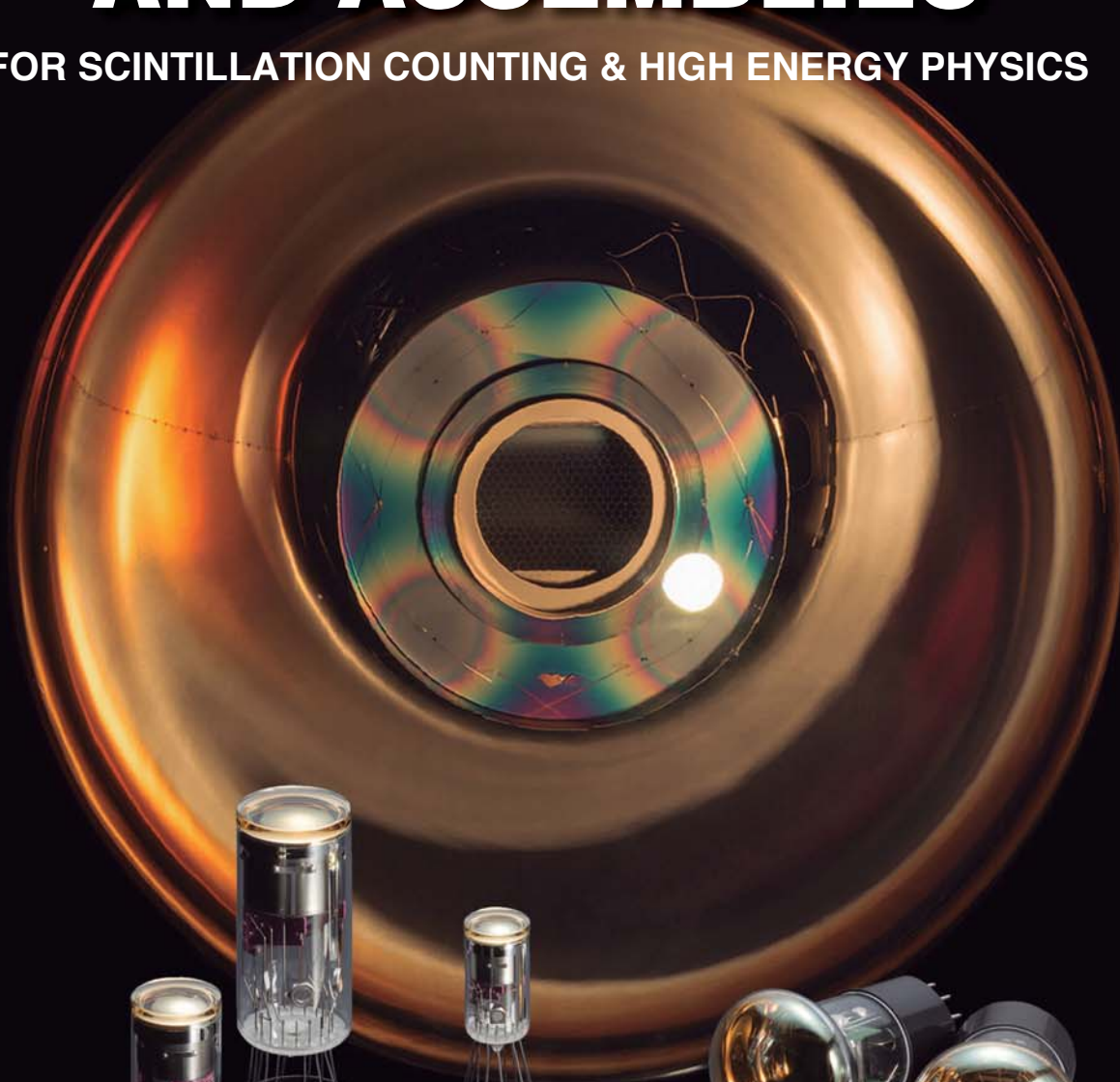


**HAMAMATSU**

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# PHOTOMULTIPLIER TUBES AND ASSEMBLIES

FOR SCINTILLATION COUNTING & HIGH ENERGY PHYSICS



HAMAMATSU PHOTONICS K.K.

## **INTRODUCTION**

In radiation measurements, scintillation counters which are combinations of scintillators and photomultiplier tubes are used as most common and useful devices in detecting X-, alpha-, beta-, gamma-rays and other high energy charged particles. A scintillator emits flashes of light in response to input radiations and a photomultiplier tube coupled to a scintillator detects these scintillation lights in a precise way.

In high energy physics experiments, one of important apparatuses is a Cherenkov counter in which photomultiplier tubes detect Cherenkov radiations emitted by high energy charged particles passing through a dielectric material.

To detect radiations accurately, photomultiplier tubes may be required to have high detecting efficiency (QE & energy resolution), wide dynamic range (pulse linearity), good time resolution (T.T.S.), high stability & reliability, and to be operatable in high magnetic field environment or at high temperature condition. In addition, a ruggedized construction is required according to circumstances. On the other hand, several kinds of position sensitive photomultiplier tubes have been developed and are used in these measurements.

This catalog provides a quick reference for Hamamatsu photomultiplier tubes, especially designed or selected for scintillation counters and Cherenkov radiation detectors, and includes most of types currently available ranging in size from 3/8" through 20" in diameter. It should be noted that this catalog is just a starting point in describing Hamamatsu product line since new types are continuously under-development.

Please feel free to contact us with your specific requirements.

# PHOTOMULTIPLIER TUBES AND ASSEMBLIES

For scintillation counting  
& high energy physics

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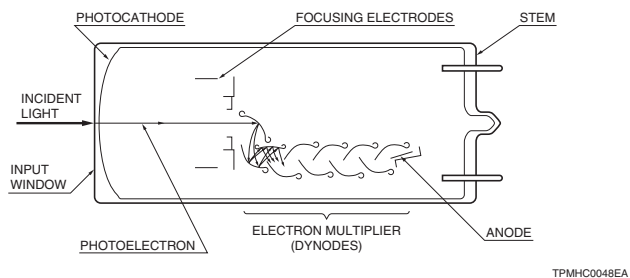
# Operating characteristics

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

## 1. GENERAL

The photomultiplier tube (PMT) is a photosensitive device consisting of an input window, a photocathode, focusing electrodes, an electron multiplier (dynodes) and an anode in a vacuum tube, as shown in Figure 1. When light enters the photocathode, the photocathode emits photoelectrons into vacuum by the external photoelectric effect. These photoelectrons are directed by the potential of focusing electrode towards the electron multiplier where electrons are multiplied by the process of secondary electron emission. The multiplied electrons are collected to the anode to produce output signal.

Figure 1: Cross-section of head-on type PMT



## 2. PHOTOCATHODE

### 2.1 Spectral response

The photocathode of PMT converts energy of incident light into photoelectrons by the external photoelectric effect. The conversion efficiency, that is photocathode sensitivity, varies with the wavelength of incident light. This relationship between the photocathode sensitivity and the wavelength is called the spectral response characteristics.

Typical spectral response curves of the variation of alkali photocathodes are shown on the inside of the back cover.

The spectral response range is determined by the photocathode material on the long wavelength edge, and by the window material on the short wavelength edge.

In this catalog, the long wavelength cut-off of spectral response range is defined as the wavelength at which the cathode radiant sensitivity drops to 1 % of the maximum sensitivity.

### 2.2 Quantum efficiency and radiant sensitivity

Spectral response is usually expressed in term of quantum efficiency and radiant sensitivity as shown on the inside the back cover.

Quantum efficiency (QE) is defined as the ratio of the number of photoelectrons emitted from the photocathode to the number of incident photons.

It's customarily stated as a percentage.

The equation of QE is as follows:

$$QE = \frac{\text{Number of photoelectrons}}{\text{Number of photons}} \times 100 (\%)$$

Radiant sensitivity (S) is the photoelectric current from the photocathode divided by the incident radiant power at a given wavelength, expressed in A/W (ampere per watt).

The equation of S is as follows:

$$S = \frac{\text{Photoelectric current}}{\text{Radiant power of light}} (A/W)$$

Quantum efficiency and radiant sensitivity have the following relationship at a given wavelength.

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

where  $\lambda$  is the wavelength in nm (nanometer).

### 2.3 Window materials

The window materials commonly used in PMT are as follows:

#### (1) Borosilicate glass

This is the most frequently used material. It transmits light from the infrared to approximately down to 300 nm.

For some scintillation applications where radioactivity of K40 contained in the glass affects the measurement, "K-free" glass is recommended.

As "K-free" glass contains very little amount of Potassium, the background counts originated by  $^{40}\text{K}$  is minimized.

#### (2) UV-transmitting glass

This glass transmits ultraviolet light well as the name implies, and it is widely used. The UV cut-off wavelength is approximately 185 nm.

#### (3) Silica glass

This material transmits ultraviolet light down to 160 nm. Silica is not suitable for the stem material of tubes because it has a different thermal expansion coefficient from kovar metal which is used for the tube leads. Thus, borosilicate glass is used for the stem. In order to seal these two materials having different thermal expansion ratios, a technique called graded seal is used. This is a technique to seal several glass materials having gradually different thermal expansion ratios. Another feature of silica is superiority in radiation hardness.

### 2.4 Photocathode materials

The photocathode is a photoemissive surface with very low work and high energy physics applications:

#### (1) Bialkali

This has a spectral response which fits the emission spectra of most scintillators. Thus, it is frequently used for scintillator applications.

#### (2) High temperature bialkali

This is particularly useful at higher operating temperatures up to 175 °C. Its major application is oil well logging. Also it can be operated with very low dark current at the room temperature.

As stated above, the spectral response range is determined by the materials of the photocathode and the window as shown in Figure 34.

It is important to select appropriate materials which will suit the application.

### 2.5 Luminous and blue sensitivity

Since the measurement of spectral response characteristics of a PMT requires a sophisticated system and time, it isn't practical to provide spectral response data on each tube. Instead, cathode and anode luminous sensitivity data are usually attached.

The cathode luminous sensitivity is the photoelectric current from the photocathode per incident light flux ( $10^{-5}$  to  $10^{-2}$  lumen) from a tungsten filament lamp operated at a distribution temperature of 2856 K.

The cathode luminous sensitivity is expressed in the unit of  $\mu\text{A/lm}$  (micro amperes per lumen).

Note that the lumen is a unit used for luminous flux in the visible region, therefore these values may be meaningless for tubes which are sensitive out of the visible region (refer to Figure 2).

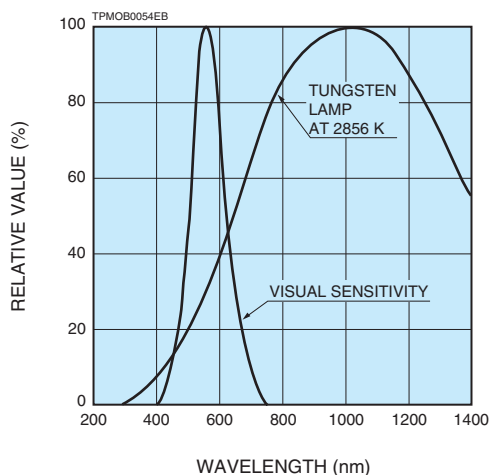
The cathode blue sensitivity is the photoelectric current from the photocathode per incident light flux of a tungsten filament lamp at 2856 K passing through a blue filter. Corning CS-5-58 filter which is polished to half stock thickness is used for the measurement of this sensitivity. This filter is a band-pass filter and its peak wavelength of transmittance is 400 nm.

Since the light flux, once transmitted through the blue filter, can not be expressed in lumen, the blue sensitivity is usually represented by the blue sensitivity index.

The blue sensitivity is a very important parameter in the scintillation counting since most of the scintillators produce emission spectrum in the blue region, and it may dominant factor of energy resolution.

These parameters of cathode luminous and blue sensitivities are particularly useful when comparing tubes having the same or similar spectral response ranges. Hamamatsu final test sheets accompanied with tubes usually indicate these parameters.

Figure 2: Typical human eye response and spectral distribution of 2856 K tungsten lamp



## 3. ELECTRON MULTIPLIER (DYNODES)

The superior sensitivity (high gain and high S/N ratio) of PMT is due to a low noise electron multiplier which amplifies electrons in a vacuum with cascade secondary emission process. The electron multiplier consists of several to up to 19 stages of electrodes which are called dynodes.

### 3.1 Dynode types

There are several principal types of dynode structures. Features of each type are as follows:

#### (1) Linear focused type

Fast time response, high pulse linearity

#### (2) Box and grid type

Good collection efficiency, good uniformity

#### (3) Box and linear focused type

Good collection efficiency, good uniformity, low profile

#### (4) Circular and linear-focused type

Fast time response, compactness

#### (5) Venetian blind type

Good uniformity, large output current

#### (6) Fine mesh type

High immunity to magnetic fields, good uniformity, high pulse linearity, position detection possible.

#### (7) Metal channel type

Compact dynode construction, fast time response, position detection possible.

## 4. ANODE

The PMT anode output is the product of photoelectric current from the photocathode and gain. Photoelectric current is proportional to the intensity of incident light. Gain is determined by the applied voltage on a specified voltage divider.

### 4.1 Luminous sensitivity

The anode luminous sensitivity is the anode output current per incident light flux ( $10^{-10}$  to  $10^{-5}$  lumen) from a tungsten filament lamp operated at a distribution temperature of 2856 K. This is expressed in the unit of  $\text{A/lm}$  (amperes per lumen) at a specified anode-to-cathode voltage with a specified voltage divider.

## 4.2 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 (cascade process), a high gain is achieved. Therefore a very small photoelectric current from the photocathode can be observed as a large output current from the anode of the PMT.

Gain is simply the ratio of the anode output current to the photoelectric current from the photocathode. Ideally, the gain of the PMT is defined as  $\delta^n$ , where  $n$  is the number of dynode stage and  $\delta$  is an average secondary emission ratio.

While the secondary electron emission ratio  $\delta$  is given by

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

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

When a voltage  $V$  is applied between the cathode and the anode of the PMT having  $n$  dynode stages, gain  $G$  becomes

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

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

Figure 3: Example of gain vs. supply voltage

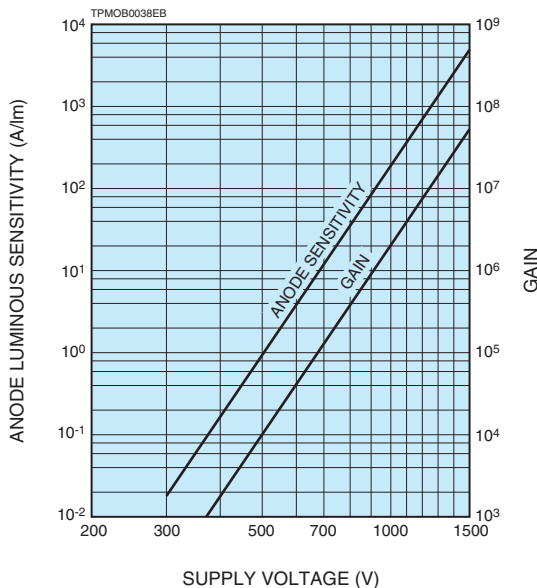


Figure 3 shows gain characteristics.

Since generally PMTs have 8 to 12 dynode stages, the anode output varies directly with the 6th to 10th power of the change in applied voltage. The output signal of the PMT is extremely susceptible to fluctuations in the power supply voltage, thus the power supply should be very stable and exhibit minimum ripple, drift and temperature coefficient. Regulated high voltage power supplies designed with this consideration are available from Hamamatsu.

## 5. ANODE DARK CURRENT

A small amount of output current flows in a PMT even when it is operated in complete darkness. This current is called the anode dark current. The dark current and the noise resulted from are critical factors to determine the lower limit of light detection.

The causes of dark current may be categorized as follows:

### (1) Thermionic emission of electrons

Since the materials of the photocathode and dynodes have very low work functions, they emit thermionic electrons even at the room temperature. Most of the dark current originates from the thermionic emissions especially from the photocathode, and it is multiplied by the dynodes.

### (2) Ionization of residual gases

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

### (3) Glass scintillation

In case electrons deviating from their normal trajectories strike the glass envelope, scintillations may occur and dark pulses may result. To eliminate these pulses, PMT's may be operated with the anode at high voltage and the cathode at the ground potential. Otherwise it is useful to coat the glass bulb with a conductive paint connected to the cathode (called HA treatment: see page 13).

### (4) Ohmic leakage

Ohmic leakage resulting from insufficient insulation of the glass stem base and socket may be another source of dark current. This is predominant when a PMT is operated at a low voltage or low temperature.

Contamination by dirt and humidity on the surface of the tube may cause ohmic leakage, and therefore should be avoided.

