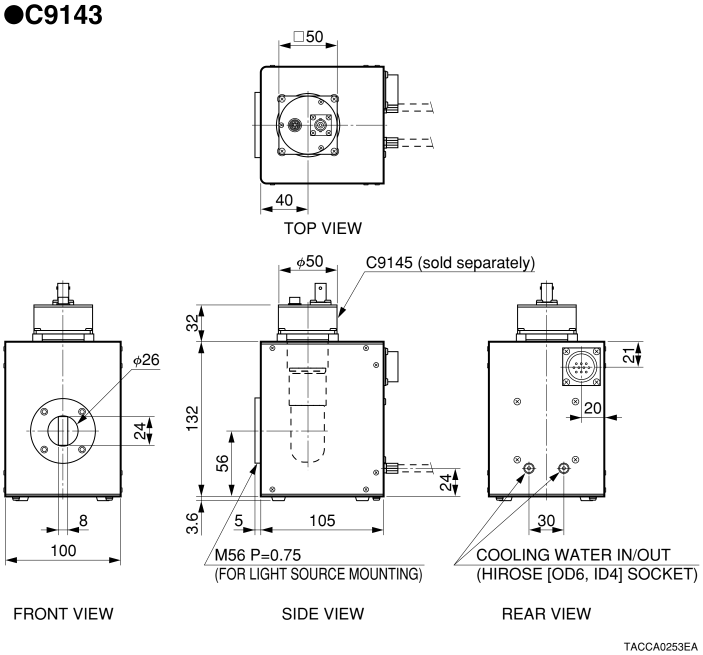


●C9144

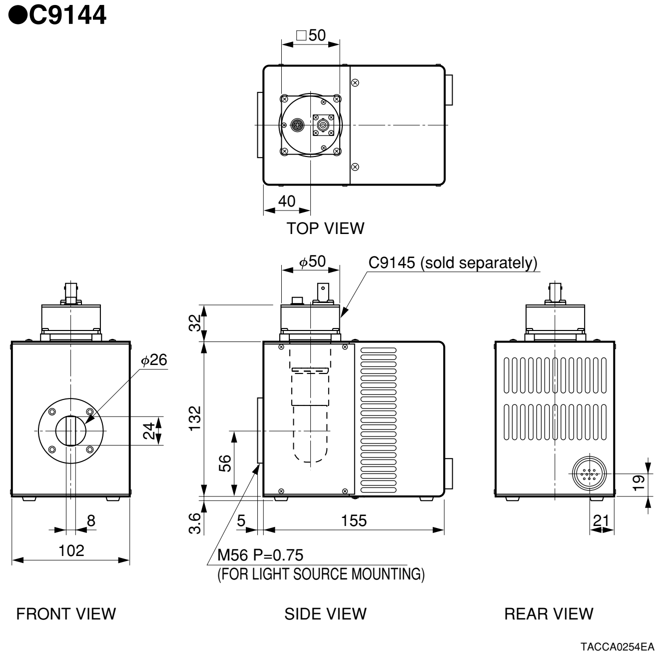


Dimensional Outlines (Unit: mm)

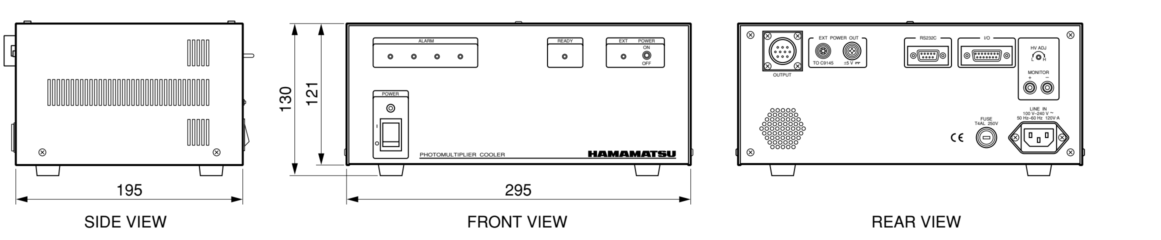
●C9143



●C9144



●CONTROLLER



Magnetic Shield Cases

Magnetic Shield Cases E989 Series

TACCF0093

Photomultiplier tubes are extremely sensitive to magnetic fields and exhibit output variations even from sources such as terrestrial magnetism. Hamamatsu E989 series magnetic shield cases are designed specifically to protect photomultiplier tubes from the influence of such magnetic fields. The E989 series uses permalloy, a material that has an extremely high permeability (approximately 10^5). The magnetic field intensity within the shield case can be attenuated from 1/1000 to 1/10000 of that outside the shield case (this ratio is called the shielding factor). The E989 series ensures a stable output for photomultiplier tubes operating in proximity to magnetic fields.

Features

- **Made of high-permeability permalloy (Ni: 78 %, Fe and others: 22 %)**
- **Various sizes available with inner diameters from 12 mm to 138 mm**
- **Lusterless black paint finish**

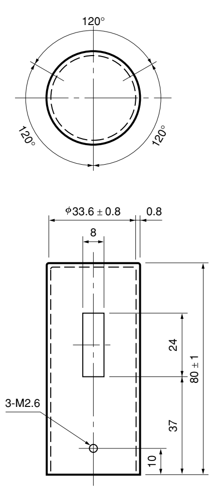
Specifications

Photomultiplier Tube Diameter		Type No.	Internal Dia. D (ϕmm)	Thickness t (mm)	Length L (mm)	Weight (g)
Side-on	ϕ13 mm (1/2")	E989-10	14.5	0.5	47 ± 0.5	10
	ϕ28 mm (1-1/8") *	E989	33.6 ± 0.8	0.8	80 ± 1	66
Head-on	ϕ10 mm (3/8")	E989-28	12 ± 0.5	0.5	48 ± 0.5	9
	ϕ13 mm (1/2")	E989-09	16 ± 0.5	0.8	75 ± 0.5	28
	ϕ19 mm (3/4")	E989-02	23 ± 0.5	0.8	95 ± 1	50
	ϕ25 mm (1")	E989-39	29 ± 0.5	0.8	48 ± 0.5	32
	ϕ28 mm (1-1/8")	E989-03	32 ± 0.5	0.8	120 ± 1	90
	ϕ38 mm (1-1/2")	E989-04	44^{+1}_{-0}	0.8	100 ± 1	102
	ϕ51 mm (2")	E989-05	60^{+1}_{-0}	0.8	130 ± 1	180
	ϕ76 mm (3")	E989-15	$80^{+1.5}_{-0}$	0.8	120 ± 1	200
	ϕ127 mm (5")	E989-26	138 ± 1.5	0.8	170 ± 1	600

* Photomultiplier tubes with HA coating extending to the base portion cannot be used. Please consult our sales offices for details.

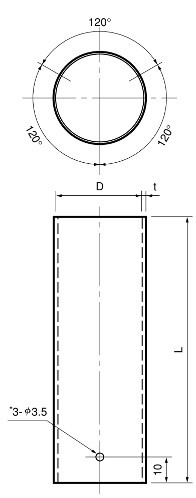
Dimensional Outlines (Unit: mm)

E989



TACCA0117EB

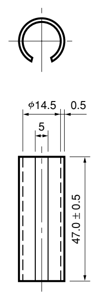
E989-02 to -05, -09*, -39*



*No mounting hole is provided for E989-09 and E989-39.