### (5) Field emission

When a PMT is operated at a voltage near the maximum rating value, some electrons may be emitted from electrodes by strong electric fields causing dark pulses. It is therefore recommended that the tube be operated at 100 volts to 300 volts lower than the maximum rating.

The anode dark current decreases along time after a PMT is placed in darkness. In this catalog, anode dark currents are specified as the state after 30 minutes storage in darkness.

## 6. TIME RESPONSE

In applications where forms of the incident light are pulses, the anode output signal should reproduce a waveform faithful to the incident pulse waveform.

This reproducibility depends on the anode pulse time response.

### (1) Rise time (refer to Figure 4)

The time for the anode output pulse to rise from 10 % to 90 % of the peak amplitude when the whole photocathode is illuminated by a delta-function light pulse.

### (2) Electron transit time (refer to Figure 4)

The time interval between the arrival of a delta-function light pulse at the photocathode and the instant when the anode output pulse reaches its peak amplitude.

### (3) T.T.S. (Transit Time Spread) (refer to Figure 5)

This is also called the transit time jitter. This is the fluctuation in transit time between individual pulses, and is defined as the FWHM of the frequency distribution of electron transit times. T.T.S. depends on the number of incident photons. The values in this catalog are measured in the single photoelectron state.

Figure 4: Definition of rise time and transit time

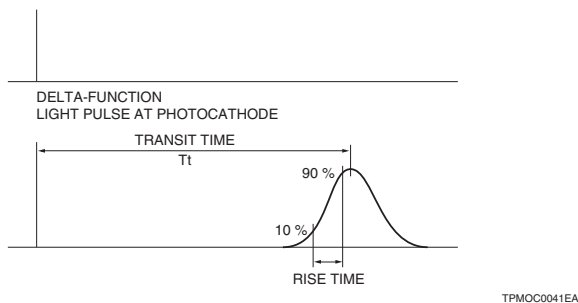
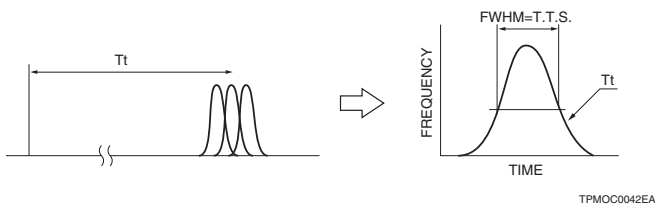


Figure 5: Definition of T.T.S.



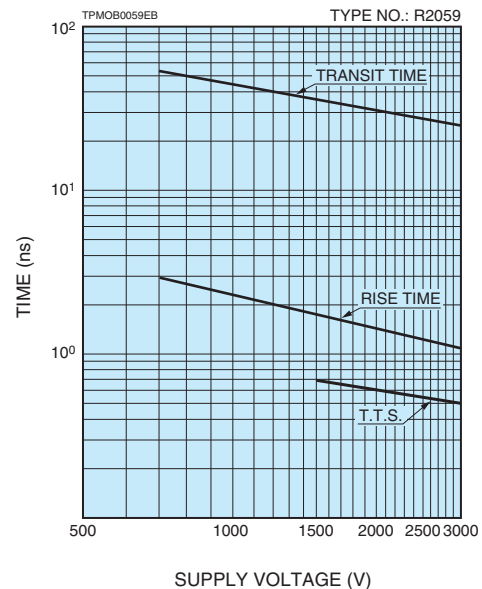
### (4) C.R.T. (Coincident Resolving Time)

This is one of the important parameters in high energy physics applications and is defined as the FWHM of a coincident timing spectrum of a pair PMT's facing each other when they detect coincident gamma-ray emission due to positron annihilation of a radiation source ( $^{22}\text{Na}$ ). The scintillators used are CsF, BGO or  $\text{BaF}_2$  crystals. These PMT's can be selected for special requirements.

These parameters are affected by the dynode structure and applied voltage. In general, PMTs of the linear focused structure exhibit better time response than that of the box-and-grid or venetian blind structure.

Figure 6 shows typical time response characteristics vs. applied voltage for types R2059 (51 mm dia. head-on, 12-stage, linear-focused type).

Figure 6: Time response characteristics vs. supply voltage



## 7. PULSE LINEARITY

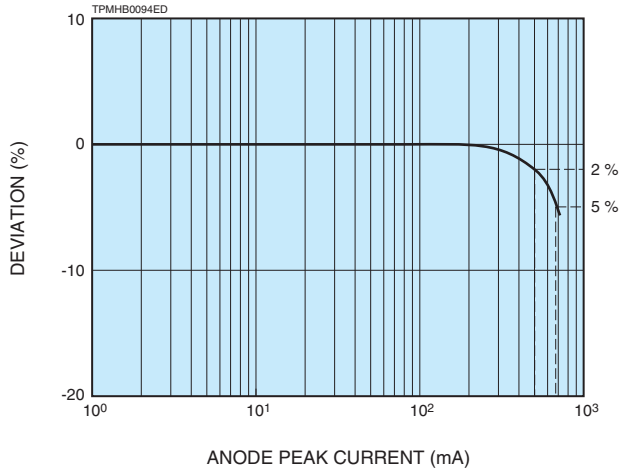
The definition of the pulse linearity is proportionality between the input light amount and the output current in the pulse operation mode. When intense light pulses are to be measured, it's necessary to know the pulse linearity range of the PMT.

In this catalog, typical values of pulse linearity are specified at two points ( $\pm 2\%$  and  $\pm 5\%$  deviations from linear proportionality), as shown in Figure 7.

The two-pulse technique is employed in this measurement. LED's are used for a pulsed light source. Its pulse width is 50 ns and the repetition rate is 1 kHz.

The deviation from the proportionality is called non-linearity in this catalog. The cause of non-linearity is mainly a space charge effect in the later stages of an electron multiplier. This space charge effect depends on the pulse height of the PMT output current and the strength of electric fields between electrodes.

Figure 7: Example of pulse linearity characteristic

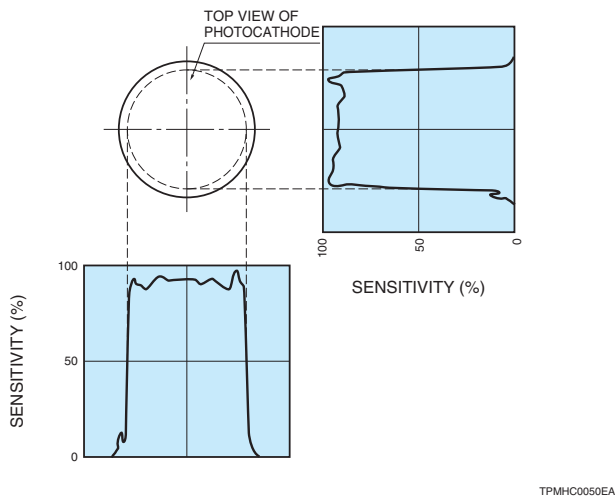


The special voltage distribution ratios are designed to achieve strong electric fields in the later stages of the electron multiplier. Some types are specified with these special voltage dividers.

## 8. UNIFORMITY

Although the focusing electrodes of a PMT 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 and collection efficiency is degraded. 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. PMTs especially designed for gamma camera applications have excellent spatial uniformity. Example of spatial uniformity is shown in Figure 8.

Figure 8: Example of spatial uniformity



## 9. STABILITY

In scintillation counting, there are two relevant stability characteristics for the PMT in pulse height mode operation, the long term and the short term. In each case a  $^{137}\text{Cs}$  source (662 keV), and an NaI(Tl) scintillator, and a multichannel pulse height analyzer are used. PMT's are warmed up for about one hour in the dark with voltage applied.

### 9.1 Long term stability (Mean gain deviation)

This is defined as follows when the PMT is operated for 16 hours at a constant count rate of  $1000 \text{ s}^{-1}$ :

$$Dg = \frac{\sum_{i=1}^n |P-P_i|}{n} \cdot \frac{100}{P} (\%)$$

where P is the mean pulse height averaged over n readings,  $P_i$  is the pulse height at the i-th reading, and n is the total number of readings.

### 9.2 Short term stability

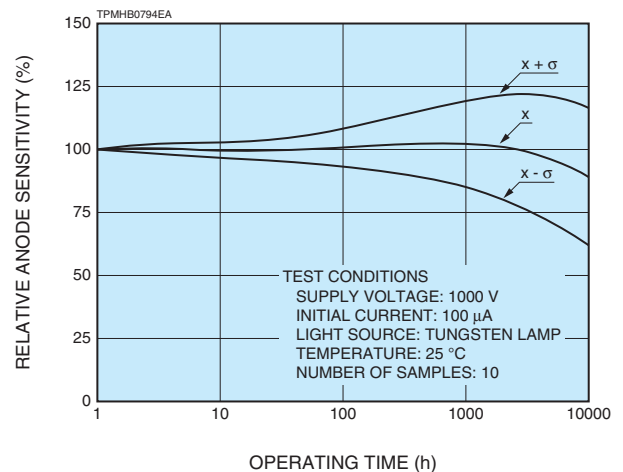
This is the gain shift against count rate change. The tube is initially operated at about  $10000 \text{ s}^{-1}$ . The photo-peak count rate is then decreased to approximately  $1000 \text{ s}^{-1}$  by increasing the distance between the  $^{137}\text{Cs}$  source and the scintillator coupled to the PMT.

### 9.3 Drift and life characteristics

While operating a photomultiplier tube continuously over a long period, anode output current of the photomultiplier tube may vary slightly with time, although operating conditions have not changed. This change is referred to as drift or in the case where the operating time is 1000 hours to 10000 hours it is called life characteristics. Figure 9 shows typical life characteristics.

Drift is primarily caused by damage to the last dynode by heavy electron bombardment. Therefore the use of lower anode current is desirable. When stability is of prime importance, the use of average anode current of  $1 \mu\text{A}$  or less is recommended.

Figure 9: Examples of life characteristics



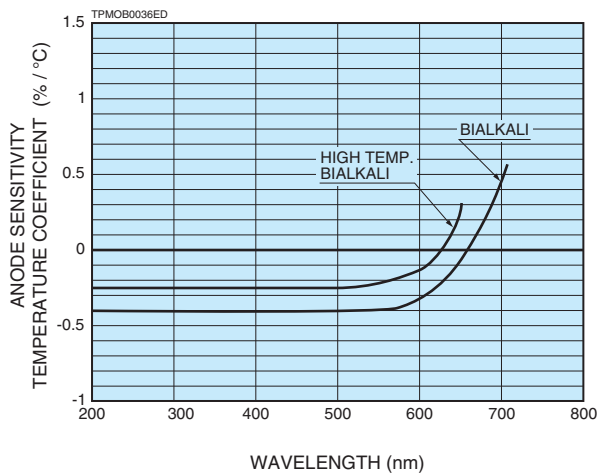


## 10. ENVIRONMENT

### 10.1 Temperature characteristics

The sensitivity of the PMT varies with the temperature. Figure 10 shows typical temperature coefficients of anode sensitivity around the room temperature for bialkali and high temp. bialkali photocathode types. In the ultraviolet to visible region, the temperature coefficient of sensitivity has a negative value, while it has a positive value near the longer wavelength cut-off. Since the temperature coefficient change is large near the longer wavelength cut-off, temperature control may be required in some applications.

Figure 10: Typical temperature coefficients of anode sensitivity



### 10.2 Magnetic field

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

When a PMT has to be operated in magnetic fields, it may be necessary to shield the PMT with a magnetic shield case. (Hamamatsu provides a variety of magnetic shield cases.)

For example, the shield case, of which inner diameter is 60 mm and the thickness is 0.8 mm, can be used in a magnetic field of around 5 mT without saturation. If a magnetic field strength is more than 10 mT, the double shielding method is necessary for a conventional PMT, otherwise proximity mesh types should be used. 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  $H_{out}$ , to that inside the shield case or  $H_{in}$ .

The magnetic shielding factor is determined by the permeability  $\mu$ , the thickness  $t$ (mm) and inner diameter  $r$ (mm) of the shield case as follows.

$$\frac{H_{out}}{H_{in}} = \frac{3\mu t}{4r}$$

It should be noted that the magnetic shielding effect decreases towards the edge of the shield case as shown in Figure 12. It is suggested to cover a PMT with a shield case longer than the PMT length by at least half the PMT diameter.

Figure 11: Typical effects by magnetic fields perpendicular to tube axis

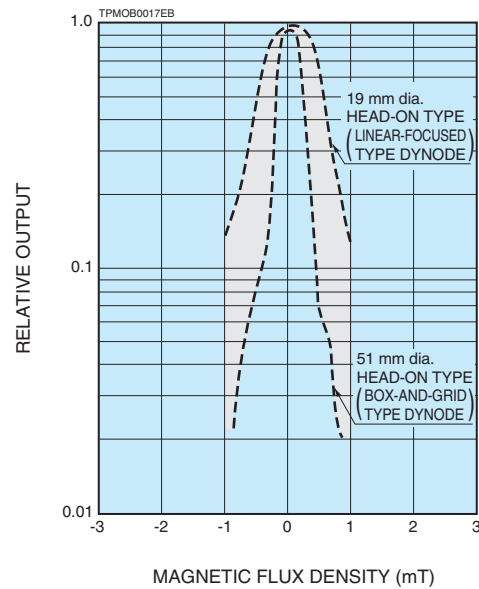
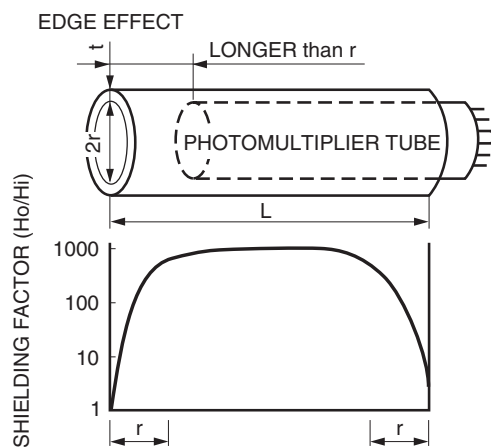


Figure 12: Edge effect of magnetic shield case



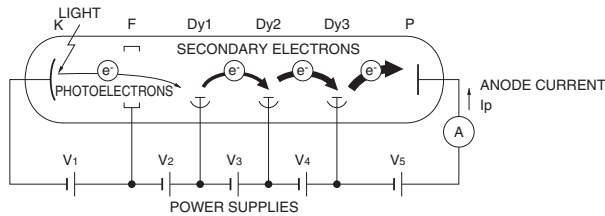
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The proximity mesh made of non-magnetic material has been introduced as alternate dynodes in PMT's. These types (see page 24) exhibit much higher immunity to external magnetic fields than the conventional PMT's. Also triode and three types (see page 24) are useful for applications at high light intensities.

## 11. 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 13 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.

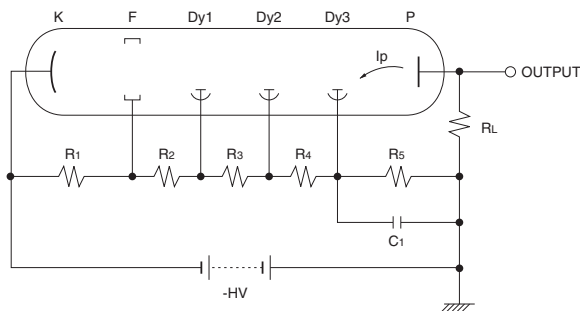
Figure 13: Schematic representation of photomultiplier tube operation



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Figure 14 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 decoupling 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 14: Anode grounded voltage divider circuit



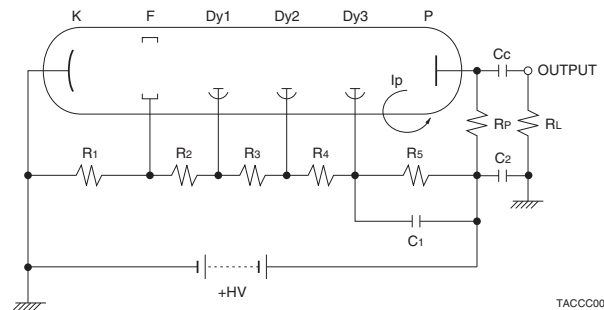
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### 11.1 Anode grounding and photocathode grounding

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 14. 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 15, 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 15: Photocathode grounded voltage divider circuit

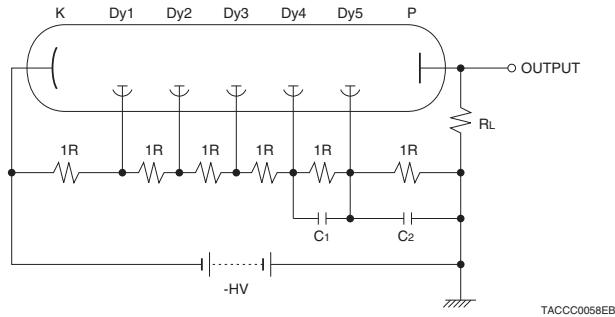


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### 11.2 Standard voltage divider circuits

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 as shown in Figure 16.