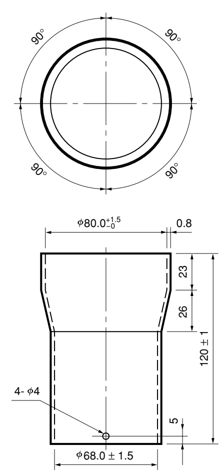
TACCA0118EA

E989-10



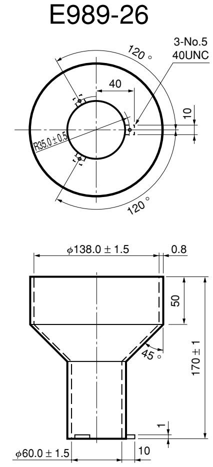
TACCA0119EC

E989-15



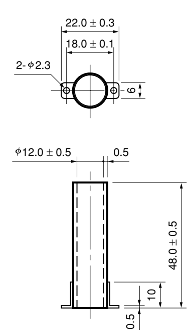
TACCA0120EC

E989-26



TACCA0121EC

E989-28



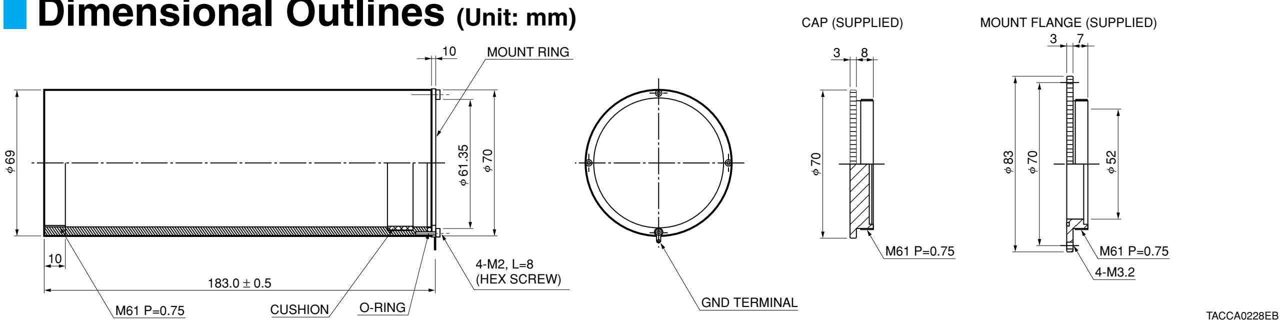
TACCA0122EC

Housing E1341-01 (For E5859 series socket assemblies)

TACCF0177

The E1341-01 is a metal housing designed for 51 mm (2") diameter head-on photomultiplier tubes operated at room temperature. The E1341-01 ensures complete light-shielding and also accommodates a magnetic shield case (E989-62 sold separately).
The E1341-01 housing can be easily attached to a monochromator by preparing a simple adapter. The Copal No. 3 shutter can be directly attached to the E1341-01.

Dimensional Outlines (Unit: mm)



TACCA0228EB

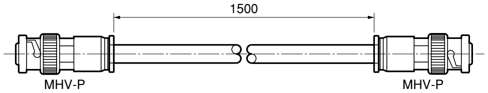
Power and Signal Cables E1168 Series, Connector Adapters A4184 Series

TACCF0153

Hamamatsu offers the E1168 series cables for connection of photomultiplier tube assemblies and their accessories. A variety of cables are available, for handling high voltage, low voltage and signals.
In addition, Hamamatsu also provides the A4184 series connector adapters designed for SHV/MHV connector conversion.

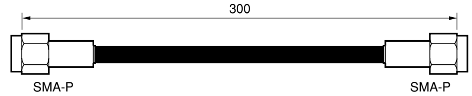
Dimensional Outlines (Unit: mm)

E1168 Series



TACCA0141EA

A5026 Series



TACCA0052EA

Selection Guide

● **For High Voltage**

Type. No.	Cable Type	Cable Diameter	Maximum Voltage	Connector Types
E1168	RG-59B/U (Red)	φ6.2 mm	2.3 kV	MHV-P—MHV-P
E1168-10				MHV-P—SHV-P
E1168-17				SHV-P—SHV-P
E1168-18	Custom High Voltage Cable (Red)	φ6.15 mm ±0.3 mm	5 kV	MHV-P—MHV-P
E1168-19				SHV-P—SHV-P
E1168-20				MHV-P—SHV-P

● **For Low Voltage**

Type. No.	Cable Type	Connector Types
E1168-13	MVVS 3 × 0.3	MC-032—MC-032
E1168-14	MVVS 2 × 0.3	SR30-10PQ-4P—SR30-10PQ-4P

● **For Signal**

Type. No.	Cable Type	Impedance	Connector Types
E1168-01	3D-2V	50 Ω	N-P—N-P
E1168-02			N-P—BNC-P
E1168-03	3C-2V	75 Ω	BNC-P—BNC-P
E1168-05	3D-2V	50 Ω	BNC-P—BNC-P
A5026	SPECIAL COAXIAL CABLE	50 Ω	SMA-P—SMA-P
A5026-01			SMA-P—SMA-J

● **Connector Adapters**

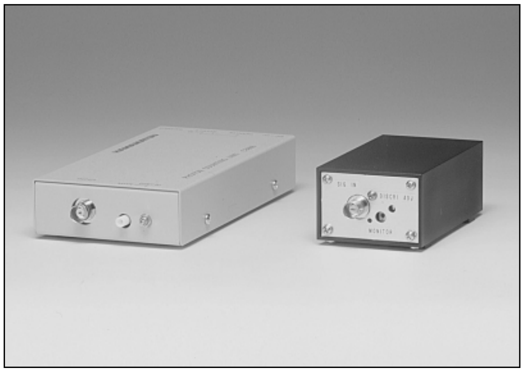
Type. No.	Connector Types
A4184-02	MHV Plug—SHV Jack
A4184-03	SHV Plug—MHV Jack

● **Relay Adapters**

Type. No.	Connector Types
A5074	SHV Jack—SHV Jack
A7992	BNC Jack—BNC Jack

Related Products for Photon Counting

Photon Counting Units C3866, C6465



▲Left: C3866 Right: C6465   TPHOF0094

These photon counting units contain an amplifier and discriminator to convert the single photoelectric pulses from a photomultiplier tube into a 5 V digital signal.
The C3866 has an output linearity up to 1×10^{7} s^{-1}, and a high-speed counter is not required when set to division by 10.
The C6465 has an output linearity up to 1×10^{6} s^{-1}, and an output pulse width of 30 ns allowing it to be used with a general-purpose counter.

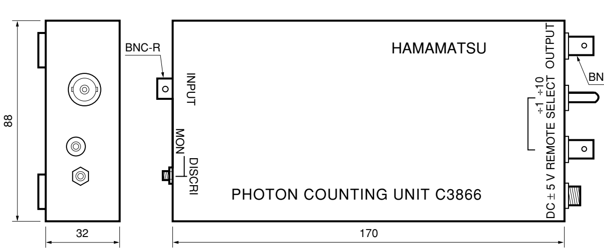
Specifications

Parameter		C3866		C6465	Unit
Input Impedance		50		50	Ω
Discrimination Level (input conversion)		-0.5 to -16		-2.2 to -31	mV
PMT Gain		3×10^{6}		5×10^{6}	—
Prescaler		÷1	÷10	—	
Count Linearity		4×10^{6}	1×10^{7}	1×10^{6}	s^{-1}
Pulse-pair Resolution		25	10	60	ns
Output Pulse		CMOS 5 V, POSITIVE LOGIC		TTL POSITIVE LOGIC	—
Output Pulse Width		10	Depends on count rate.	30	ns
Supply Voltage		+5.2 ± 0.2 V, 150 mA/-5.2 ± 0.2 V, 300 mA		+5 V, 60 mA/-5 V, 120 mA	—
Connector	Input	BNC-R		BNC-R	—
	Output	BNC-R		BNC-R	—
	Remote	BNC-R		—	—
	Power	HIROSE SR30-10R-4S *1		DIN (6-pin) *2	—
Dimensions		88 × 32 × 170		60 × 43.2 × 105	mm
Operating Ambient Temperature Ⓐ		0 to +50		0 to +50	°C
Storage Temperature Ⓐ		-10 to +60		-10 to +50	°C
Weight		Approx. 320		Approx. 250	g

*1: Supplied with a cable (1 m) attached to the mating plug (Hirose SR30-10PQ-4P).
*2: Supplied with a cable (1.5 m) attached to the mating plug.
NOTE: ⒶNo condensation

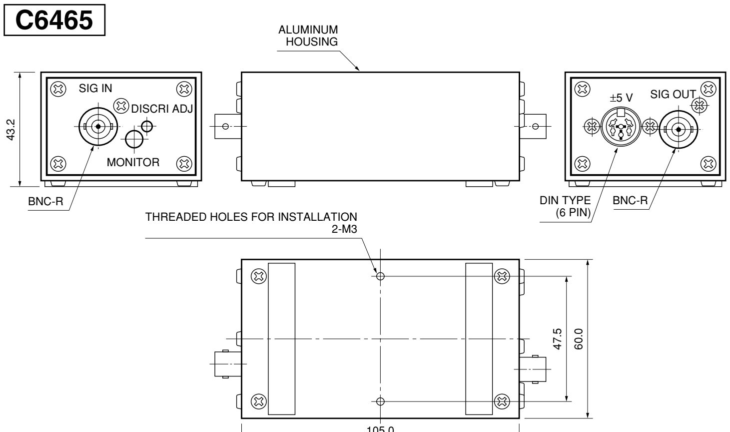
Dimensional Outlines (Unit: mm)

C3866



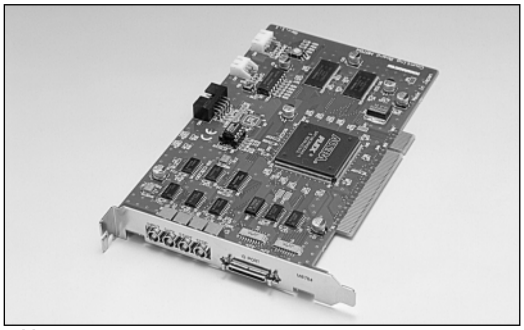
TPHOA0002EB

C6465



TPHOA0015EA

Counting Board M8784 / Counting Unit C8855



▲M8784

▲C8855

The M8784 and the C8855 can be used as a photon counter when cambined with a photon counting head, etc. The M8784 and the C8855 have two counter circuits (double counter method) which enable the user to count signal without dead time.
The M8784 is a PCI bus add-in board type counter. The internal memory allows pulse counting over extended periods with a high time resolution (10 µs).
The C8855 has a USB interface to allow users to operate it at various fields by connecting to a notebook PC. When used with a photon counting head, the C8855 supplies power (+5 V / 200 mA) necessary to operate the photon counting head.

Specifications

M8784

Parameter		Description / Value
Input	Number of Input Signals	1 ch
	Signal Input Level	TTL positive logic
	Signal Pulse Width	8 ns or longer
	Input Impedance	50 Ω
Counter	Counter Method	Double counter method
	Max.Count Rate	50 MHz
	Max.Counter Capacity	2^{32} counts/counter gate
Counter Gate	Counter Gate Mode	Internal, external, START-STOP
	Internal Counter Gate Time	10 µs to 10 s (1, 2, 5 step)
	External Counter Gate Time	100 ns or longer
Trigger	Trigger Method	Software or external trigger
	External Trigger Signal	TTL negative logic
Memory	Memory Method	Double memory method
	Memory Date Width	128 000 (when capacity of 2^{32} is selected) / 256 000 (when capacity of 2^{16} is selected)
	Memory Capacity	2^{32} (32 bit) / 2^{16} (16 bit)
General Output Section	Signal Input	TTL negative logic / 8 bit
	Signal output	Open collector / 8 bit
Compatible OS		Windows® 98/98SE/Me/2000
Bus Type		PCI
Supply Voltage		5 V / 1 A (supplied from PCI bus)
Size		Half size
Weight		150 g
Operating Ambient Temperature / Humidity Ⓐ		+5 °C to +45 °C / 80 % or less
Storage Temperature / Humidity Ⓐ		0 °C to +50 °C / 85 % or less
CE Marking		Conforms to the EMC directive (89/336/EEC) of the European Union.

NOTE: ⒶNo condensation

Supplied: CD-ROM (containing instruction manual, device driver, DLL, sample software*, etc.), Signal input cable (E1168-22), General-purpose I/O connector (JAE: TXA20A-26PH1-D2P1-D1), Connection cable set (JAE: XHP-3, XHP-4)

*: Sample software is configured from Lab VIEW™ of National Instruments, Inc.

C8855

Parameter		Description / Value
Input	Number of Input Signals	1 ch
	Signal Input Level	TTL positive logic
	Signal Pulse Width	8 ns or longer
	Input Impedance	50 Ω
Counter	Counter Method	Double counter method
	Max.Count Rate	50 MHz
	Max.Counter Capacity	2^{32} counts/counter gate
Counter Gate	Counter Gate Mode	Internal counter gate only
	Internal Counter Gate Time	50 µs to 10 s (1, 2, 5 step)
Trigger	Trigger Method	Software or external trigger
	External Trigger Signal	TTL negative logic
General Output Section		Open collector / 2 bits
Voltage Output		+5 V / 200 mA Max.
Compatible OS		Windows® 98/98SE/Me/2000
Interface		USB (Ver. 1.1)
Supply Voltage		+5 V / 500 mA Max. (supplied from accessory AC adapter)
Dimensions (W × H × D)		148 mm × 30 mm × 96 mm (excluding rubber feet and projecting parts)
Weight		300 g
Operating Ambient Temperature / Humidity Ⓐ		+5 °C to +45 °C / 80 % or less
Storage Temperature / Humidity Ⓐ		0 °C to +50 °C / 85 % or less
CE Marking		Conforms to the EMC directive (89/336/EEC) and the low voltage directive (73/23/EEC) of the European Union.
AC Adapter	AC Input	90 V to 264 V
	Output	7 V / 1.6 A

NOTE: ⒶNo condensation

Supplied: CD-ROM (containing instruction manual, device driver, DLL, sample software*, etc.) USB cable, AC adapter, AC cable, power output connector.

*: Sample software is configured from Lab VIEW™ of National Instruments, Inc.

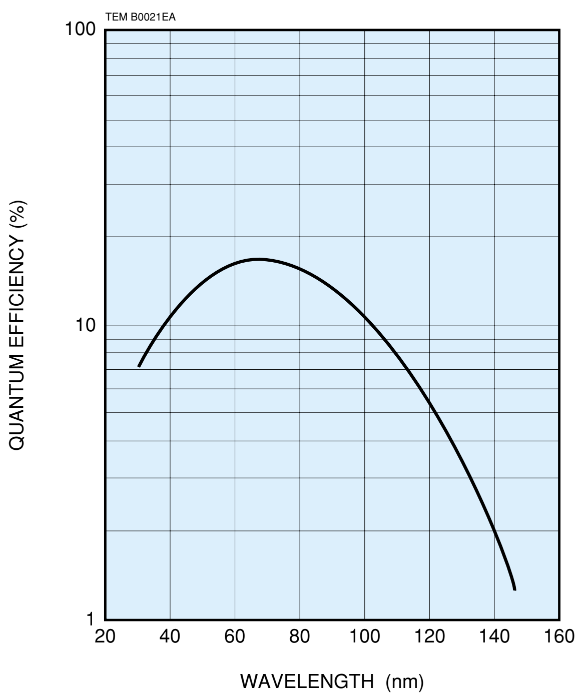
Electron Multipliers

Electron multipliers (also called ion multipliers) are specially designed for the detection and measurement of electrons, ions, charged particles, VUV radiation and soft X-rays. Hamamatsu electron multipliers deliver high gain and low noise, making them ideal for the detection of very small or low energy particles by using the counting method. Especially useful applications include mass spectroscopy, field ion microscopy and electron or VUV spectroscopy such as Auger spectroscopy and ESCA.