Figure 16: Equally divided voltage divider circuit



### 11.3 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 17. 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.

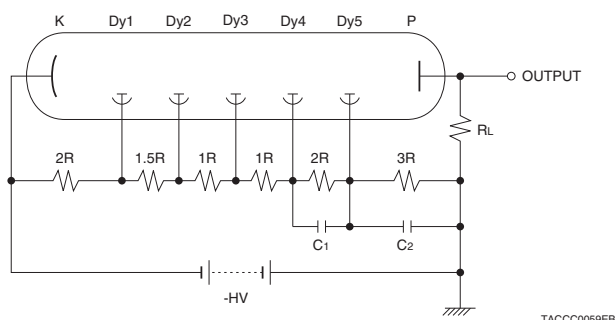
#### Tapered circuit at the first few stages

- (resistance: large <First dynode> → small <Latter dynode>)
- 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 <First dynode> → large <Latter dynode>)
- 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

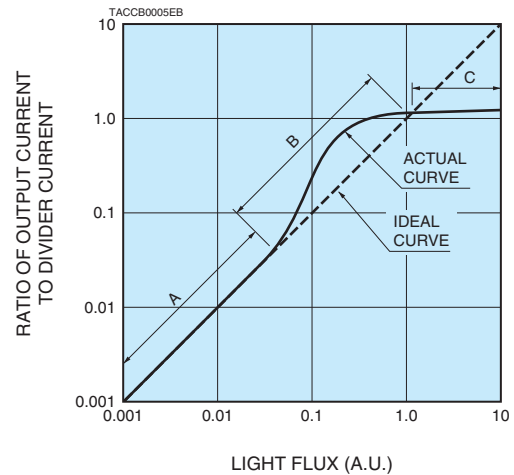
Figure 17: Tapered voltage divider circuit



### 11.4 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 18, 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.

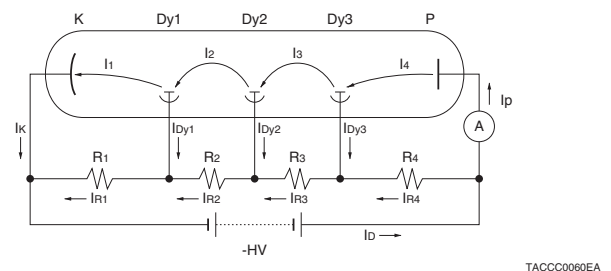
Figure 18: Output linearity of photomultiplier tube



### 11.5 Output linearity in DC mode

Figure 19 is a simplified representation showing photomultiplier tube operation in the DC output mode, with three stages of dynodes and four dividing resistors R1 through R4 having the same resistance value.

Figure 19: 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 20 (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**

$$I_1=I_2=I_3=I_4 (= 0 \text{ A})$$

**Electrode current of photomultiplier tube**

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

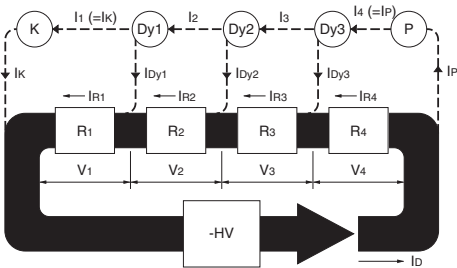
**Voltage divider circuit current**

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

**Voltage divider circuit voltage**

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

Figure 20: 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 20, the resulting currents can be considered to flow through the photomultiplier tube and the voltage divider circuit as schematically illustrated in Figure 21. 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  $\Delta I_D$  (equal to average interelectrode current). The current flowing through each dividing resistor  $R_n$  becomes as follows:

$$I_{Rn'} = I_{D'} - I_{n'}$$

Where  $I_{n'}$  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 21: Operation with light input

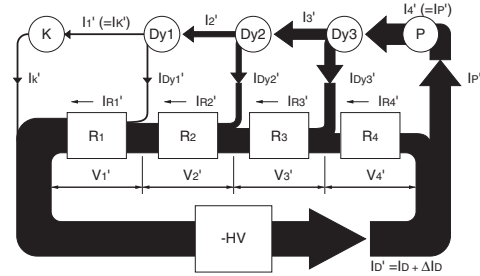
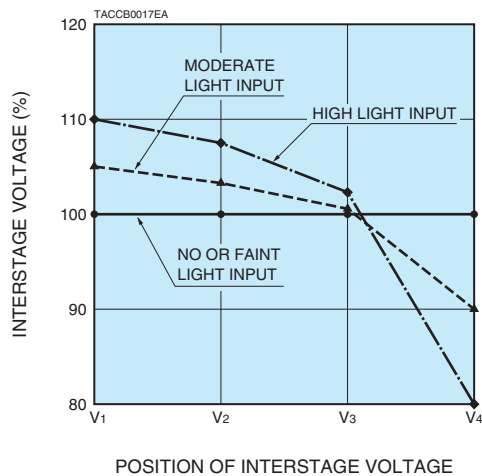


Figure 22 shows changes in the interstage voltages as the incident light level varies. The interstage voltage  $V_4'$  with light input drops significantly compared to  $V_4$  in dark state operation. This voltage loss is redistributed to the other stages, resulting in increases in  $V_1'$ ,  $V_2'$  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 ( $\delta_1$ ,  $\delta_2$  and  $\delta_3$ ) at the dynodes  $Dy_1$ ,  $Dy_2$  and  $Dy_3$ , 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  $V_4'$  approaches 0 volts, output saturation occurs in region C.

Figure 22: Changes in interstage voltages at different incident light levels



### 11.6 Linearity improvement in DC output mode

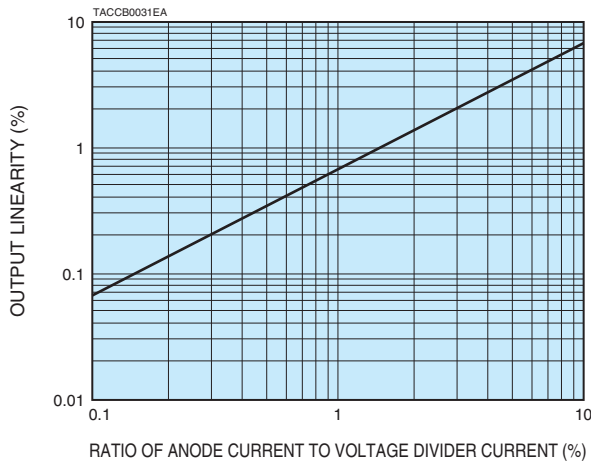
To improve the linearity in DC output mode, it is important to minimize the changes in the interstage voltage when photocurrent flows through the photomultiplier tube. There are several specific methods for improving the linearity, as discussed below.

#### ① Increasing the voltage divider current

Figure 23 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. For example, to obtain an output linearity of 1 %, it can be seen from the figure that the anode current should be set approximately 1.4 % of the divider circuit current. However, this is a calculated 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 23: Output linearity vs. anode current to voltage divider current ratio

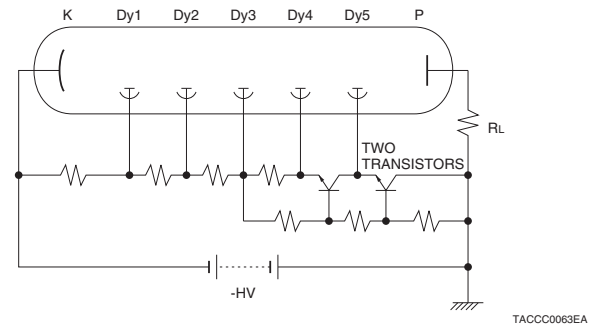


As stated above, good output linearity can be obtained simply by increasing the voltage divider current. However, this is accompanied by heat emanating from the voltage divider. If this heat is conducted to the photomultiplier tube, it may cause problems such as an increase in the dark current, and variation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

#### ② Using 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 24.

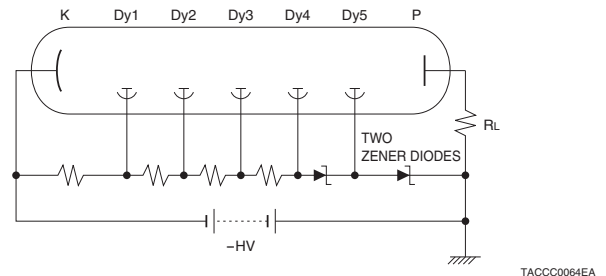
Figure 24: Active voltage divider circuit



#### ③ Using 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 25 shows a typical voltage divider circuit using Zener diodes.

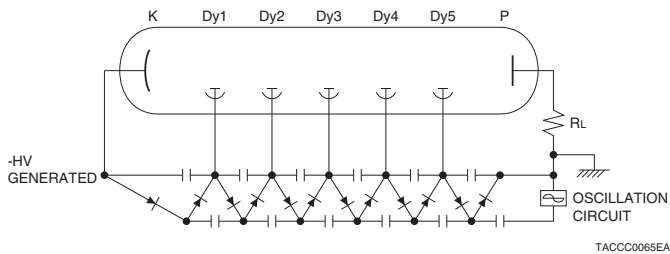
Figure 25: Voltage divider circuit using zener diodes



#### ④ Using Cockcroft-Walton circuit

When a Cockcroft-Walton circuit as shown in Figure 26 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  $\mu$ A 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.

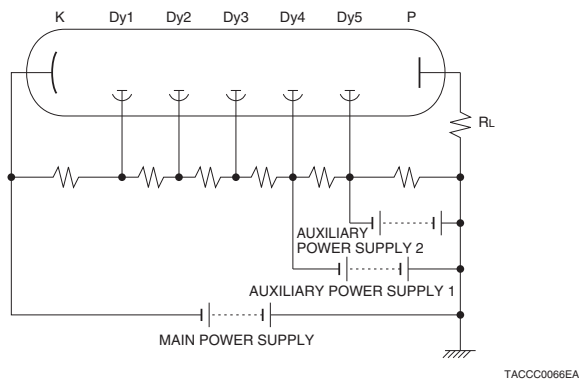
Figure 26: Cockcroft-Walton circuit



#### ⑤ Using multiple high voltage power supplies

As shown in Figure 27, 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 27: Voltage divider circuit using multiple power supplies (Booster method)



#### 11.7 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.

#### 11.8 Improving linearity in pulsed output mode

##### ① Using decoupling 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 decoupling capacitors as shown in Figure 28. There are two methods for connecting these decoupling capacitors: the serial method and the parallel method. As Figures 28 and 29 show, the serial method is more widely used since it requires lower tolerance voltages of the capacitors. The capacitance value  $C$  (farads) of the decoupling capacitor between the last dynode and the anode should be at least 100 times the output charge as follows:

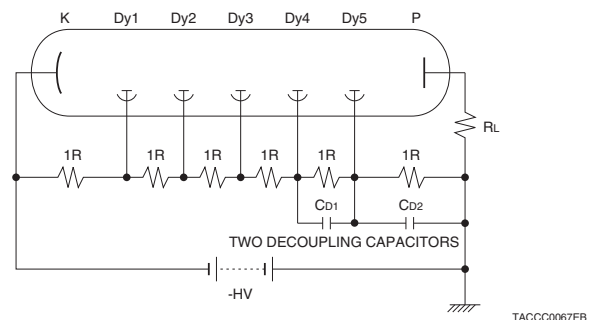
$$C > 100 \cdot Q/V$$

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 28: Equally divided voltage divider circuit and decoupling capacitors

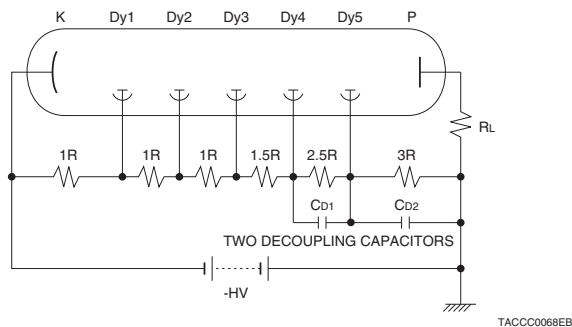


## ② Using tapered voltage divider circuit with decoupling capacitors

Use of the above voltage divider circuit having decoupling 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 29. 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 29: Tapered voltage divider circuit using decoupling capacitors



## 12. EXTERNAL POTENTIAL

If the input window or glass envelope near the photocathode is grounded, slight conductivity of glass material causes a current flow between the photocathode, which has a high negative potential, and ground.

This may cause electrolysis of photocathode, leading to significant deterioration.

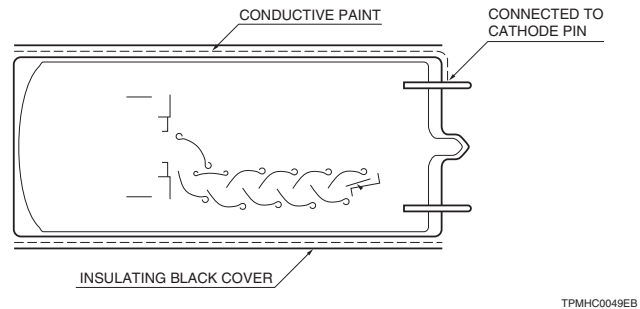
Also this may cause noise resulted from the light flashes at the above input window or glass envelope.

For those reasons, when designing a PMT housing with an electrostatic or magnetic shield case, extreme care should be required.

When the anode ground scheme is used, bringing a grounded metallic holder or magnetic shield case near the glass envelope of PMT can cause electrons to strike the inner glass wall, resulting in the noise.

This problem can be solved by applying a black conductive paint around the glass envelope and connecting it to the cathode potential. Then PMT is wrapped with an insulating black cover, as shown in Figure 30. This method is called HA treatment.

Figure 30: HA treatment



## 13. SCINTILLATION COUNTING

### 13.1 General

Scintillation counting is one of the most common and effective methods in detecting radiation particles. It uses a PMT coupled to a scintillator which produces light by incidence of radiation particles.

In radiation particle measurement, there are two parameters that should be measured. One is the energy of individual particle and the other is the amount of particles. When radiation particles enter the scintillator, they produce light flashes in response to each particle. The amount of flash is proportional to the energy of the incident particle and individual light flashes are detected by the PMT. Consequently, the output pulses obtained from the PMT contain information on both the energy and number of pulses, as shown in Figure 31.

Figure 31: Incident particles and PMT output

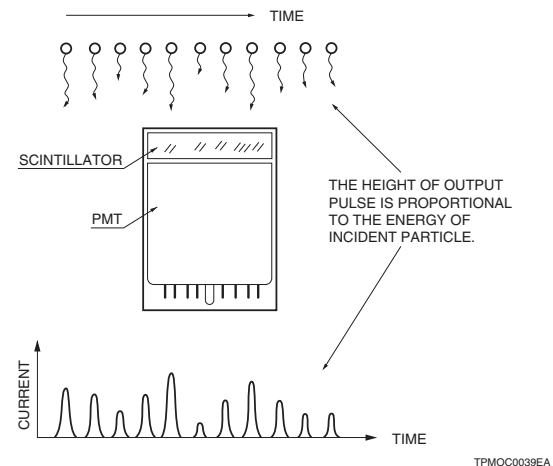
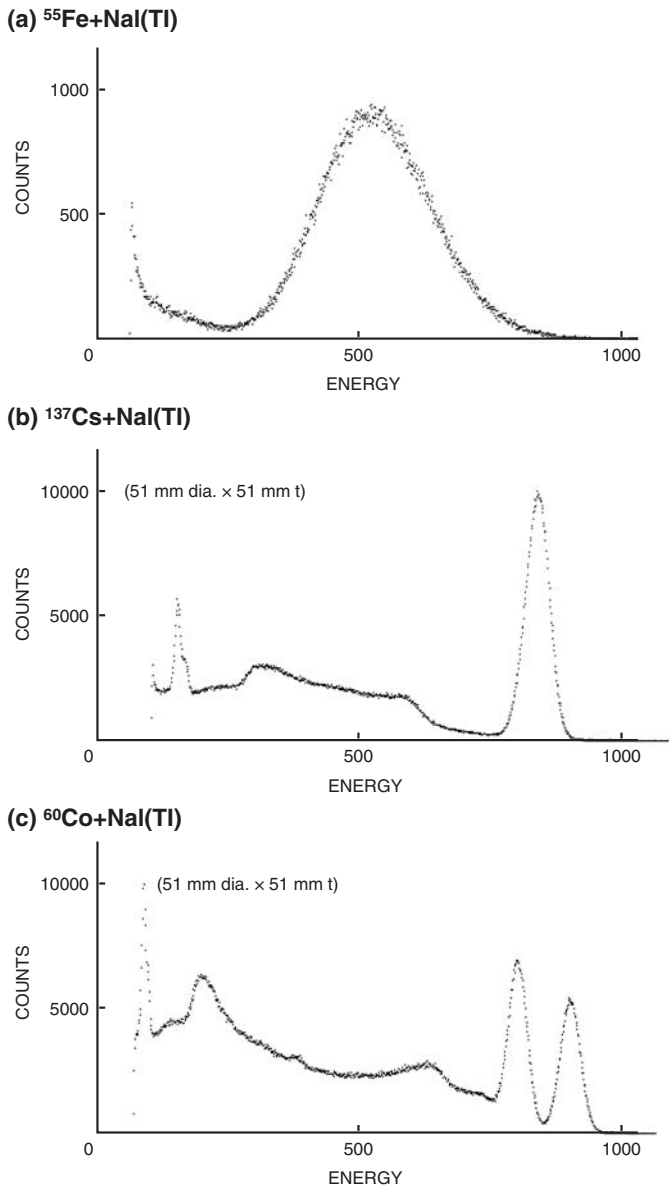


Figure 32: Typical pulse height distribution (Energy spectral)

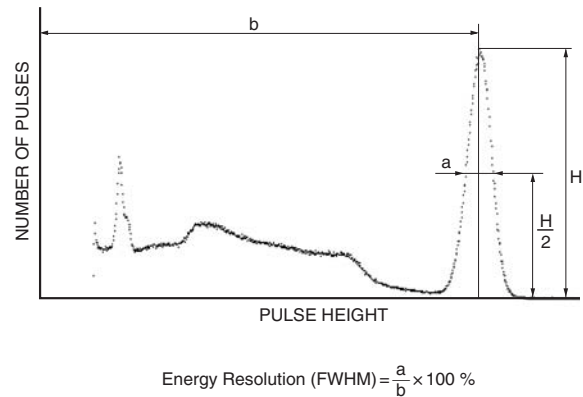


By analyzing these output pulses using a multichannel analyzer (MCA), pulse height distribution (PHD), or energy spectra, as shown in Figure 32, are obtained. From the PHD, the number of incident particles at various energy levels can be measured.

### 13.2 Energy resolution

For the energy spectrum measurement, it is very important to have a distinct peak at each energy level. This characteristic is evaluated as the pulse height resolution or the energy resolution and is most significant in the radiation particle identification. Figure 33 shows the definition of the energy resolution using NaI(Tl) scintillator and  $^{137}\text{Cs}$   $\gamma$ -ray source. It is customarily stated as a percentage.

Figure 33: Definition of pulse height resolution



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The following factors determine the energy resolution.

- (1) Energy conversion efficiency of the scintillator
- (2) Intrinsic energy resolution of the scintillator
- (3) Quantum efficiency of the photocathode
- (4) Collection efficiency of photoelectrons at the first dynode
- (5) Secondary emission yield of dynodes (especially first dynode)

The equation of the pulse height resolution is described as follows:

$$R(E)^2 = R_s(E)^2 + R_p(E)^2$$

where  $R(E)$  : energy resolution  
 $R_s(E)$  : energy resolution of a scintillator  
 $R_p(E)$  : energy resolution of a PMT

$R_p(E)^2$  is described as follows:

$$R_p(E)^2 = \frac{2.35^2}{N\eta\alpha} \times \frac{\delta}{\delta-1}$$

where  $N$  : mean number of incident photon  
 $\eta$  : quantum efficiency  
 $\alpha$  : collection efficiency  
 $\delta$  : mean secondary emission yield of each dynode

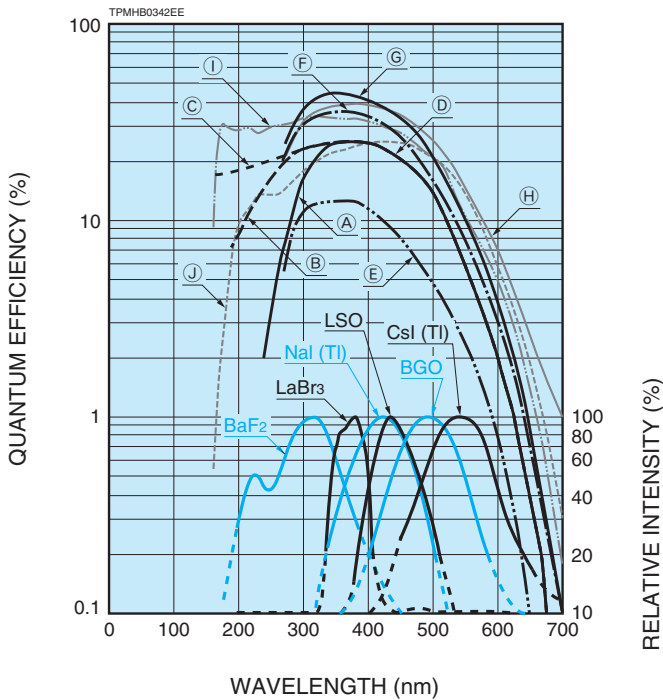
To obtain a good energy resolution, it is important to use a good scintillator having a high efficiency and a good intrinsic energy resolution. It is also important to reduce a light loss between a PMT and a scintillator. For this purpose, it is useful to couple them with silicon oil having a refractive index close to that of the faceplate window of the PMT or scintillator material or its protective window.



### 13.3 Emission spectrum of scintillator

The quantum efficiency of the PMT is one of the main factors to determine its energy resolution. It is necessary to choose a PMT whose spectral response matches the scintillator emission. Figure 34 shows PMT typical spectral response vs. emission spectra of scintillators. For NaI(Tl), which is the most popular scintillator, bialkali photocathode PMTs are widely used.

Figure 34: Typical spectral response and emission spectra of scintillators



- (A): Bialkali Photocathode (Borosilicate Glass)
- (B): Bialkali Photocathode (UV Glass)
- (C): Bialkali Photocathode (Silica Glass)
- (D): Bialkali Photocathode
- (E): High Temp. Bialkali Photocathode
- (F): Super Bialkali
- (G): Ultra Bialkali
- (H): Extended Green Bialkali
- (I): Low Temp. (down to -110 °C) Bialkali Photocathode
- (J): Low Temp. (down to -186 °C) Bialkali Photocathode

### 13.4 Features of scintillators

Figure 35 shows typical temperature responses of various scintillators. These characteristics should be considered in the actual operation.

Table 1 shows a summary of scintillator characteristics. These data are reported by scintillator manufacturers.

Figure 35: Typical temperature response of various scintillators

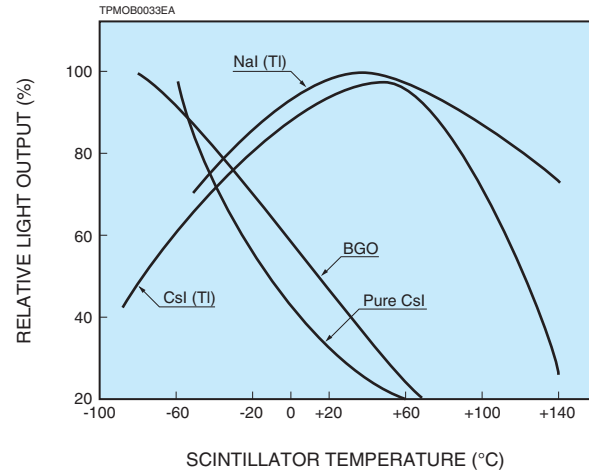


Table 1: Summary of scintillator characteristics

	NaI(Tl)	BGO	CsI(Tl)	Pure CsI	BaF <sub>2</sub>	GSO: Ce	Plastic	LaBr <sub>3</sub> : Ce	LSO: Ce	YAP: Ce
Density (g/cm <sup>3</sup> )	3.67	7.13	4.51	4.51	4.88	6.71	1.03	5.29	7.35	5.55
L <sub>rad</sub> (cm)	2.59	1.12	1.85	1.85	2.10	1.38	40	2.1	0.88	2.70
Refractive index	1.85	2.15	1.80	1.80	1.58	1.85	1.58	1.9	1.82	1.97
Hygroscopic	Yes	No	Slightly	Slightly	Slightly	No	No	Yes	No	No
Luminescence (nm)	410	480	530	310	220 / 325	430	400	380	420	380
Decay time (ns)	230	300	1000	10	0.9 / 630	30	2.0	16	40	30
Relative light output	100	15	45 to 50	<10	20	20	25	165	70	40

## 14. METAL PACKAGE PHOTOMULTIPLIER TUBE

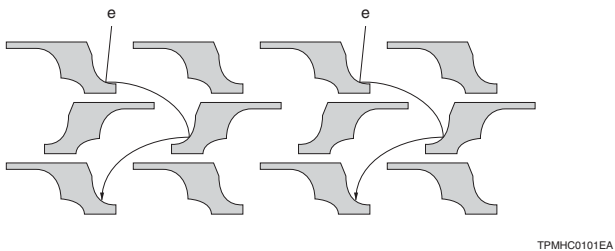
In general including, the development of more compact and portable equipment has continuously progressed. This has led to a strong demand for miniaturization of highly sensitive photodetectors like PMTs. However, it is difficult to miniaturize conventional PMTs with glass envelopes and sophisticated electrode structures.

Accordingly, PMTs have been mainly used in high-precision photometric systems, while semiconductor sensors have been used in general purpose, compact and portable equipments/applications. To meet the increasing needs for small photodetectors with high sensitivity, Hamamatsu has developed subminiature PMTs (R9880 series) using a metal package in place of the traditional glass envelope. These tubes have a size as small as semiconductor sensors, without sacrificing high sensitivity, and have the high speed response offered by conventional PMTs. The remarkable features of R9880 series are: smallest size, fast time response, ability of low light level detection and good immunity to magnetic fields.

R9880 series are a subminiature PMT that incorporates an eight stages electron multiplier constructed with stacked thin electrodes (metal channel dynode) into a TO-8 type metal can package of 15 mm in diameter and 10 mm in height. The development of this metal package and its unique thin electrodes have made the fabrication of this subminiature PMT possible. The electrode structure of the electron multiplier was designed by means of advanced computer simulation and electron trajectory analysis.

Furthermore, our long experience with micromachining technology has achieved a closed proximity assembly of these thin electrodes. Figure 36 shows a cross section of the metal channel dynode with simulated electron trajectories.

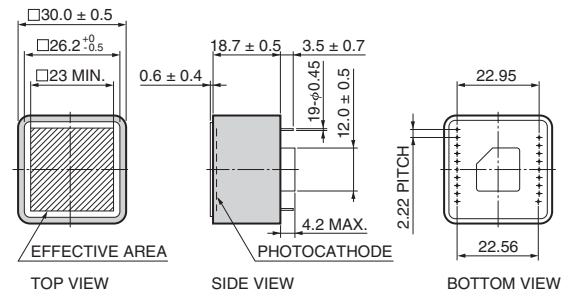
Figure 36: Cross section of metal channel dynode with electron trajectories



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The R5900 / R7600 / R8520 / R11265 series is another version of metal package PMT. It incorporates 10 to 12 stages of metal channel dynodes into a metal package of 26 mm × 26 mm square and about 20 mm in height. The prime features are similar to those of R9880 series, but its effective area is different of R9880. The dimensional outline of R11265U is shown in Figure 37. In this figure, "U" means a tube having an insulation plastic cover. It is necessary to prevent electric shock with some insulation material, because a metal package has a cathode potential voltage.

Figure 37: Insulation plastic cover of R11265U



TPMHA0585EA

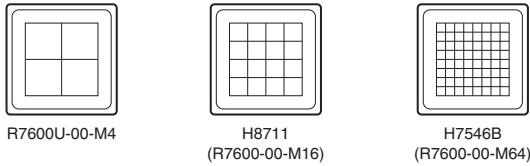
As the metal channel dynode is a sort of an array of small linear focused dynodes, secondary electrons hardly go to the adjacent dynode channel in a process of multiplication. It is possible to make multi-anode PMTs utilizing this feature. These anode shapes are categorized into 5 groups. The first group is multianode in matrix. 4 (2 × 2), 16 (4 × 4) and 64 (8 × 8) matrix channels types are available. (see Figure 38-A) Those are suitable for scintillating fiber readout as well as RICH (Ring Image CHerenkov counter). The second group is linear anode. 16 (1 × 16) and 32 (1 × 32) linear channels types are available. (see Figure 38-B) Those are suitable for coupling with slit shape scintillators and ribbon-shaped scintillating fiber bundle.

R11265 series are wider effective area and shorter length compare with those of R7600 series. Those are also offering matrix channel type as well as single channel type (see Figure 38-C).

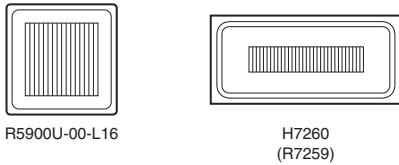
Flat panel PMT assemblies use a 52 mm square photomultiplier tube having an effective area ratio of 89 % and a 64-channel or 256-channel multianode. These flat panel PMTs offer a wide photosensitive area and come in thin, compact shape (see Figure 38-D). These PMTs can be efficiently arrayed in rows or matrices with almost no unused space between them. (See figure 38-E)

Figure 38: Various anode shape

(A) Matrix channel type

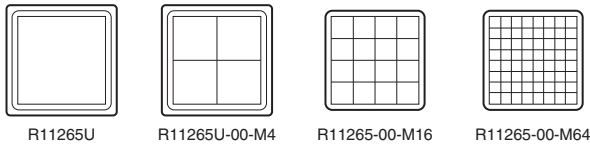


(B) Linear channel type



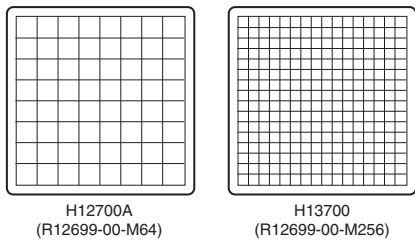
\* R5900 series has flange at the bottom of the metal package, whereas R7600 series doesn't have it.

(C) R11265 series

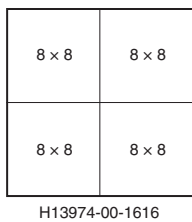


\* R11265 series have wider effective area and low profile with those of R7600 series.

(D) Flat panel type



(E) Flat panel PMT array



TPMHC0204EC

15. FINE MESH PHOTOMULTIPLIER TUBE

As indicated in section 10.2, normal photomultiplier tubes exhibit a large variation in a magnetic field, for example, sensitivity reduces at least one order of magnitude in a magnetic field of 10 milliteslas. In high-energy physics applications, however, photomultiplier tubes capable of operating in a magnetic field of more than one tesla are demanded. To meet these demands, special photomultiplier tubes with fine-mesh dynodes have been developed and put into use. 1) The structure of this photomultiplier tube is illustrated in Figure 39. Figure 40 shows current relative output of a 19-stage photomultiplier tube versus magnetic field at different angles.

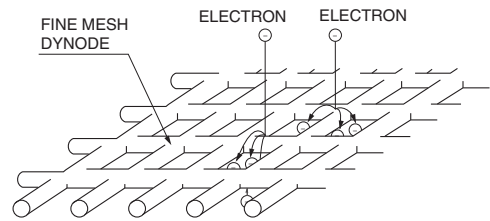
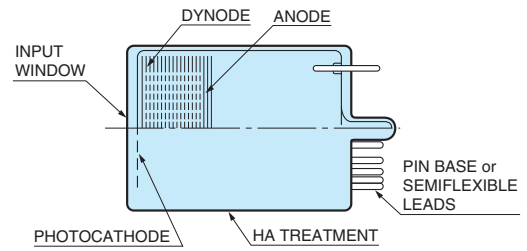
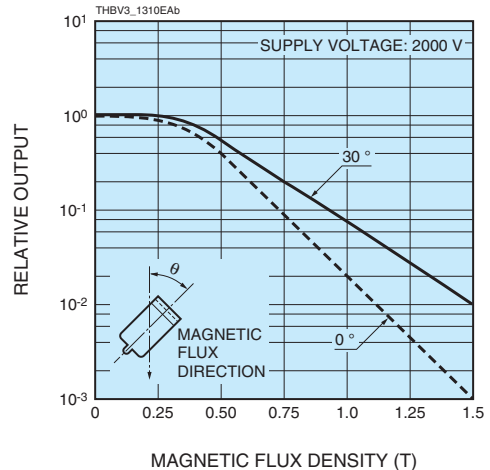


Figure 39: Structure of a photomultiplier tube designed for use in highly magnetic fields



THBV3\_1309EA

Figure 40: Magnetic characteristics of photomultiplier tubes for highly magnetic fields



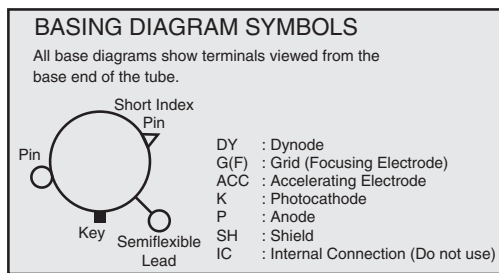
# List guide for photomultiplier tubes

Tube diameter	Type No.	① Outline No.	② Spectral response		Cathode characteristics				Anode characteristics								
			Spectral response range (nm)	Curve code	③ Q.E. at peak Typ. (%)	④ Lumi-nous Typ. (μA/lm)	⑤ Blue sensitivity index (CS 5-58) Typ. (mA/W)	⑥ Radiant Typ. (mA/W)	⑦ Anode to cathode supply voltage (V)	⑧ Lumi-nous Typ. (A/lm)	⑨ Radiant Typ. (A/W)	Gain Typ.	⑩ Dark current		⑪ Time response		
													Typ. (nA)	Max. (nA)	Rise time Typ. (ns)	Transit time Typ. (ns)	T.T.S. Typ. (FWHM) (ns)

## ① Outline No.

This number corresponds to that of PMT dimensional outline drawing shown on later pages.