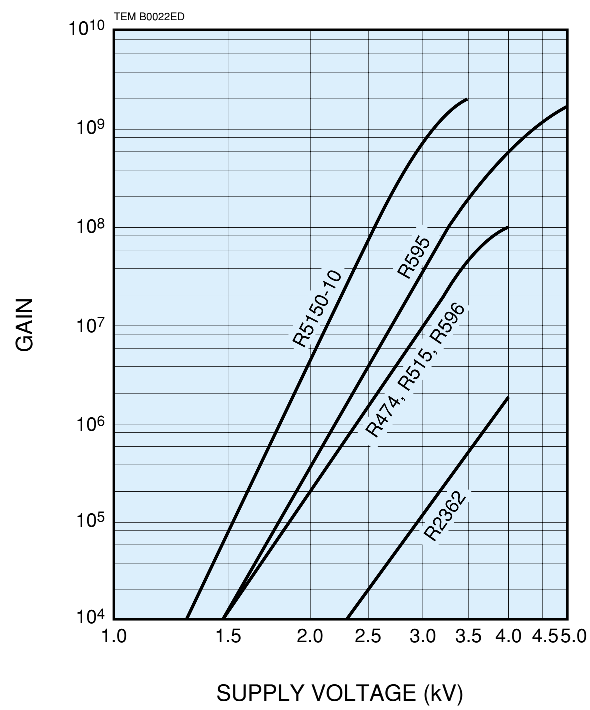
Each type has Cu-BeO dynodes connected by built-in divider resistors of 1 MΩ per stage. The first dynode can be replaced by a photocathode of Cs-I, K-Br, and so on for use in VUV spectroscopy. In applications where the operating vacuum level is inadequate, the R5150 is recommended. In TOF-MS applications, the R2362 with mesh dynodes is recommended.

		Dynode				Characteristics				Max. Ratings			
Type No. Ⓐ	Outline	Number of Stages	Structure	Material	Radiation Operating (mm)	Supply Voltage (V)	Gain Typ.	Rise Time Typ. (ns)	Anode to all Other Electrode Capacitance (pF)	Anode to First Dynode Voltage (V)	Anode to Last Dynode Voltage (V)	Ⓙ Average Anode Current (μA)	Operating Vacuum Level (Pa)
Head-on Type													
*R5150-10	❶	17	Box and Line	Cu-BeO	ϕ8	2000	5×10^6	1.7	4.0	3500	350	10	133×10^{-4}
R2362	❷	23	Mesh	Cu-BeO	ϕ20	3450	5×10^5	3.5	23	4000	350	10	133×10^{-4}
R474	❸	16	Box and Grid	Cu-BeO	8×6	2400	1×10^6	9.3	5.0	4000	350	10	133×10^{-4}
R515	❹	16	Box and Grid	Cu-BeO	8×6	2400	1×10^6	9.3	4.0	4000	350	10	133×10^{-4}
R596	❻	16	Box and Grid	Cu-BeO	12×10	2400	1×10^6	10	9.0	4000	400	10	133×10^{-4}
R595	❺	20	Box and Grid	Cu-BeO	12×10	3000	4×10^7	12	9.0	5000	400	10	133×10^{-4}

Spectral Response (Cu-BeO)

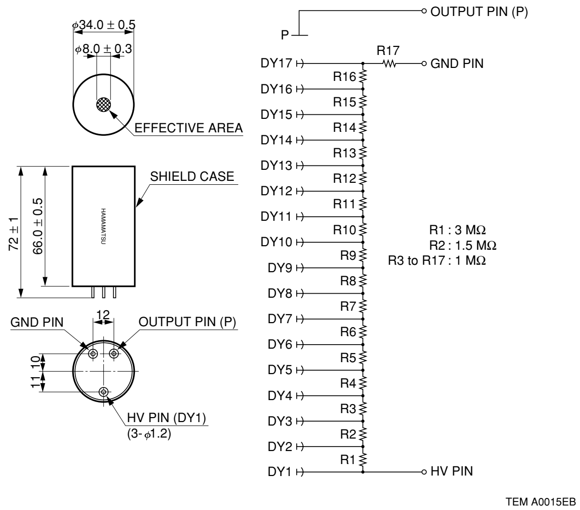


Gain

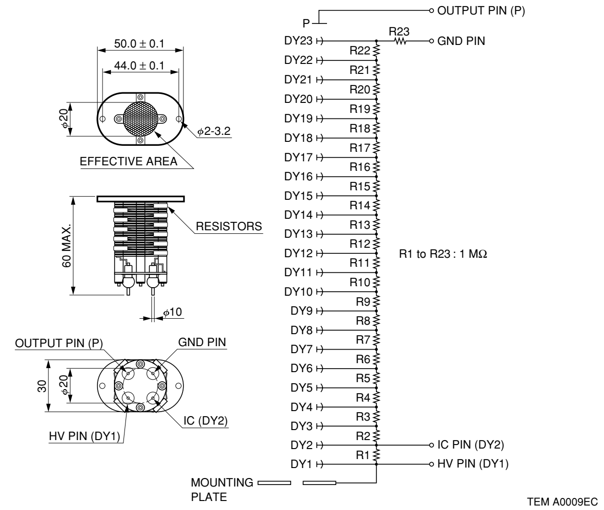


Dimensional Outlines (Unit: mm)