Basing diagram symbols are explained as follows:



TPMOC0068EC

## ② Spectral response

The relationship between photocathode sensitivity and wavelength of input light.

Curve code corresponds to that of spectral response curve on the inside back cover.

(Refer to section 2 on page 2 for further details.)

## ③ QE (Quantum Efficiency)

The ratio of the number of photoelectrons emitted from the photocathode to the number of incident photons.

This catalog shows quantum efficiency at the peak wavelength.

(Refer to section 2.2 on page 2 for further details.)

## ④ Cathode sensitivity (Luminous)

The photoelectric current from the photocathode per incident light flux from a tungsten filament lamp operated at 2856 K.

(Refer to section 2.5 on page 3 for further details.)

## ⑤ Cathode blue sensitivity index

The photoelectric current from the photocathode per incident light flux from a tungsten filament lamp operated at 2856 K passing through a blue filter which is Corning CS 5-58 polished to 1/2 stock thickness.

(Refer to section 2.5 on page 3 for further details.)

## ⑥ Radiant

Measured at the peak sensitivity wavelength.

(Refer to section 2.2 on page 2 for further details.)

## ⑦ Anode to cathode supply voltage

The voltage indicates a standard applied voltage used to measure characteristics. The number in circles corresponds to that of the voltage distribution ratio on page 56 and 57.

## ⑧ Anode sensitivity (Luminous)

The output current from the anode per incident light flux from a tungsten filament lamp operated at 2856 K.

(Refer to section 4.1 on page 3 for further details.)

## ⑨ Gain (Current amplification)

The ratio of the anode output current to the photoelectric current from the photocathode.

(Refer to section 4.2 on page 4 for further details.)

## ⑩ Anode dark current

The output current from the anode measured after 30 minutes storage in complete darkness.

(Refer to section 5 on page 4 for further details.)

## ⑪ Time response

### <Rise time>

The time for the anode output pulse to rise from 10 % to 90 % of the peak amplitude.

### <Electron transit time>

The time interval between the arrival of a delta function light pulse at the photocathode and the instant when the anode output pulse reaches its peak amplitude.

### <T.T.S. (Transit Time Spread)>

This is the fluctuation in transit time among individual pulses, and is defined as the FWHM of the frequency distribution of transit time.

(Refer to section 6 on page 5 for further details.)

Max. ratings <sup>12</sup>		Typical pulse height resolution <sup>13</sup>	Stability <sup>14</sup>		Pulse linearity <sup>15</sup>		Remarks		Note	Type No.
Anode to cathode voltage (V)	Average anode current (mA)		Long term Typ. (%)	Short term Typ. (%)	2 % deviation Typ. (mA)	5 % deviation Typ. (mA)	Dynode structure / stage <sup>16</sup>	Socket & socket assembly <sup>17</sup>		

## 12 Maximum rating

### <Anode to cathode voltage>

The maximum anode to cathode voltages are limited by the internal structure of the PMT.

Excessive voltage causes electrical breakdown. The voltage lower than the maximum rating should be applied to the PMT.

### <Average anode current>

This indicates the maximum averaged current over any interval of 30 seconds. For practical use, operating at lower average anode current is recommended.

(Refer to section 9.3 on page 6 for further details)

★ 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.

## 13 Pulse height resolution (P.H.R.)

The P.H.R. is measured with the combination of an NaI(Tl) scintillator and a <sup>137</sup>Cs source as a standard measurement. If other scintillators or γ-ray sources are used, note is attached.

(Refer to section 13.2 on page 14 for further details.)

## 14 Stability

### <Long term stability (Mean gain deviation)>

This is defined as follows under the operation for 16 hours at a constant count rate of 1000 s<sup>-1</sup>:

$$Dg = \frac{\sum_{i=1}^n |P - P_i|}{n} \cdot \frac{100}{P} (\%)$$

where P is the mean pulse height averaged over n readings, P<sub>i</sub> is the pulse height at the i-th reading, and n is the total number of readings.

### <Short term stability>

This is the gain shift on count rate change. The tube is first operated at about 10000 s<sup>-1</sup>. The photo-peak count rate is then decreased to about 1000 s<sup>-1</sup> by increasing the distance between the <sup>137</sup>Cs source and the tube coupled to the NaI(Tl) scintillator. (Refer to section 9 on page 6 for further details.)

## 15 Pulse linearity

Typical values of pulse linearity are specified at two points (±2 % and ±5 % deviation points from linear proportionality). (Refer to section 7 on page 5 and 6 for further details.)

## 16 Dynode

### <Dynode structure>

Each mark means dynode structure as follows:

- LINE : linear focused
- BOX : box and grid
- B + L : box and linear focused
- C + L : circular and linear focused
- VB : venetian blind
- FM : fine mesh
- MC : metal channel

### <No. of stages>

The number of dynodes used.

(Refer to section 3 on page 4 for further details.)

## 17 Socket & socket assembly

★ mark : A socket will be supplied with a PMT.

no mark : A socket will be supplied as an option.

The number in square corresponds to the outline number of the PMT socket assembly on page 58 and 59.

# Photomultiplier tubes

Tube diameter	Type No.	① Out-line No.	② Spectral response		Cathode characteristics				Anode characteristics									
			Spectral response range (nm)	Curve code	③ Q.E. at peak Typ. (%)	④ Luminous Typ. (μA/lm)	⑤ Blue sensitivity index (CS 5-58) Typ.	⑥ Radiant Typ. (mA/W)	⑦ Anode to cathode supply voltage (V)	⑧ Luminous Typ. (A/lm)	⑨ Radiant Typ. (A/W)	⑩ Gain Typ.	⑩ Dark current		⑪ Time response			
													Typ. (nA)	Max. (nA)	Rise time Typ. (ns)	Transit time Typ. (ns)	T.T.S. Typ. (FWHM) (ns)	
10 mm (3/8")	R1635	①	300 to 650	A-D	25	100	10.0	80	1250	③	100	8.0 × 10 <sup>4</sup>	1.0 × 10 <sup>6</sup>	1	50	0.8	9	0.5
	R2496	①	160 to 650	C-D	25	100	10.0	80	1250	⑤	100	8.0 × 10 <sup>4</sup>	1.0 × 10 <sup>6</sup>	2	50	0.7	9	0.5
13 mm (1/2")	R647-01	③	300 to 650	A-D	25	110	10.0	80	1000	⑬	150	1.1 × 10 <sup>5</sup>	1.4 × 10 <sup>6</sup>	1	2	2.1	22	2.0
	R4124	②	300 to 650	A-D	25	100	10.0	80	1000	⑰	100	8.0 × 10 <sup>4</sup>	1.0 × 10 <sup>6</sup>	1	15	1.1	12	0.5
	R4177-06	③	300 to 650	A-E	12	30	4.5	38	1500	⑬	15	1.9 × 10 <sup>4</sup>	5.0 × 10 <sup>5</sup>	0.5	10	2.0	20	—
	R12421	④	300 to 650	A-D	25	110	10	80	1000	⑲	220	1.6 × 10 <sup>5</sup>	2.0 × 10 <sup>6</sup>	0.5	2	1.2	14	1.4
	R12421-300	④	300 to 700	H	32	160	14	105	1000	⑲	320	2.1 × 10 <sup>5</sup>	2.0 × 10 <sup>6</sup>	1	5	1.2	14	1.4
19 mm (3/4")	R1166	⑤	300 to 650	A-D	26	110	10.5	85	1000	⑳	110	8.5 × 10 <sup>4</sup>	1.0 × 10 <sup>6</sup>	1	5	2.5	27	2.8
	R1450	⑥	300 to 650	A-D	27	115	11.0	88	1500	㉕	200	1.5 × 10 <sup>5</sup>	1.7 × 10 <sup>6</sup>	3	50	1.8	19	0.76
	R3478	⑦	300 to 650	A-D	27	115	11.0	88	1700	⑩	200	1.5 × 10 <sup>5</sup>	1.7 × 10 <sup>6</sup>	10	300	1.3	14	0.36
	R3991A-04	⑧	300 to 650	A-E	12	30	4.5	38	1500	㉖	10	1.3 × 10 <sup>4</sup>	3.3 × 10 <sup>5</sup>	0.1	10	1.0	10	—
	R4125	⑥	300 to 650	A-D	27	115	11.0	88	1500	㉑	100	7.7 × 10 <sup>4</sup>	8.7 × 10 <sup>5</sup>	10	50	2.5	16	0.85
	R5611A-01	⑧	300 to 650	A-D	26	90	10.5	85	1000	㉖	50	4.7 × 10 <sup>4</sup>	5.5 × 10 <sup>5</sup>	3	20	1.3	12	0.8
25 mm (1")	R1288A-06	⑨	300 to 650	A-E	12	30	4.5	38	1500	㉖	10	1.2 × 10 <sup>4</sup>	3.3 × 10 <sup>5</sup>	0.1	10	1.3	13	—
	R1924A	⑨	300 to 650	A-D	26	90	10.5	85	1000	㉖	180	1.7 × 10 <sup>5</sup>	2.0 × 10 <sup>6</sup>	3	20	1.5	17	0.9
	R4998	⑩	300 to 650	A-D	23	80	9.5	76	2250	⑰	400	3.8 × 10 <sup>5</sup>	5.0 × 10 <sup>6</sup>	10	200	0.7	10	0.16
	R7899-01	⑪	300 to 650	A-D	27	95	11.0	88	1250	⑰	190	1.8 × 10 <sup>5</sup>	2.0 × 10 <sup>6</sup>	2	15	1.6	17	0.6
									1500	㉘	160	1.5 × 10 <sup>5</sup>	1.7 × 10 <sup>6</sup>	2	20	1.6	16	0.7
	R8619	⑫	300 to 650	A-D	27	95	11.0	88	1000	⑰	250	2.3 × 10 <sup>5</sup>	2.6 × 10 <sup>6</sup>	2	15	2.5	28	1.2
	R9800	⑬	300 to 650	A-D	27	95	11.0	88	1300	⑨	100	9.3 × 10 <sup>4</sup>	1.1 × 10 <sup>6</sup>	5	50	1.0	11	0.27
	R9800-100	⑬	300 to 650	F	35	130	13.5	110	1300	⑨	140	1.2 × 10 <sup>5</sup>	1.1 × 10 <sup>6</sup>	10	100	1.0	11	0.27
R13478	⑭	300 to 650	A-D	25	95	10.0	80	1500	②	50	4.2 × 10 <sup>4</sup>	5.3 × 10 <sup>5</sup>	3	30	0.9	9.1	0.13	
28 mm (1-1/8")	R3998-02	⑮	300 to 650	A-D	26	90	10.5	85	1000	⑬	120	1.1 × 10 <sup>5</sup>	1.3 × 10 <sup>6</sup>	2	10	4.4	32	3.5
	R3998-100-02	⑮	300 to 650	F	35	130	13.5	110	1000	⑬	130	1.1 × 10 <sup>5</sup>	1.0 × 10 <sup>6</sup>	5	25	4.4	32	3.5
	R6427	⑯	300 to 650	A-D	27	100	11.0	88	1500	⑳	500	4.4 × 10 <sup>5</sup>	5.0 × 10 <sup>6</sup>	10	200	1.7	16	0.5
									1500	㉑	190	1.7 × 10 <sup>5</sup>	2.0 × 10 <sup>6</sup>	4	80	1.8	17	0.5
	R7111	⑰	300 to 650	A-D	26	90	10.5	85	1000	㉖	180	1.7 × 10 <sup>5</sup>	2.0 × 10 <sup>6</sup>	3	20	1.6	18	0.9
	R7525	⑱	300 to 650	A-D	27	95	11.0	88	1500	⑥	45	4.7 × 10 <sup>4</sup>	5.3 × 10 <sup>5</sup>	5	100	1.3	14	0.55
									1500	⑦	19	1.8 × 10 <sup>4</sup>	2.1 × 10 <sup>5</sup>	2	40	1.3	15	0.58
R13449	⑲	300 to 650	A-D	25	95	10.0	80	1500	②	50	4.2 × 10 <sup>4</sup>	5.3 × 10 <sup>5</sup>	3	30	0.9	10	0.17	
38 mm (1-1/2")	R580	⑳	300 to 650	A-D	27	95	11.0	88	1250	㉓	100	4.7 × 10 <sup>4</sup>	1.1 × 10 <sup>6</sup>	3	20	2.7	37	4.5
									1500	㉔	75	7.0 × 10 <sup>4</sup>	7.9 × 10 <sup>5</sup>	2	15	2.7	40	4.5
	R11102	㉑	300 to 650	A-D	28	120	11.5	89	1000	㉓	120	8.9 × 10 <sup>4</sup>	1.0 × 10 <sup>6</sup>	2	20	3.2	34	4.8
	R3886A	㉒	300 to 650	A-D	26	90	10.5	85	1000	㉓	180	1.7 × 10 <sup>5</sup>	2.0 × 10 <sup>6</sup>	3	20	2.6	30	2.0
	R9420	㉓	300 to 650	A-D	27	95	11.0	88	1300	⑨	47	4.4 × 10 <sup>4</sup>	5.0 × 10 <sup>5</sup>	10	100	1.6	17	0.55
	R9420-100	㉓	300 to 650	F	35	130	13.5	110	1300	⑨	65	5.5 × 10 <sup>4</sup>	5.0 × 10 <sup>5</sup>	10	100	1.6	17	0.55
R13408	㉔	300 to 650	A-D	25	95	10.0	80	1500	②	50	4.2 × 10 <sup>4</sup>	5.3 × 10 <sup>5</sup>	3	30	1.2	13	0.19	

Note: The data shown in   is measured with tapered voltage distribution ratio. Please refer to page 18 and 19 for each item in the above list.