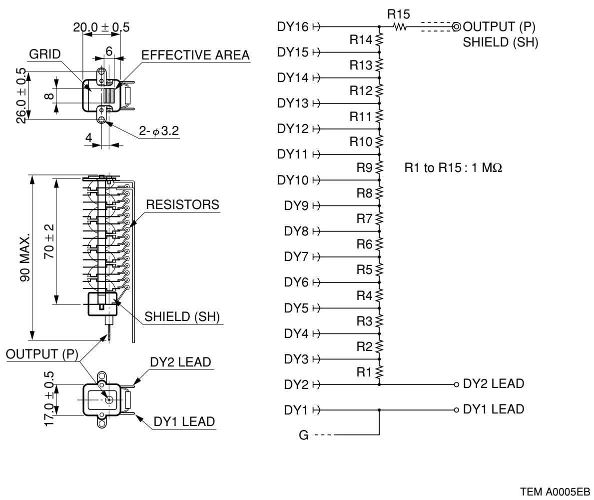
❶ R5150-10



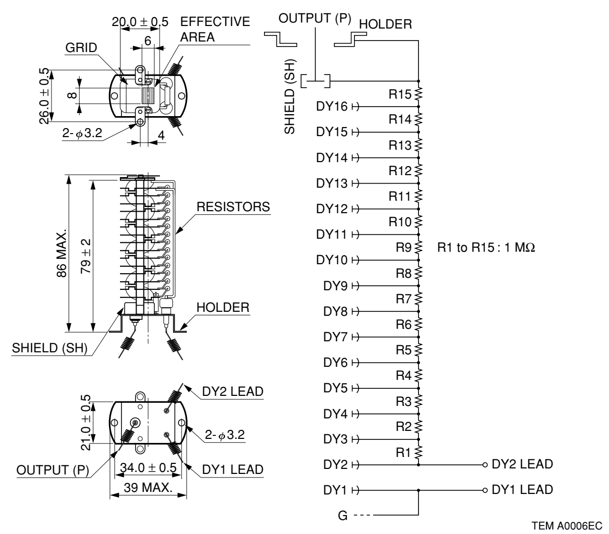
❷ R2362



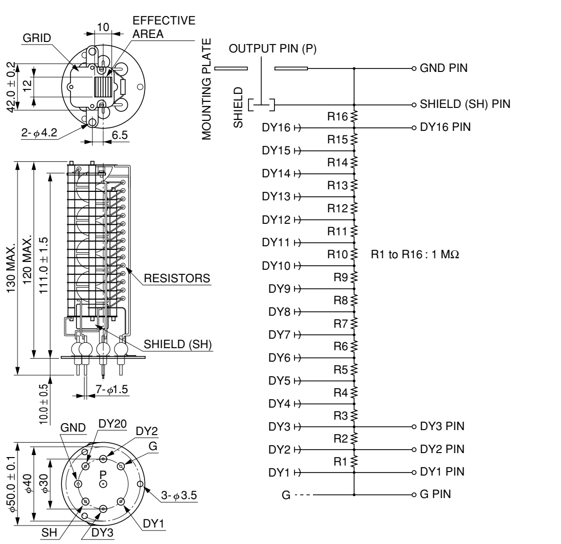
❸ R474



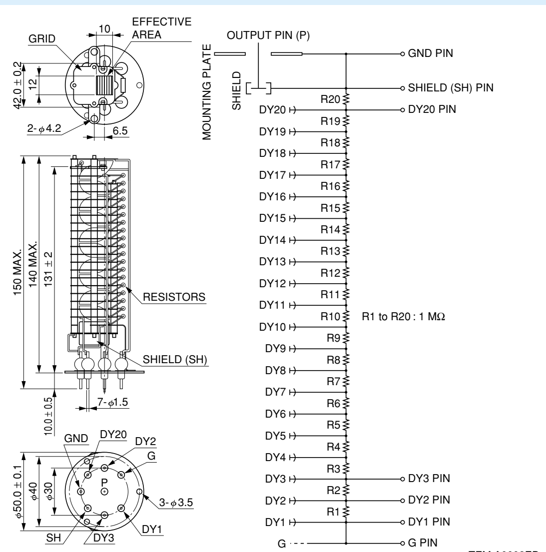
❹ R515



❺ R596



❻ R595



Caution and Warranty

SAFETY PRECAUTIONS

WARNING

HIGH VOLTAGE

A high voltage is applied to a photomultiplier tube during operation. Always provide adequate safety measures to prevent the operator or service personnel from electrical shock and the equipment from being damaged.

HANDLING PRECAUTIONS

● Handle tubes with extreme care.
Photomultiplier tubes have evacuated glass envelopes. Allowing the glass to be scratched or subjected to shock can cause cracks. Take extreme care during handling, particularly for tubes with graded sealing on synthetic silica bulbs.

● Keep faceplate and base clean.
Do not touch the faceplate and base with bare hands. Dirt and grime on the faceplate causes loss of transmittance and dirt or grime on the base may cause ohmic leakage. If the faceplate becomes soiled wipe it clean using alcohol.

● Do not expose to strong light.
The photocathode of photomultiplier tubes may be damaged if exposed to direct sunlight or intense illumination. Never allow strong light to strike the photocathode.

● Carefully handle tubes with a glass base.
Photomultiplier tubes with a glass base (also called button stem) are less rugged than tubes with a plastic base, so sufficient care must be taken when handling this type of tube. When fabricating a voltage-divider circuit by soldering resistors and capacitors to socket lugs, solder them while the tube is fully inserted into the socket.

● Helium permeation through silica bulb
Helium will permeate through silica bulbs and increase noise, leading to damage that makes photomultiplier tubes unusable. Avoid operating or storing them in an atmosphere where helium is present.

WARRANTY

Hamamatsu photomultiplier tubes and related products are warranted to the original purchaser for a period of 12 months after delivery. The warranty is limited to repair or replacement of a defective product due to defects in workmanship or materials used in its manufacture.
However, even if within the warranty period the warranty shall not apply to failures or damages caused by misoperation, mishandling, modification or accidents such as natural or man-made disasters.
The customer should inspect and test all products as soon as they are delivered.

ORDERING INFORMATION

This catalog lists photomultiplier tubes and related products currently available from Hamamatsu Photonics. Please select those products that best match your design specifications. If you do not find the products you want in this catalog, feel free to contact our sales office nearest you. We will modify our current products or design new types to meet your specific needs.

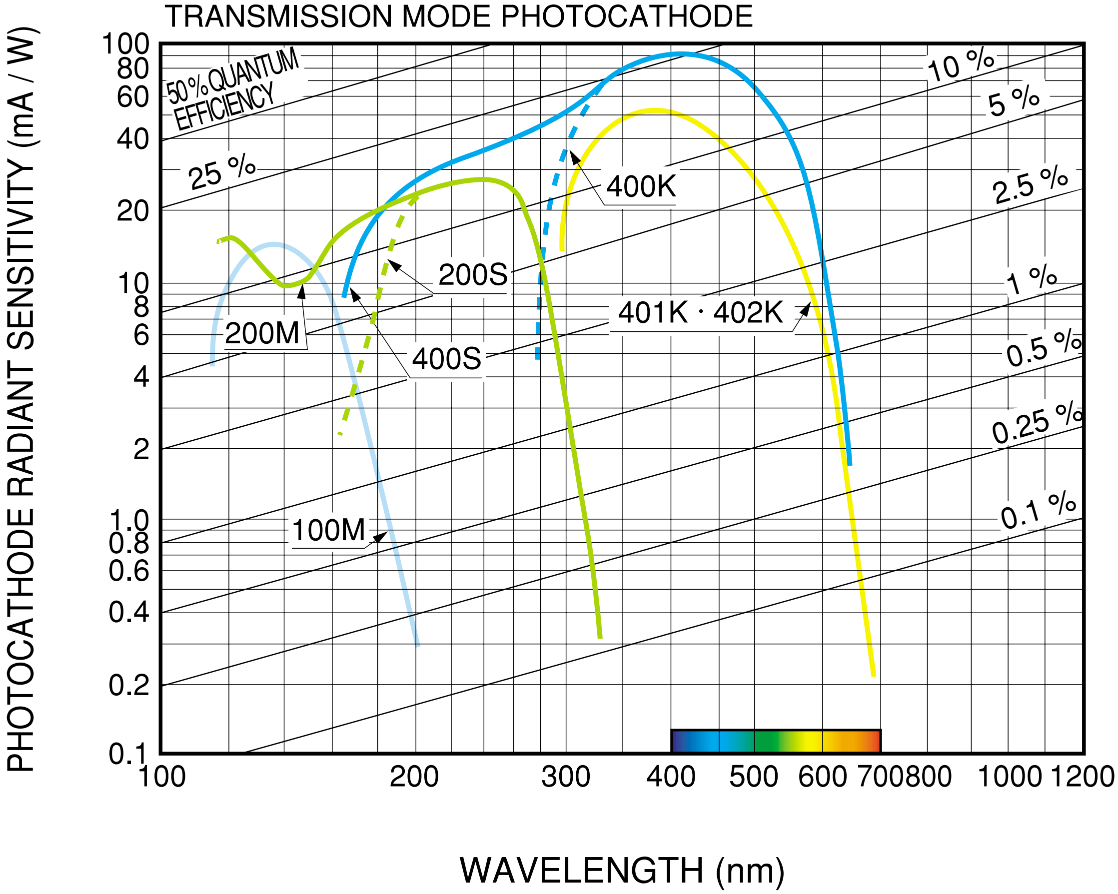
* Characteristics and specifications in this catalog are subject to change without prior notice due to product improvement or other factors.
Before you design equipment according to the characteristics and specifications of our products listed in this catalog, please contact us to check the product specifications.

Typical Photocathode Spectral Response

	Curve Codes	photocathode Materials	Window Materials	Spectral Response			PMT Examples
				Range	Peak Wavelength		
					Radiant Sensitivity (nm)	Q.E. (nm)	
				(nm)			
Semitransparent Photocathode							
○	100M	Cs-I	MgF2	115 to 200	140	130	R972, R1081, R6835
○	200M	Cs-Te	MgF2	115 to 320	240	240	R1080, R6836
○	200S	Cs-Te	Syinthetic silica	160 to 320	240	240	R759, R821, R1893, R6834
	201S	Cs-Te	Syinthetic silica	160 to 320	240	220	R2078
○	400K	Bialkali	Borosilicate	300 to 650	420	390	R329-02, R331-05, R464, R5496, R1635, R647, R1166, R2154-02, R3998-02, R7899, R6427,R6091, R6095, R580, R1828-01, R5611-01, R4998, R1924A, R3234-01
	400U	Bialkali	UV	185 to 650	420	390	R1584
○	400S	Bialkali	Syinthetic silica	160 to 650	420	390	R2496
○	401K	High temp. bialkali	Borosilicate	300 to 650	375	360	R1288A, R1705, R3991,R4177-01, R4607-01
○	402K	Low noise bialkali	Borosilicate	300 to 650	375	360	R2557, R3550A
	430U	Bialkali	UV	185 to 650	375	300	R2693
○	500K(S-20)	Multialkali	Borosilicate	300 to 850	420	360	R550, R649, R1387, R1513, R1617, R1878, R1894, R1925A
○	500S	Multialkali	Syinthetic silica	160 to 850	420	280	R375
○	500U	Multialkali	UV	185 to 850	420	290	R374, R1463, R2368
○	502K(Super S20)	Multialkali	Borosilicate	300 to 900	420	400	R5070A, R5929
○	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
Reflection mode Photocathode							
○	250S	Cs-Te	Fused silica	160 to 320	230	190	R6354, R7154
○	250M	Cs-Te	MgF2	115 to 320	200	190	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
○	452U	Bialkali	UV	185 to 750	420	220	R3788, R6352
	453K	Bialkali	Borosilicate	300 to 650	400	360	931B
○	456U	Low noise bialkali	UV	185 to 680	400	300	R1527, R4220, R6353
	550U	Multialkali	UV	185 to 850	530	250	R3811, R6355
	552U	Multialkali	UV	185 to 900	400	260	R2949
○	555U	Multialkali	UV	185 to 900	450	260	R3896
	556U	Multialkali	UV	185 to 850	430	280	R4632
	561U	Multialkali	UV	185 to 830	530	300	R6358
○	562U	Multialkali	UV	185 to 900	400	260	R928
○	650U	GaAs(Cs)	UV	185 to 930	300 to 800	300	R636-10
○	650S	GaAs (Cs)	Syinthetic 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 114, 115