(at 25 °C)

Max. ratings <sup>12</sup>		Typical pulse height resolution <sup>13</sup>	Stability <sup>14</sup>		Pulse linearity <sup>15</sup>		Remarks		Note	Type No.
Anode to cathode voltage (V)	Average anode current (mA)		Long term Typ. (%)	Short term Typ. (%)	2 % deviation Typ. (mA)	5 % deviation Typ. (mA)	Dynode structure / stage <sup>16</sup>	Socket & socket assembly <sup>17</sup>		
1500	0.03	23 / BGO *1	1.0	2.0	3	7	LINE / 8	E678-11* 1	UV type (R3878)	R1635
1500	0.03	23 / BGO *1	1.0	2.0	3	7	LINE / 8	E678-11* 1		R2496
1250	0.1	7.8	1.0	2.0	3	7	LINE / 10	E678-13F* 2	SILICA (R760) and UV (R960) types	R647-01
1250	0.03	8.1	1.0	2.0	2	5	LINE / 10	E849-68 3	UV type (R4141)	R4124
1800	0.02	12.0	2.0	2.0	8	13	LINE / 10	E678-13E*	Flying lead type (R4177-04)	R4177-06
1250	0.1	—	—	—	3	12	LINE / 10	E678-13F* 3	UV types (R12421-03)	R12421
1250	0.1	—	—	—	3	12	LINE / 10	E678-13F* 3	EGBA type	R12421-300
1250	0.1	7.8	1.0	2.0	4	7	LINE / 10	E678-12L* 4	SILICA (R762) and UV (R750) types	R1166
1800	0.1	7.8	1.0	2.0	4	8	LINE / 10	E678-12L* 5		R1450
1800	0.1	7.8	1.0	2.0	4	8	LINE / 8	E678-12L* 6	SILICA (R2076) and UV (R3479) types	R3478
1800	0.02	11.0	1.0	2.0	20	40	C+L / 10	E678-12R*		R3991A-04
1800	0.1	7.8	1.0	2.0	100	170	LINE / 10	E678-12L* 7		R4125
1250	0.1	8.0	1.0	2.0	10	20	LINE / 10	E678-12A*	Glass base type (R5611A)	R5611A-01
1800	0.02	9.0	1.0	2.0	30	50	C+L / 10	E678-14-03*	Flying lead type (R1288A-04)	R1288A-06
1250	0.1	7.8	1.0	2.0	30	50	C+L / 10	E678-14C* 11	Flying lead type (R1924A-01)	R1924A
2500	0.1	8.0	1.0	2.0	40	70	LINE / 10	E678-12A*	SILICA type (R5320)	R4998
1800	0.1	7.8	1.0	2.0	30	50	LINE / 10	E678-12A*	Glass base type (R7899)	R7899-01
1800	0.1	7.8	1.0	2.0	100	150	LINE / 10	E678-12A*		
1500	0.1	8.0	1.0	2.0	5	8	LINE / 10	E678-12A*		R8619
1500	0.1	7.8	1.0	2.0	30	50	LINE / 8	E678-12A*		R9800
1500	0.1	—	—	—	30	50	LINE / 8	E678-12A*	SBA type	R9800-100
1750	0.1	8.0	—	—	10	25	LINE / 8	E678-20B*		R13478
1500	0.1	7.5	1.0	1.0	8	10	B+L / 9	E678-14C* 10		R3998-02
1500	0.1	7.0	1.0	1.0	8	10	B+L / 9	E678-14C* 10	SBA type	R3998-100-02
2000	0.1	7.8	1.0	2.0	10	30	LINE / 10	E678-14C* 12 13	UV type (R7056)	R6427
2000	0.1	7.8	1.0	2.0	100	150	LINE / 10	E678-14C* 12 13		
1250	0.1	7.8	1.0	2.0	30	50	C+L / 10	E678-14C* 11		R7111
1750	0.2	7.8	1.0	2.0	10	30	LINE / 8	E678-14C*		R7525
1750	0.2	7.8	1.0	2.0	100	150	LINE / 8	E678-14C*		
1750	0.1	8.0	—	—	10	30	LINE / 8	E678-20B*		R13449
1750	0.1	7.7	1.0	1.0	40	60	LINE / 10	E678-12A* 14		R580
1750	0.1	7.7	1.0	1.0	150	200	LINE / 10	E678-12A* 14		
1250	0.1	7.6	0.5	0.5	10	30	C+L / 10	E678-12A 14		R11102
1250	0.1	7.5	1.0	2.0	20	30	C+L / 10	E678-12A* 14		R3886A
1500	0.1	7.8	1.0	2.0	30	50	LINE / 8	E678-12A*		R9420
1500	0.1	7.0	1.0	2.0	30	50	LINE / 8	E678-12A*	SBA type	R9420-100
1750	0.1	8.0	—	—	20	50	LINE / 8	E678-20B*		R13408

Note 1: This data is measured with <sup>22</sup>Na source and BGO scintillator.





(at 25 °C)

Max. ratings <sup>12</sup>		Typical pulse height resolution <sup>13</sup>	Stability <sup>14</sup>		Pulse linearity <sup>15</sup>		Remarks		Note	Type No.
Anode to cathode voltage (V)	Average anode current (mA)		Long term Typ. (%)	Short term Typ. (%)	2 % deviation Typ. (mA)	5 % deviation Typ. (mA)	Dynode structure / stage <sup>16</sup>	Socket & socket assembly <sup>17</sup>		
2700	0.2	7.6	1.0	1.0	15	30	LINE / 12	E678-21C* <sup>20</sup>	SILICA type (R2256-02)	R329-02
2700	0.2	7.6	1.0	1.0	100	200			UV type (R5113-02)	
2500	0.2	—	—	—	15	30	LINE / 12	E678-21C* <sup>20</sup>		R331-05
1500	0.1	6.3 (8.5) *3	0.5	0.5	1	5	BOX / 8	E678-14W <sup>17/18</sup>	K-FREE type (R1306-15)	R1306
3000	0.2	7.8	1.0	1.0	100	200	LINE / 12	E678-20B* <sup>16</sup>	SILICA type (R2059)	R1828-01
3000	0.2	7.8	1.0	1.0	250	500			UV type (R4004)	
3500	0.2	7.8	1.0	2.0	100	150	LINE / 8	E678-19J*	SILICA type (R3377)	R2083
1750	0.1	7.6	1.0	1.0	50	70	LINE / 10	E678-14W <sup>15</sup>	Glass base type (R3149)	R2154-02
1750	0.1	7.6	1.0	1.0	150	200				
1800	0.02	10.0	2.0	2.0	30	60	C+L / 10	E678-15C*		R4607A-06
1000	0.1	—	—	—	40	—	MC / 12	—		R6041
1000	0.1	—	—	—	40	—	MC / 12	—	For low temperature operation down to -110 °C Low radicoactivity material	R6041-406
1000	0.1	—	—	—	40	—	MC / 12	—	For low temperature operation down to -186 °C Low radicoactivity material	R6041-506
1500	0.1	6.3 (8.5) *3	0.5	0.5	5	10	B+L / 8	E678-14W <sup>19</sup>	Semiflexible lead type (R6231-01)	R6231
1500	0.1	6.1	0.5	0.5	5	10	B+L / 8	E678-14W <sup>19</sup>	SBA type	R6231-100
2000	0.2	7.6	1.0	1.0	80	100	LINE / 8	E678-21C* <sup>20</sup>		R7723
2000	0.2	7.6	1.0	1.0	60	90	LINE / 10	E678-21C* <sup>20</sup>		R7724
2000	0.2	—	1.0	1.0	60	90	LINE / 10	E678-21C <sup>20</sup>	SBA type	R7724-100
2000	0.2	7.6	1.0	1.0	40	80	LINE / 12	E678-21C* <sup>20</sup>		R7725
1750	0.1	8.0	—	—	30	60	LINE / 8	E678-20B*		R13089
2000	0.1	8.0	—	—	30	60	LINE / 10	E678-20B*		R13435
1500	0.1	6.3 (8.5) *3	0.5	0.5	5	10	B+L / 8	E678-14W <sup>19</sup>	Semiflexible lead type (R6232-01)	R6232
1500	0.1	6.3 (8.5) *3	0.5	0.5	1	5	BOX / 8	E678-14W <sup>17/18</sup>	K-FREE type (R1307-07)	R1307
2500	0.2	7.8	1.0	1.0	40	60	LINE / 12	E678-21C* <sup>20</sup>		R6091
2500	0.2	7.8	1.0	1.0	80	110				
1500	0.1	6.3 (8.5) *3	0.5	0.5	5	10	B+L / 8	E678-14W <sup>19</sup>	Semiflexible lead type (R6233-01)	R6233
1500	0.1	6.1	0.5	0.5	5	10	B+L / 8	E678-14W <sup>19</sup>	SBA type	R6233-100
1750	0.1	—	—	—	20	25	B+L / 12	E678-20B*	For low temperature operation down to -186 °C Low radicoactivity material	R11065
1750	0.1	—	—	—	20	25	B+L / 12	E678-20B*	For low temperature operation down to -110 °C Low radicoactivity material	R11410
1500	0.1	—	—	—	—	—	C+L / 10	E678-14W		R12199
1500	0.1	6.3 (8.5)	0.5	0.5	5	10	B+L / 8	E678-14W <sup>19</sup>	Semiflexible lead type (R10233-01)	R10233
1500	0.1	6.1	0.5	0.5	5	10	B+L / 8	E678-14W <sup>19</sup>	SBA type	R10233-100
1500	0.1	—	1.0	2.0	5	10	B+L / 8	E678-14W <sup>19</sup>		R10806
1500	0.1	—	1.0	2.0	5	10	B+L / 8	E678-14W <sup>19</sup>	SBA type	R10806-100
1500	0.1	8.0	1.0	1.0	10	20	BOX / 10	E678-14W <sup>21/22</sup>	K-FREE type (R877-01)	R877
1500	0.1	7.6	1.0	1.0	10	20	BOX / 10	E678-14W <sup>21/22</sup>	SBA type	R877-100
3000	0.2	8.3	1.0	1.0	100	150	LINE / 14	E678-20B* <sup>23</sup>		R1250
3000	0.2	8.3	1.0	1.0	160	250				
2000	0.1	—	—	—	30	50	B+L / 10	E678-20B*		R6594
2000	0.1	—	—	—	100	150				
1500	0.1	—	1.0	1.0	10	30	B+L / 8	E678-14W		R11833-03
1500	0.1	—	1.0	1.0	10	30	B+L / 8	E678-14W	SBA type	R11833-100-03
2000	0.1	—	—	—	40	60	B+L / 10	E678-20B* <sup>24</sup>		R5912
2000	0.1	—	—	—	30	60	B+L / 14	E678-20B*		R5912-02
2000	0.1	—	—	—	40	60	B+L / 10	E678-20B <sup>24</sup>	SBA type	R5912-100
2000	0.1	—	—	—	40	60	B+L / 10	E678-20B* <sup>24</sup>		R7081
2000	0.1	—	—	—	30	60	B+L / 14	E678-20B* <sup>24</sup>		R7081-20
2000	0.1	—	—	—	40	60	B+L / 10	E678-20B <sup>24</sup>	SBA type	R7081-100
2500	0.1	—	—	—	20	40	B+L / 10	E678-20B		R12860

Note 3: This data in parentheses is measured with <sup>57</sup>Co.

# Photomultiplier tubes of special shapes

Tube diameter	Type No.	① Out-line No.	② Spectral response		Cathode characteristics				Anode characteristics									
			Spectral response range (nm)	Curve code	③ Q.E. at peak Typ. (%)	④ Luminous Typ. (μA/lm)	⑤ Blue sensitivity index (CS 5-58) Typ.	⑥ Radiant Typ. (mA/W)	⑦ Anode to cathode supply voltage (V)	⑧ Luminous Typ. (A/lm)	⑨ Radiant Typ. (A/W)	⑩ Gain Typ.	⑩ Dark current		⑪ Time response			
													Typ. (nA)	Max. (nA)	Rise time Typ. (ns)	Transit time Typ. (ns)	T.T.S. Typ. (FWHM) (ns)	

## Metal package photomultipliers

25 mm (1")	R8520-406	53	160 to 650	I	30	100	11.0	100	800	15	100	$1.0 \times 10^5$	$1.0 \times 10^6$	2	20	1.8	12.4	0.8
	R8520-506	53	160 to 650	J	25	100	9.5	80	800	15	100	$8.0 \times 10^4$	$1.0 \times 10^6$	2	20	1.8	12.4	0.8
30 mm square type	R7600U	54	300 to 650	A-D	24	80	9.5	80	800	22	160	$1.6 \times 10^5$	$2.0 \times 10^6$	2	20	1.6	9.6	0.35
	R7600U-100	54	300 to 650	F	35	105	13.5	110	800	22	105	$1.1 \times 10^5$	$1.0 \times 10^6$	2	20	1.6	9.6	0.35
	R7600U-200	54	300 to 650	G	43	135	15.5	130	800	22	135	$1.3 \times 10^5$	$1.0 \times 10^6$	2	20	1.6	9.6	0.35
	R7600U-300	54	300 to 700	H	39	160	14	125	800	22	320	$2.5 \times 10^5$	$2.0 \times 10^6$	2	20	1.6	9.6	0.35
	R7600U-100-M4	55	300 to 650	F	35	105	13.5	110	800	22	140	$1.4 \times 10^5$	$1.3 \times 10^6$	0.5/ch	5/ch	1.2	9.5	0.36
	R7600U-200-M4	55	300 to 650	G	43	135	15.5	130	800	22	175	$1.7 \times 10^5$	$1.3 \times 10^6$	0.5/ch	5/ch	1.2	9.5	0.36
	R7600U-300-M4	55	300 to 700	H	39	160	14	125	800	22	210	$1.6 \times 10^5$	$1.3 \times 10^6$	0.5/ch	5/ch	1.2	9.5	0.36
	R7600U-00-M4	55	300 to 650	A-D	24	80	9.5	80	800	22	140	$1.4 \times 10^5$	$1.8 \times 10^6$	0.5/ch	5/ch	1.2	9.5	0.36
	R5900U-00-L16	56	300 to 650	A-D	21	70	8.5	72	800	16	280	$2.9 \times 10^5$	$4.0 \times 10^6$	0.2/ch	2/ch	0.6	7.4	0.18
	R5900U-100-L16	56	300 to 650	F	35	105	13.5	110	800	16	105	$1.1 \times 10^5$	$1.0 \times 10^6$	0.2/ch	2/ch	0.6	7.4	0.18
	R5900U-200-L16	56	300 to 650	G	43	135	15.5	130	800	16	135	$1.3 \times 10^5$	$1.0 \times 10^6$	0.2/ch	2/ch	0.6	7.4	0.18
	R9880U-110	57	230 to 700	F	35	105	13.5	110	1000	14	210	$2.2 \times 10^5$	$2.0 \times 10^6$	1	10	0.57	2.7	0.2
	R9880U-210	57	230 to 700	G	43	135	15.5	130	1000	14	270	$2.6 \times 10^5$	$2.0 \times 10^6$	1	10	0.57	2.7	0.2
	R11265U-100	58	300 to 650	F	35	105	13.5	110	900	41	126	$1.3 \times 10^5$	$1.2 \times 10^6$	2	20	1.3	5.8	0.27
R11265U-200	58	300 to 650	G	43	135	15.5	130	900	41	162	$1.6 \times 10^5$	$1.2 \times 10^6$	2	20	1.3	5.8	0.27	
R11265U-300	58	300 to 700	H	39	160	14	125	900	41	192	$1.5 \times 10^5$	$1.2 \times 10^6$	2	20	1.3	5.8	0.27	

## Fine mesh photomultipliers

25 mm (1")	R5505-70	59	300 to 650	A-D	23	80	9.5	76	2000	53	40	$3.8 \times 10^4$	$5.0 \times 10^5$	5	30	1.5	5.6	0.35
39 mm (1.5")	R7761-70	60	300 to 650	A-D	23	80	9.5	76	2000	54	800	$7.6 \times 10^5$	$1.0 \times 10^7$	15	100	2.1	7.5	0.35
51 mm (2")	R5924-70	61	300 to 650	A-D	22	70	9.0	72	2000	54	700	$7.2 \times 10^5$	$1.0 \times 10^7$	30	200	2.5	9.5	0.44

## Square, Rectangular shape photomultipliers

10 mm (3/8")	R2248	62	300 to 650	A-D	25	100	10.0	80	1250	3	100	$8.0 \times 10^4$	$1.0 \times 10^6$	1	50	0.9	9.0	0.6
60 mm	R6236	63	300 to 650	A-D	28	110	11.5	95	1000	4	30	$2.6 \times 10^4$	$2.7 \times 10^5$	2	20	9.5	52	8.5
76 mm (3")	R6237	64	300 to 650	A-D	28	110	11.5	95	1000	4	30	$2.6 \times 10^4$	$2.7 \times 10^5$	2	20	9.5	52	8.5
25 mm (1")	R1548-07	65	300 to 650	A-D	23	80	9.5	76	1250	30	200	$1.9 \times 10^5$	$2.5 \times 10^6$	20	250	1.8	20	1.0
38 mm (1-1/2")	R8997	66	300 to 650	A-D	23	80	9.5	76	1250	29	100	$9.9 \times 10^4$	$1.2 \times 10^6$	10	200	5.0	25	2.8
	R10550	67	300 to 650	A-D	25	80	10.0	80	1300	9	100	$1.0 \times 10^5$	$1.3 \times 10^6$	10	100	1.3	12	0.6

## Hexagonal shape photomultipliers

60 mm	R6234	68	300 to 650	A-D	28	110	11.5	95	1000	4	30	$2.6 \times 10^4$	$2.7 \times 10^5$	2	20	9.5	52	8.5
76 mm (3")	R6235	69	300 to 650	A-D	28	110	11.5	95	1000	4	30	$2.6 \times 10^4$	$2.7 \times 10^5$	2	20	9.5	52	8.5

## 2π shape photomultipliers

25 mm (1")	R7373A-01	70	300 to 650	A-D	26	90	10.5	85	1000	26	100	$9.4 \times 10^4$	$1.1 \times 10^6$	3	20	2	19	1.1
28 mm (1-1/8")	R8143	71	300 to 650	A-D	26	90	10.5	85	1000	36	200	$1.8 \times 10^5$	$2.2 \times 10^6$	2	10	25	72	—