SEMITRANSPARENT PHOTOCATHODE SPECTRAL RESPONSE CHARACTERISTICS



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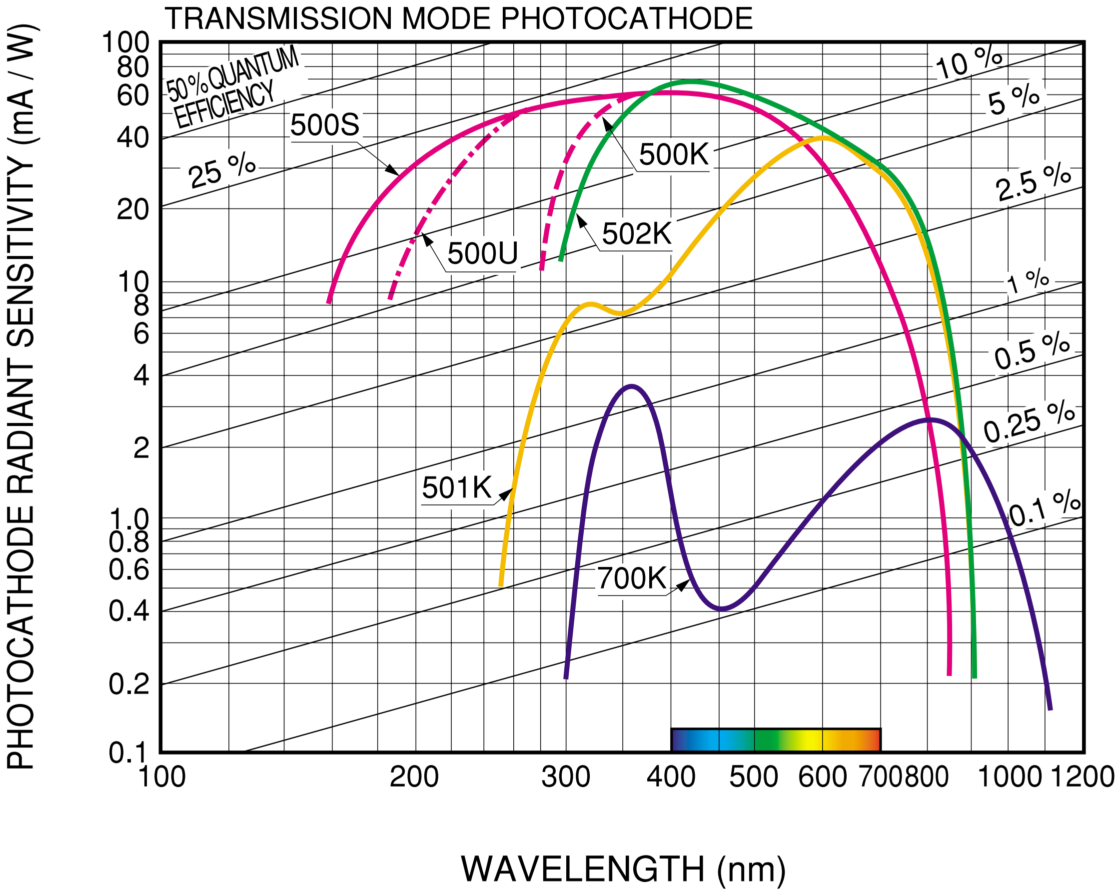
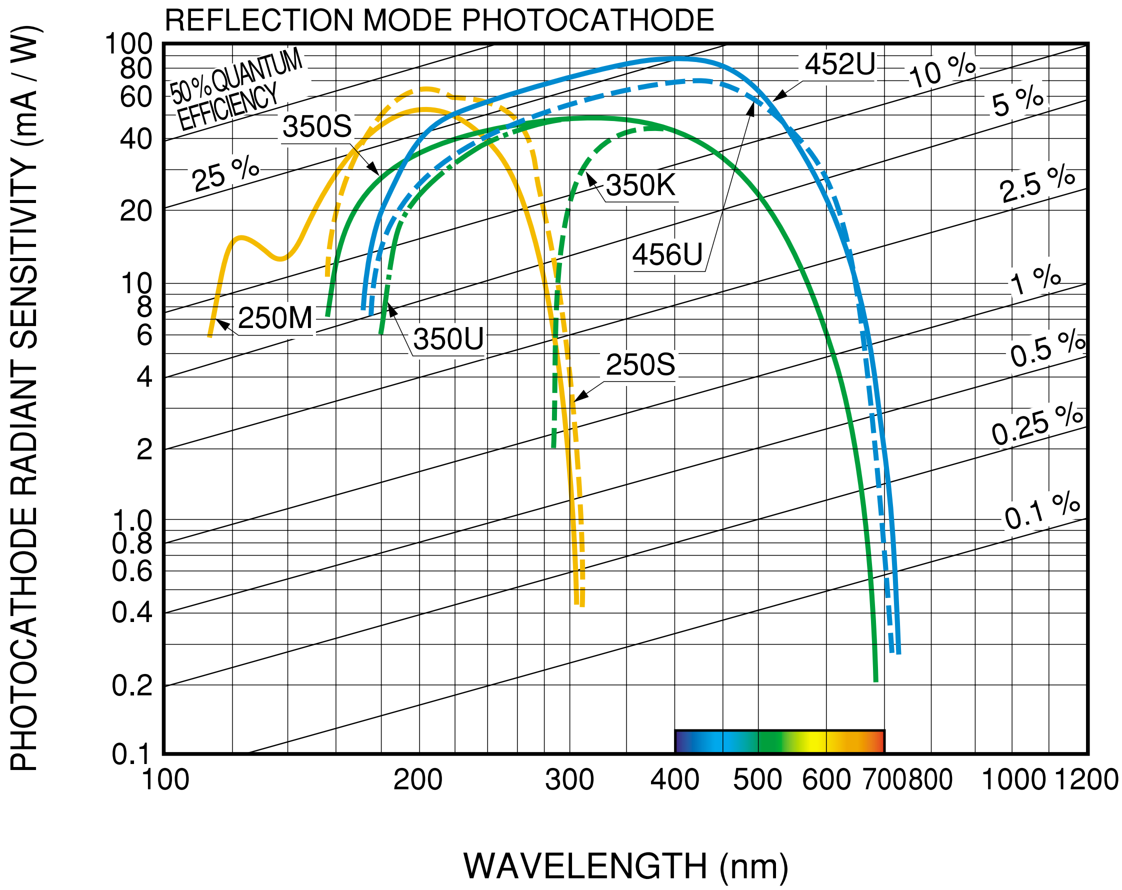
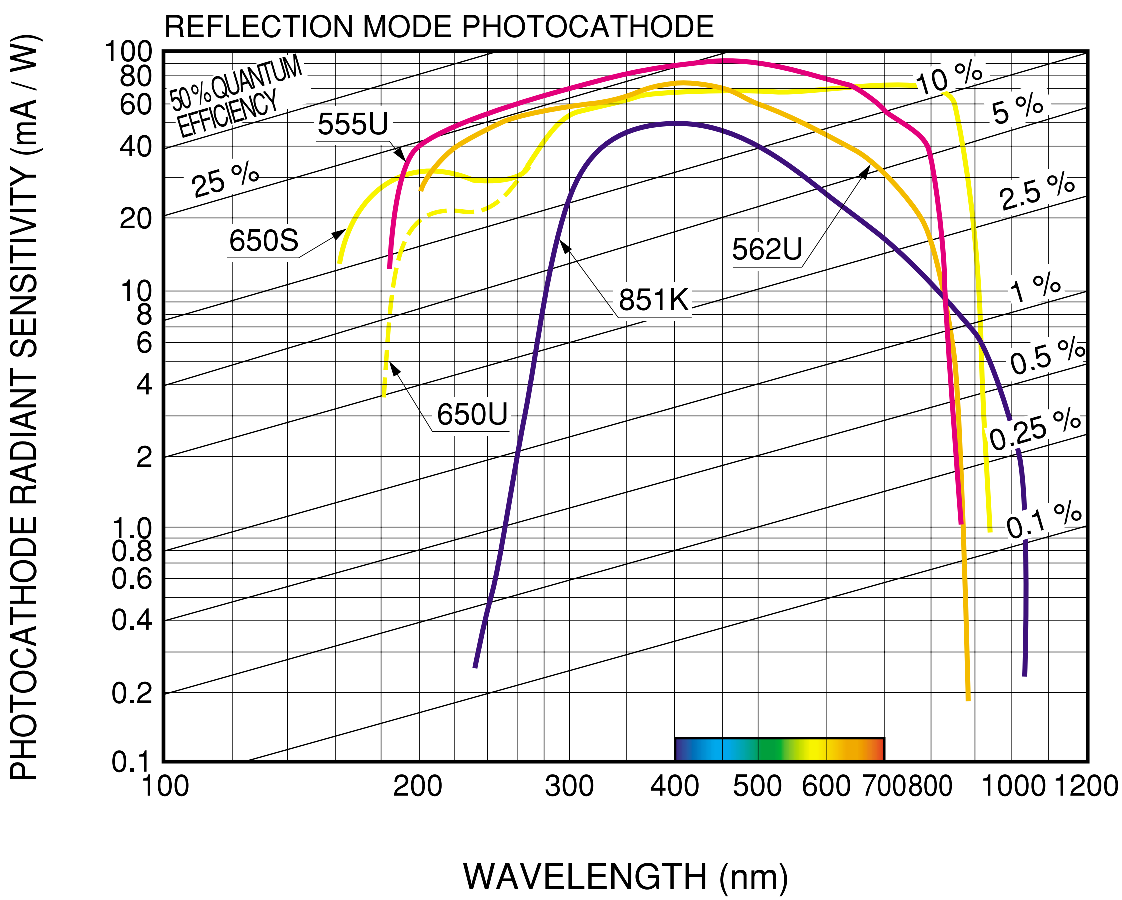


TPMOB0078EE

OPAQUE PHOTOCATHODE SPECTRAL RESPONSE CHARACTERISTICS





Notes

❶ Types marked ⁎ are newly listed in this catalog.

❷ See pages 114 and 115 for typical spectral response charts.

❸ Photocathode materials

BA :	Bialkali
LBA :	Low noise bialkali
HBA :	High temperature bialkali
MA :	Multialkali
EMA :	Extended red multialkali
DIA :	Diamond

Other photocathodes are indicated by the element symbols.

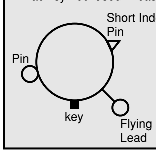
❹ Window materials

MF :	MgF_2
Q :	Quartz (Fused silica or synthetic silica)
K :	Borosilicate glass
U :	UV glass

❺ Base diagram

BASING DIAGRAM SYMBOLS

All base diagrams show terminals viewed from the base end of the tube.
Each symbol used in basing diagrams signifies the following.



DY : Dynode
G(F) : Grid (Focusing electrode)
ACC : Accelerating electrode
K : Photocathode
P : Anode
SH : Shield
IC : Internal connection (Do not use.)
NC : No connection (Do not use.)

❻ 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

❼ See page 78 for suitable socket assemblies.
Mating sockets (E678 series)
*: A socket will be supplied with the tube.
No mark: Sockets may be obtained from electronics supply houses or our sales office.

❽ Operating ambient temperature range for the photomultiplier itself is -30 °C to +50 °C except for some types of tubes.
However, when photomultiplier tubes are operated below -30 °C at their base section, please consult us in advance.

❾ Averaged over any interval of 30 seconds maximum.

❿ Measured at the peak sensitivity wavelength.

⓫ See page 62 for voltage distribution ratio.