(at 25 °C)

Max. ratings <sup>12</sup>		Typical pulse height resolution <sup>13</sup>	Stability <sup>14</sup>		Pulse linearity <sup>15</sup>		Remarks		Note	Type No.
Anode to cathode voltage (V)	Average anode current (mA)		Long term Typ. (%)	Short term Typ. (%)	2 % deviation Typ. (mA)	5 % deviation Typ. (mA)	Dynode structure / stage <sup>16</sup>	Socket & socket assembly <sup>17</sup>		
900	0.03	—	—	—	30	60	MC / 10	E678-32B <sup>25</sup>	For low temperature operation down to -110 °C Low radioactivity material	R8520-406
900	0.03	—	—	—	30	60	MC / 10	E678-32B <sup>25</sup>	For low temperature operation down to -186 °C Low radioactivity material	R8520-506
900	0.1	—	1.0	2.0	30 *5	60	MC / 10	E678-32B <sup>26</sup>	UV type (R7600U-03) is available	R7600U
900	0.1	—	—	—	30 *5	60	MC / 10	E678-32B <sup>26</sup>	SBA type	R7600U-100
900	0.1	—	—	—	30 *5	60	MC / 10	E678-32B	UBA type	R7600U-200
900	0.1	—	—	—	30 *5	—	MC / 10	E678-32B <sup>26</sup>	EGBA type	R7600U-300
900	0.1	—	—	—	10/ch	30/ch	MC / 10	E678-32B <sup>27</sup>	SBA type	R7600U-100-M4
900	0.1	—	—	—	10/ch	30/ch	MC / 10	E678-32B <sup>27</sup>	UBA type	R7600U-200-M4
900	0.1	—	—	—	10/ch	30/ch	MC / 10	E678-32B <sup>27</sup>	EGBA type	R7600U-300-M4
900	0.1	—	—	—	10	30	MC / 10	E678-32B <sup>27</sup>	*4	R7600U-00-M4
900	0.1	—	—	—	0.8/ch	1.2/ch	MC / 10	E678-32B <sup>28</sup>	*4	R5900U-00-L16
900	0.1	—	—	—	0.8/ch	1.2/ch	MC / 10	E678-32B <sup>28</sup>	SBA type *4	R5900U-100-L16
900	0.1	—	—	—	0.8/ch	1.2/ch	MC / 10	E678-32B <sup>28</sup>	UBA type *4	R5900U-200-L16
1100	0.1	—	—	—	10	30	MC / 10	E678-12-01 <sup>30</sup>	SBA type	R9880U-110
1100	0.1	—	—	—	10	30	MC / 10	E678-12-01 <sup>31</sup>	UBA type	R9880U-210
1000	0.1	—	—	—	20 *5	60	MC / 12	E678-19K <sup>30</sup>	SBA type	R11265U-100
1000	0.1	—	—	—	20 *5	60	MC / 12	E678-19K <sup>30</sup>	UBA type	R11265U-200
1000	0.1	—	—	—	20 *5	60	MC / 12	E678-19K <sup>30</sup>	EGBA type	R11265U-300
2300	0.01	9.5	2.0	2.0	180	250	FM / 15	E678-17D* <sup>9</sup>	For +HV operation	R5505-70
2300	0.01	9.5	2.0	2.0	320	450	FM / 19	—	For +HV operation	R7761-70
2300	0.1	9.5	2.0	2.0	500	700	FM / 19	—	For +HV operation	R5924-70
1500	0.03	23 / BGO *1	1.0	2.0	3	7	LINE / 8	E678-11N* <sup>1</sup>		R2248
1500	0.1	6.3 (8.5) *3	0.5	0.5	5	10	B+L / 8	E678-14W <sup>19</sup>	Semiflexible lead type (R6236-01) is available	R6236
1500	0.1	6.3 (8.5) *3	0.5	0.5	5	10	B+L / 8	E678-14W <sup>19</sup>	Semiflexible lead type (R6237-01) is available	R6237
1750	0.1	20 / BGO *1	1.0	2.0	10	15	LINE / 10	E678-17D* <sup>8</sup>	*4, Dual (2) channel	R1548-07
1600	0.1	16 / BGO *1	2.0	2.0	4	10	L+VB / 10	E678-20B*	*4, Quadrant (4) channel	R8997
1600	0.1	—	—	—	10	30	LINE / 8	E678-20B*	*4, Quadrant (4) channel	R10550
1500	0.1	6.3 (8.5) *3	0.5	0.5	5	10	B+L / 8	E678-14W <sup>19</sup>	Semiflexible lead type (R6234-01) is available	R6234
1500	0.1	6.3 (8.5) *3	0.5	0.5	5	10	B+L / 8	E678-14W <sup>19</sup>	Semiflexible lead type (R6235-01) is available	R6235
1250	0.1	7.8	1.0	2.0	15	30	LINE / 10	E678-12A*		R7373A-01
1250	0.1	8	1.0	2.0	0.2	0.5	BOX / 11	E678-14C*		R8143

Note 1: This data is measured with <sup>22</sup>Na source and BGO scintillator.

Note 3: This data in parentheses is measured with <sup>57</sup>Co.

Note 4: Dark current, time response and pulse linearity data is typical value for channel.

Note 5: Tapered divider type is available.

# Photomultiplier tubes assemblies

Tube diameter	Type No.	① Out-line No.	② Spectral response		Cathode characteristics				Anode characteristics									
			Spectral response range (nm)	Curve code	③ Q.E. at peak Typ. (%)	④ Luminous Typ. (μA/lm)	⑤ Blue sensitivity index (CS 5-58) Typ.	⑥ Radiant Typ. (mA/W)	⑦ Anode to cathode supply voltage (V)	⑧ Luminous Typ. (A/lm)	⑨ Radiant Typ. (A/W)	⑩ Gain Typ.	⑩ Dark current		⑪ Time response			
													Typ. (nA)	Max. (nA)	Rise time Typ. (ns)	Transit time Typ. (ns)	T.T.S. Typ. (FWHM) (ns)	
30 mm square type	H8711	72	300 to 650	A-D	24	80	9.5	80	-800	39	280	$2.8 \times 10^5$	$3.5 \times 10^6$	0.8/ch	4/ch	0.83	12	0.33
	H8711-100	72	300 to 650	F	35	105	13.5	110	-800	39	210	$2.2 \times 10^5$	$2.0 \times 10^6$	0.8/ch	4/ch	0.83	12	0.33
	H8711-200	72	300 to 650	G	43	135	15.5	130	-800	39	270	$2.6 \times 10^5$	$2.0 \times 10^6$	0.8/ch	4/ch	0.83	12	0.33
	H8711-300	72	300 to 700	H	39	160	14	125	-800	39	400	$3.1 \times 10^5$	$2.5 \times 10^6$	0.8/ch	4/ch	0.83	12	0.33
	H7546B	73	300 to 650	A-D	24	80	9.5	80	-800	42	50	$4.8 \times 10^4$	$6.0 \times 10^5$	0.2/ch	2/ch	1.0	12	0.38
	H7546B-100	73	300 to 650	F	35	105	13.5	110	-800	42	53	$5.5 \times 10^4$	$5.0 \times 10^5$	0.2/ch	2/ch	1.0	12	0.38
	H7546B-200	73	300 to 650	G	43	135	15.5	130	-800	42	68	$6.5 \times 10^4$	$5.0 \times 10^5$	0.2/ch	2/ch	1.0	12	0.38
	H7546B-300	73	300 to 700	H	39	160	14	125	-800	42	80	$6.2 \times 10^4$	$5.0 \times 10^5$	0.2/ch	2/ch	1.0	12	0.38
	H8804	74	300 to 650	A-D	24	80	9.5	80	-800	42	50	$5.0 \times 10^4$	$6.0 \times 10^5$	0.2/ch	2/ch	1.0	12	0.38
	H8804-100	74	300 to 650	F	35	105	13.5	110	-800	42	53	$5.5 \times 10^4$	$5.0 \times 10^5$	0.2/ch	2/ch	1.0	12	0.38
	H8804-200	74	300 to 650	G	43	135	15.5	130	-800	42	68	$6.5 \times 10^4$	$5.0 \times 10^5$	0.2/ch	2/ch	1.0	12	0.38
	H8804-300	74	300 to 650	H	39	160	14	125	-800	42	80	$6.2 \times 10^4$	$5.0 \times 10^5$	0.2/ch	2/ch	1.0	12	0.38
	H11934-100	75	300 to 650	F	35	105	13.5	110	-900	41	126	$1.3 \times 10^5$	$1.2 \times 10^6$	2	20	1.3	5.8	0.27
	H11934-200	75	300 to 650	G	43	135	15.5	130	-900	41	162	$1.6 \times 10^5$	$1.2 \times 10^6$	2	20	1.3	5.8	0.27
	H11934-300	75	300 to 700	H	39	160	14	130	-900	41	192	$1.5 \times 10^5$	$1.2 \times 10^6$	2	20	1.3	5.8	0.27
	H13226A-100	76	300 to 650	F	35	105	13.5	110	-1000	56	105	$1.1 \times 10^5$	$1.0 \times 10^6$	1/ch	4/ch	1.1	5.3	0.39
	H13226A-200	76	300 to 650	G	43	135	15.5	130	-1000	56	135	$1.3 \times 10^5$	$1.0 \times 10^6$	1/ch	4/ch	1.1	5.3	0.39
	H12445-100	77	300 to 650	F	35	105	13.5	110	-1000	56	105	$1.1 \times 10^5$	$1.0 \times 10^6$	0.4/ch	4/ch	0.52	5	0.34
	H12445-200	77	300 to 650	G	43	135	15.5	130	-1000	56	135	$1.3 \times 10^5$	$1.0 \times 10^6$	0.4/ch	4/ch	0.52	5	0.34
	H12428-100	78	300 to 650	F	35	105	13.5	110	-1000	56	105	$1.1 \times 10^5$	$1.0 \times 10^6$	0.4/ch	4/ch	0.6	5.1	0.35
H12428-200	78	300 to 650	G	43	135	15.5	130	-1000	56	135	$1.3 \times 10^5$	$1.0 \times 10^6$	0.4/ch	4/ch	0.6	5.1	0.35	
H10515B-100	79	300 to 650	F	35	105	13.5	110	-800	16	105	$1.1 \times 10^5$	$1.0 \times 10^6$	0.2/ch	2/ch	0.6	7.4	0.18	
H10515B-200	79	300 to 650	G	43	135	15.5	130	-800	16	135	$1.3 \times 10^5$	$1.0 \times 10^6$	0.2/ch	2/ch	0.6	7.4	0.18	
51 mm square type	H12700A	80	300 to 650	A-D	32	95	12	100	-1000	55	142	$1.5 \times 10^5$	$1.5 \times 10^6$	0.1/ch	—	0.52	4.9	0.35
	H12700A-10	80	300 to 650	A-D	32	95	12	100	-1000	55	38	$4.0 \times 10^4$	$4.0 \times 10^5$	0.1/ch	—	0.52	4.9	0.35
	H12700B	81	300 to 650	A-D	32	95	12	100	-1000	55	142	$1.5 \times 10^5$	$1.5 \times 10^6$	0.1/ch	—	0.52	4.9	0.35
	H12700B-10	81	300 to 650	A-D	32	95	12	100	-1000	55	38	$4.0 \times 10^4$	$4.0 \times 10^5$	0.1/ch	—	0.52	4.9	0.35
	H13700	82	300 to 650	A-D	29	75	12	90	-1000	55	110	$1.4 \times 10^5$	$1.5 \times 10^6$	0.02/ch	—	0.45	5.2	0.38
106 mm square type	H13974-00-1616	83	300 to 650	A-D	32	95	12	100	-1000	55	142	$1.5 \times 10^5$	$1.5 \times 10^6$	0.1/ch	—	0.52	4.9	0.35
Rectangle type	H7260	84	300 to 650	A-D	21	70	8.5	72	-800	16	140	$1.4 \times 10^5$	$2.0 \times 10^6$	0.2/ch	2/ch	0.60	6.8	0.18
	H7260-100	84	300 to 650	F	35	105	13.5	110	-800	16	210	$2.2 \times 10^5$	$2.0 \times 10^6$	0.2/ch	2/ch	0.60	6.8	0.18
	H7260-200	84	300 to 650	G	43	135	15.5	130	-800	16	270	$2.6 \times 10^5$	$2.0 \times 10^6$	0.2/ch	2/ch	0.60	6.8	0.18

(at 25 °C)

Max. ratings <sup>12</sup>		Typical pulse height resolution <sup>13</sup>	Stability <sup>14</sup>		Pulse linearity <sup>15</sup>		Remarks		Note	Type No.
Anode to cathode voltage (V)	Average anode current (mA)		Long term Typ. (%)	Short term Typ. (%)	2 % deviation Typ. (mA)	5 % deviation Typ. (mA)	Dynode structure / stage <sup>16</sup>	Built-in PMT (Type No. for referring)		
-1000	0.017	—	—	—	0.5/ch	1/ch	MC / 12	R7600-00-M16	*4	H8711
-1000	0.017	—	—	—	0.5/ch	1/ch	MC / 12	R7600-100-M16	SBA type	H8711-100
-1000	0.017	—	—	—	0.5/ch	1/ch	MC / 12	R7600-200-M16	UBA type	H8711-200
-1000	0.017	—	—	—	0.5/ch	1/ch	MC / 12	R7600-300-M16	EGBA type	H8711-300
-1000	0.023	—	—	—	0.3/ch	0.6/ch	MC / 12	R7600-00-M64	*4	H7546B
-1000	0.023	—	—	—	0.3/ch	0.6/ch	MC / 12	R7600-100-M64	SBA type	H7546B-100
-1000	0.023	—	—	—	0.3/ch	0.6/ch	MC / 12	R7600-200-M64	UBA type	H7546B-200
-1000	0.023	—	—	—	0.3/ch	0.6/ch	MC / 12	R7600-300-M64	EGBA type	H7546B-300
-1000	0.023	—	—	—	0.3/ch	0.6/ch	MC / 12	R7600-00-M64	*4	H8804
-1000	0.023	—	—	—	0.3/ch	0.6/ch	MC / 12	R7600-100-M64	SBA type	H8804-100
-1000	0.023	—	—	—	0.3/ch	0.6/ch	MC / 12	R7600-200-M64	UBA type	H8804-200
-1000	0.023	—	—	—	0.3/ch	0.6/ch	MC / 12	R7600-300-M64	EGBA type	H8804-300
-1000	0.018	—	—	—	20 *5	60	MC / 12	R11265-100	SBA type	H11934-100
-1000	0.018	7.4 / 3.1	—	—	20 *5	60	MC / 12	R11265-200	UBA type	H11934-200
-1000	0.018	—	—	—	20 *5	60	MC / 12	R11265-300	EGBA type	H11934-300
-1100	0.018	—	—	—	4/ch *5	7/ch	MC / 12	R11265-100-M4	SBA type *4	H13226A-100
-1100	0.018	—	—	—	4/ch *5	7/ch	MC / 12	R11265-200-M4	UBA type *4	H13226A-200
-1100	0.018	—	—	—	0.8/ch	2/ch	MC / 12	R11265-100-M16	SBA type *4	H12445-100
-1100	0.018	—	—	—	0.8/ch	2/ch	MC / 12	R11265-200-M16	UBA type *4	H12445-200
-1100	0.018	—	—	—	0.2/ch	0.4/ch	MC / 12	R11265-100-M64	SBA type *4	H12428-100
-1100	0.018	—	—	—	0.2/ch	0.4/ch	MC / 12	R11265-200-M64	UBA type *4	H12428-200
-900	0.1	—	—	—	0.8/ch	1.2/ch	MC / 10	R5900-100-L16	SBA type *4	H10515B-100
-900	0.1	—	—	—	0.8/ch	1.2/ch	MC / 10	R5900-200-L16	UBA type *4	H10515B-200
-1100	0.1	—	—	—	1/ch	—	MC / 10	R12699-00-M64	UV types (H12700A-03)	H12700A
-1100	0.1	—	—	—	3/ch	—	MC / 10	R12699-00-M64	Tapered divider type *4	H12700A-10
-1100	0.1	—	—	—	1/ch	—	MC / 10	R12699-00-M64	UV types (H12700A-03) *4	H12700B
-1100	0.1	—	—	—	3/ch	—	MC / 10	R12699-00-M64	Tapered divider type *4	H12700B-10
-1100	0.1	—	—	—	0.15/ch	—	MC / 10	R12699-00-M256	UV types (H13700A-03) *4	H13700
-1100	0.1	—	—	—	1/ch	—	MC / 10	R12699-00-M64	2x2 PMT array, UV type (H13974-03-1616) *4	H13974-00-1616
-900	0.1	—	—	—	0.6/ch	0.8/ch	MC / 10	R7259	*4	H7260
-900	0.1	—	—	—	0.6/ch	0.8/ch	MC / 10	R7259-100	SBA type *4	H7260-100
-900	0.1	—	—	—	0.6/ch	0.8/ch	MC / 10	R7259-200	UBA type *4	H7260-200

Note 4: Dark current, time response and pulse linearity data is typical value for channel.