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

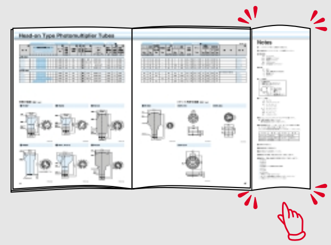
Cathode and anode characteristics are measured under the following conditions if noted.

ⓐ 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 count per second (s^{-1})
ⓙ Dark count per second (s^{-1}) after one hour storage at -20 °C
ⓚ Background noise per minute (min^{-1})

How to Use This Folding Page

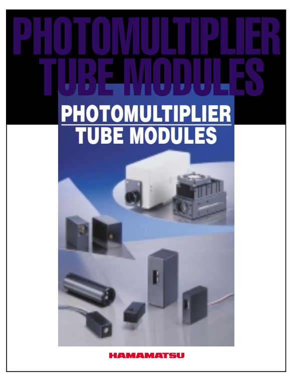
To read this catalog, open this page as shown below.

●"NOTES" are listed on the inside of this page so that you can refer to them while looking at the specification tables.



Related Product Catalogs

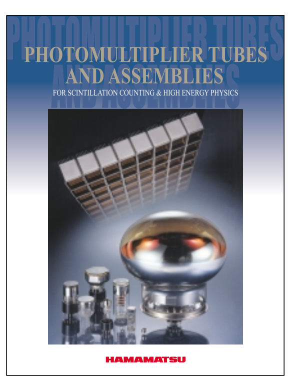
Photomultiplier Tube Modules



The photomultiplier tube module is basically comprised of a photomultiplier tube, a high-voltage power supply circuit to operate the photomultiplier tube, and a voltage divider circuit to distribute the optimum voltage to each dynode, all integrated into a compact case. In addition to these basic configurations, Hamamatsu also provides modules having various added functions such as signal conversion, photon counting, cooling and interfacing to a PC.

Photomultiplier Tubes and Assemblies

For Scintillation Counting & High Energy Physics



This catalog is a selection guide for Hamamatsu photomultiplier tubes and assemblies specially fabricated and selected for scintillation counting and high energy physics applications. These photomultiplier tubes offer high quantum efficiency, high energy resolution, wide dynamic range and fast time response, as well as remarkable resistance to harsh environments ranging from strong magnetic fields to high temperatures. A wide variety of products are listed here ranging in diameter from 3/8 inches up to 20 inches.

HAMAMATSU

HAMAMATSU PHOTONICS K.K., Electron Tube Center
314-5, Shimokanzo, Toyooka-village, Iwata-gun, Shizuoka-ken, 438-0193, Japan
Telephone: (81)539/62-5248, Fax: (81)539/62-2205
http://www.hamamatsu.com

Main Products

Electron Tubes
Photomultiplier Tubes
Light Sources
Microfocus X-ray Sources
Image Intensifiers
X-ray Image Intensifiers
Microchannel Plates
Fiber Optic Plates

Opto-semiconductors
Si Photodiodes
Photo IC
PSD
InGaAs PIN photodiodes
Compound semiconductor photosensors
Image sensors
Light emitting diodes
Application products and modules
Optical communication devices
High energy particle/X-ray detectors

Imaging and Processing Systems
Video Cameras for Measurement
Image Processing Systems
Streak Cameras
Optical Measurement Systems
Imaging and Analysis Systems

DEC. 2003 REVISED

Sales Offices

ASIA:
HAMAMATSU PHOTONICS K.K.
325-6, Sunayama-cho,
Hamamatsu City, 430-8587, Japan
Telephone: (81)53-452-2141, Fax: (81)53-456-7889

U.S.A.:
HAMAMATSU CORPORATION
Main Office
360 Foothill Road, P.O. BOX 6910,
Bridgewater, N.J. 08807-0910, U.S.A.
Telephone: (1)908-231-0960, Fax: (1)908-231-1218
E-mail: usa@hamamatsu.com

Western U.S.A. Office:
Suite 110, 2875 Moorpark Avenue
San Jose, CA 95128, U.S.A.
Telephone: (1)408-261-2022, Fax: (1)408-261-2522
E-mail: usa@hamamatsu.com

United Kingdom:
HAMAMATSU PHOTONICS UK LIMITED
Main Office
2 Howard Court, 10 Tewin Road Welwyn Garden City
Hertfordshire AL7 1BW, United Kingdom
Telephone: 44-(0)1707-294888, Fax: 44-(0)1707-325777
E-mail: info@hamamatsu.co.uk

South Africa Office:
PO Box 1112, Buccleuch 2066,
Johannesburg, South Africa
Telephone/Fax: (27)11-802-5505

France, Portugal, Belgiun, Switzerland, Spain:
HAMAMATSU PHOTONICS FRANCE S.A.R.L.
8, Rue du Saule Trapu, Parc du Moulin de Massy,
91882 Massy Cedex, France
Telephone: (33)1 69 53 71 00
Fax: (33)1 69 53 71 10
E-mail: infos@hamamatsu.fr

Swiss Office:
Richtersmattweg 6a
CH-3054 Schüpfen, Switzerland
Telephone: (41)31/879 70 70,
Fax: (41)31/879 18 74
E-mail: swiss@hamamatsu.ch

Belgian Office:
7, Rue du Bosquet
B-1348 Louvain-La-Neuve, Belgium
Telephone: (32)10 45 63 34
Fax: (32)10 45 63 67
E-mail: epirson@hamamatsu.com

Spanish Office:
Centro de Empresas de Nuevas Tecnologies
Parque Tecnologico del Valles
08290 CERDANYOLA, (Barcelona) Spain
Telephone: (34)93 582 44 30
Fax: (34)93 582 44 31
E-mail: spain@hamamatsu.com

Germany, Denmark, Netherland, Poland:
HAMAMATSU PHOTONICS DEUTSCHLAND GmbH
Arzbergerstr. 10,
D-82211 Herrsching am Ammersee, Germany
Telephone: (49)8152-375-0, Fax: (49)8152-2658
E-mail: info@hamamatsu.de

Danish Office:
Skyttehusgade 36, 1. TV DK-7100 Vejle, Denmark
Telephone: (45)4346/6333, Fax: (45)4346/6350
E-mail: lkoldbaek@hamamatsu.de

Netherlands Office:
PO Box 50.075, 1305 AB Almere The Netherland
Telephone: (31)36-5382123, Fax: (31)36-5382124
E-mail: hamamatsu_NL@compuserve.com

Poland Office:
02-525 Warsaw, 8 St. A. Boboli Str., Poland
Telephone: (48)22-660-8340, Fax: (48)22-660-8352
E-mail: info@hamamatsu.de

North Europe and CIS:
HAMAMATSU PHOTONICS NORDEN AB
Smidesvägen 12
SE-171 41 Solna, Sweden
Telephone: (46)8-509-031-00, Fax: (46)8-509-031-01
E-mail: info@hamamatsu.se

Russian Office:
Riverside Towers
Kosmodamianskaya nab. 52/1, 14th floor
RU-113054 Moscow, Russia
Telephone/Fax: (7)095 411 51 54
E-mail: info@hamamatsu.ru

Italy:
HAMAMATSU PHOTONICS ITALIA S.R.L.
Strada della Moia, 1/E
20020 Arese, (Milano), Italy
Telephone: (39)02-935 81 733, Fax: (39)02-935 81 741
E-mail: info@hamamatsu.it

Rome Office:
Viale Cesare Pavese, 435, 00144 Roma, Italy
Telephone: (39)06-50513454, Fax: (39)06-50513460
E-mail: inforoma@hamamatsu.it

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