Note 5: Tapered divider type is available.

# Photomultiplier tubes assemblies

Tube diameter	Type No.	① Out-line No.	② Spectral response		Cathode characteristics				Anode characteristics								
			Spectral response range (nm)	Curve code	③ Q.E. at peak Typ. (%)	④ Luminous Typ. (μA/lm)	⑤ Blue sensitivity index (CS 5-58) Typ.	⑥ Radiant Typ. (mA/W)	⑦ Anode to cathode supply voltage (V)	⑧ Luminous Typ. (A/lm)	⑨ Radiant Typ. (A/W)	⑩ Gain Typ.	⑩ Dark current		⑪ Time response		
													Typ. (nA)	Max. (nA)	Rise time Typ. (ns)	Transit time Typ. (ns)	T.T.S. Typ. (FWHM) (ns)
10 mm (3/8")	H3164-10 85	85	300 to 650	A-D	25	100	10	80	-1250	100	$8.0 \times 10^4$	$1.0 \times 10^6$	1	50	0.8	9.0	0.5
	H3695-10 86	86	160 to 650	C-D	25	100	10	80	-1250	100	$8.0 \times 10^4$	$1.0 \times 10^6$	2	50	0.7	9	0.5
13 mm (1/2")	H3165-10 87	87	300 to 650	A-D	25	110	10	80	-1000	150	$1.1 \times 10^5$	$1.4 \times 10^6$	1	2	2.1	22	2.0
	H12690 88	88	300 to 650	A-D	25	110	10	80	-1000	220	$1.6 \times 10^5$	$2.0 \times 10^6$	0.5	2	1.2	14	1.4
	H12690-300 88	88	300 to 700	H	31	160	14	105	-1000	320	$2.1 \times 10^5$	$2.0 \times 10^6$	1	5	1.2	14	1.4
19 mm (3/4")	H6520 89	89	300 to 650	A-D	26	110	10.5	85	-1000	110	$8.5 \times 10^4$	$1.0 \times 10^6$	1	5	2.5	27	2.8
	H6524 90	90	300 to 650	A-D	27	115	11.0	88	-1500	200	$1.5 \times 10^5$	$1.7 \times 10^6$	3	50	1.8	19	0.76
	H6612 91	91	300 to 650	A-D	27	115	11.0	88	-1700	200	$1.5 \times 10^5$	$1.7 \times 10^6$	10	300	1.3	14	0.36
	H6613 92	92	160 to 650	C-D	27	115	11.0	88	-1700	120	$8.6 \times 10^4$	$1.0 \times 10^6$	10	300	1.3	14	0.36
	H8135 93	93	300 to 650	A-D	26	90	10.5	85	-1000	50	$4.7 \times 10^4$	$5.5 \times 10^5$	3	20	1.3	12	0.8
25 mm (1")	H6533 94	94	300 to 650	A-D	23	80	9.5	76	-2250	400	$3.8 \times 10^5$	$5.0 \times 10^6$	10	200	0.7	10	0.16
	H6152-70 95	95	300 to 650	A-D	23	80	9.5	76	+2000	40	$3.8 \times 10^4$	$5.0 \times 10^5$	5	30	1.5	5.6	0.35
	H8643 96	96	300 to 650	A-D	27	95	11.0	88	-1500	160	$1.5 \times 10^5$	$1.7 \times 10^6$	2	20	1.6	16	0.7
	H10580 97	97	300 to 650	A-D	27	95	11.0	88	-1300	100	$9.3 \times 10^4$	$1.1 \times 10^6$	5	50	1.0	11	0.27
28 mm (1-1/8")	H7415 98	98	300 to 650	A-D	27	100	11.0	88	-1500	500	$4.4 \times 10^5$	$5.0 \times 10^6$	10	200	1.7	16	0.5
38 mm (1-1/2")	H3178-51 99	99	300 to 650	A-D	27	95	11.0	88	-1500	75	$7.0 \times 10^4$	$7.9 \times 10^5$	2	15	2.7	40	4.5
	H8409-70 100	100	300 to 650	A-D	23	80	9.5	76	+2000	800	$7.6 \times 10^5$	$1.0 \times 10^7$	15	100	2.1	7.5	0.35
51 mm (2")	H6410 101	101	300 to 650	A-D	26	90	10.5	85	-2000	270	$2.5 \times 10^5$	$3.0 \times 10^6$	10	100	2.7	40	1.1
	H7195 102	102	300 to 650	A-D	26	90	10.5	85	-2000	270	$2.5 \times 10^5$	$3.0 \times 10^6$	10	100	2.7	40	1.1
	H1949-50 103	103	300 to 650	A-D	26	90	10.5	85	-2500	1800	$1.7 \times 10^6$	$2.0 \times 10^7$	50	400	1.3	28	0.55
	H1949-51 104	104	300 to 650	A-D	26	90	10.5	85	-2500	1800	$1.7 \times 10^6$	$2.0 \times 10^7$	50	400	1.3	28	0.55
	H2431-50 105	105	300 to 650	A-D	25	80	10.0	80	-3000	200	$2.0 \times 10^5$	$2.5 \times 10^6$	100	800	0.8	16	0.37
	H6614-70 106	106	300 to 650	A-D	22	70	9.0	72	+2000	700	$7.2 \times 10^5$	$1.0 \times 10^6$	30	200	2.5	9.5	0.44
76 mm (3")	H6559 107	107	300 to 650	A-D	26	90	10.5	85	-2000	900	$8.5 \times 10^5$	$1.0 \times 10^7$	30	120	2.7	40	1.5
127 mm (5")	H6527 108	108	300 to 650	A-D	22	70	9.0	72	-3000	1000	$1.0 \times 10^6$	$1.4 \times 10^7$	50	300	2.5	54	1.2

(at 25 °C)

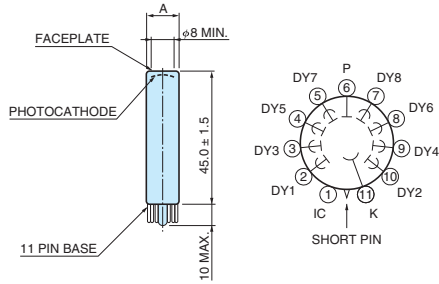
Max. ratings <sup>12</sup>		Typical pulse height resolution <sup>13</sup>	Stability <sup>14</sup>		Pulse linearity <sup>15</sup>		Remarks		Note	Type No.
Anode to cathode voltage (V)	Average anode current (mA)		Long term Typ. (%)	Short term Typ. (%)	2 % deviation Typ. (mA)	5 % deviation Typ. (mA)	Dynode structure / stage <sup>16</sup>	Built-in PMT (Type No. for referring)		
-1500	0.03	23/BGO *1	1.0	2.0	3	7	LINE / 8	R1635		H3164-10
-1500	0.03	23/BGO *1	1.0	2.0	3	7	LINE / 8	R2496		H3695-10
-1250	0.1	7.8	1.0	2.0	3	7	LINE / 10	R647-01		H3165-10
-1250	0.1	—	—	—	3	12	LINE / 10	R12421		H12690
-1250	0.1	—	—	—	3	12	LINE / 10	R12421-300	EGBA type	H12690-300
-1250	0.1	7.8	1.0	2.0	4	7	LINE / 10	R1166		H6520
-1800	0.1	7.8	1.0	2.0	4	8	LINE / 10	R1450		H6524
-1800	0.1	7.8	1.0	2.0	4	8	LINE / 8	R3478		H6612
-1800	0.1	7.8	1.0	2.0	4	8	LINE / 8	R2076		H6613
-1250	0.1	8.0	1.0	2.0	10	20	C+L/10	R5611A		H8135
-2500	0.1	8.0	1.0	2.0	40	70	LINE / 10	R4998	Silica type H6610 (R5320)	H6533
+2300	0.01	9.5	2.0	2.0	180	250	FM/15	R5505-70	For +HV operation	H6152-70
-1800	0.1	7.8	1.0	2.0	100	150	LINE / 10	R7899-01		H8643
-1500	0.1	7.8	1.0	2.0	30	50	LINE / 8	R9800		H10580
-2000	0.2	7.8	1.0	2.0	10	30	LINE / 10	R6427	Silica type H7416 (R7056)	H7415
-1750	0.1	7.7	1.0	1.0	150	200	LINE / 10	R580		H3178-51
+2300	0.01	9.5	2.0	2.0	320	450	FM/19	R7761-70	For +HV operation	H8409-70
-2700	0.2	7.6	1.0	1.0	100	200	LINE / 12	R329-02	UV type H6522 (R5115-02) Silica type H6521 (R2256-02)	H6410
-2700	0.2	7.6	1.0	1.0	80	110	LINE / 12	R329-02		H7195
-3000	0.2	7.8	1.0	1.0	100	200	LINE / 12	R1828-01	UV type H4022-50 (R4004) Silica type H3177-50 (R2059)	H1949-50
-3000	0.2	7.8	1.0	1.0	100	200	LINE / 12	R1828-01	UV type H4022-51 (R4004) Silica type H3177-51 (R2059)	H1949-51
-3500	0.2	7.8	1.0	2.0	100	150	LINE / 8	R2083	Silica type H3378-50 (R3377)	H2431-50
+2300	0.1	9.5	2.0	2.0	500	700	FM/19	R5924-70	For +HV operation	H6614-70
-2500	0.2	7.8	1.0	1.0	100	200	LINE / 12	R6091		H6559
-3000	0.2	8.3	1.0	1.0	100	150	LINE / 14	R1250		H6527

Note 1: This data is measured with <sup>22</sup>Na source and BGO scintillator.

# Dimensional outline and basing diagrams

## For photomultiplier tubes

### 1 R1635, R2496



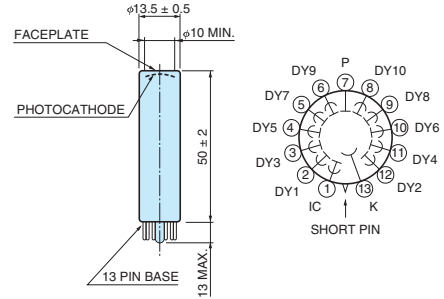
	A
R1635	$9.7 \pm 0.4$
R2496	$10.5 \pm 0.5$

R2496 has a plano-concave faceplate.

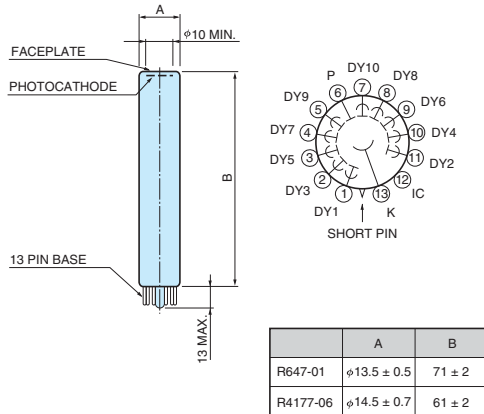
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### 2 R4124



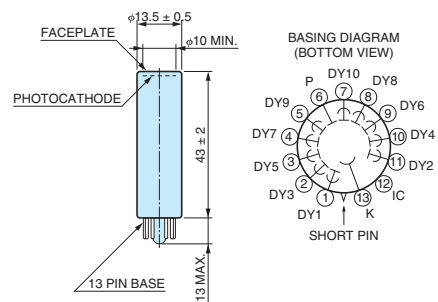
### 3 R647-01, R4177-06



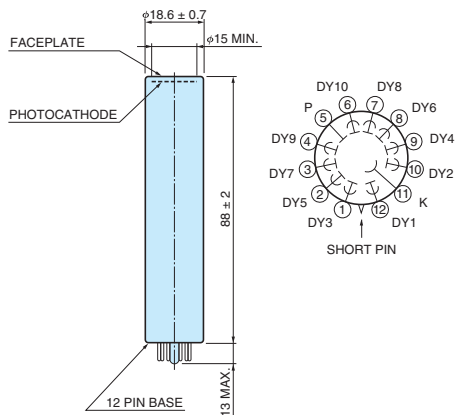
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### 4 R12421, R12421-300

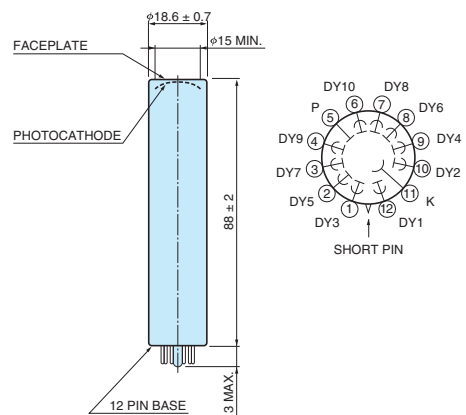


### 5 R1166



TPMHA0344EA

### 6 R1450, R4125

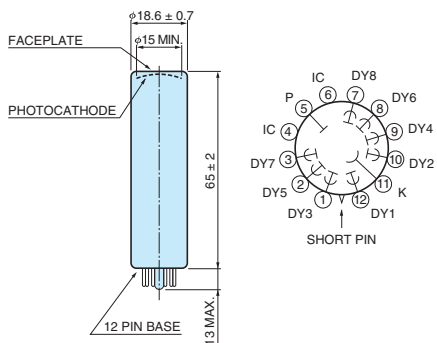


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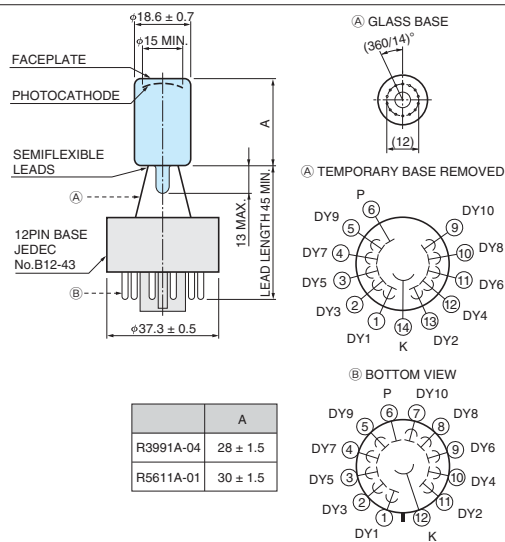
(Unit: mm)

7 R3478



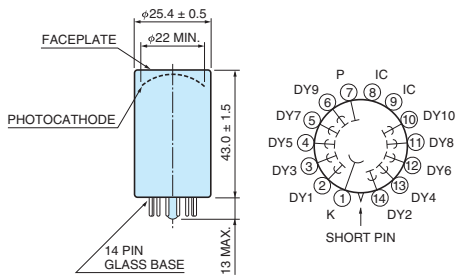
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8 R3991A-04, R5611A-01



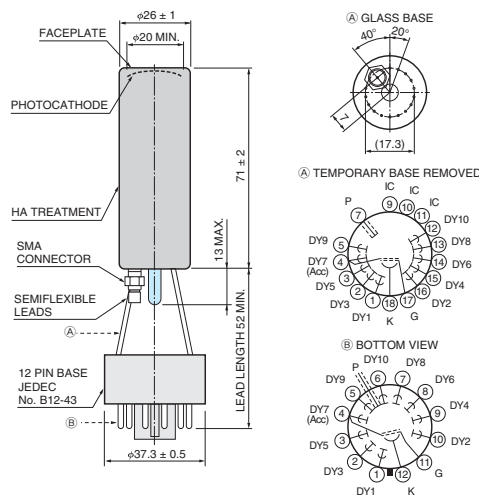
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9 R1288A-06, R1924A



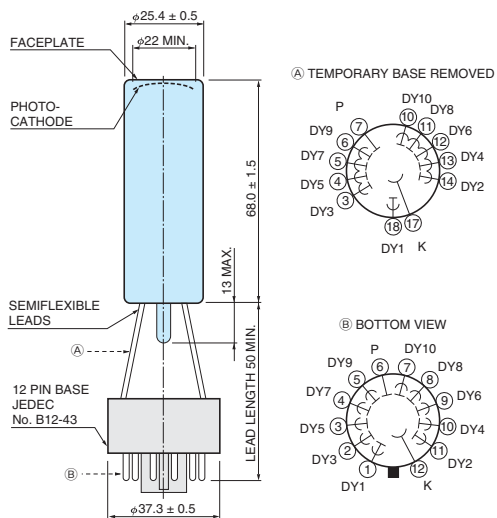
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10 R4998



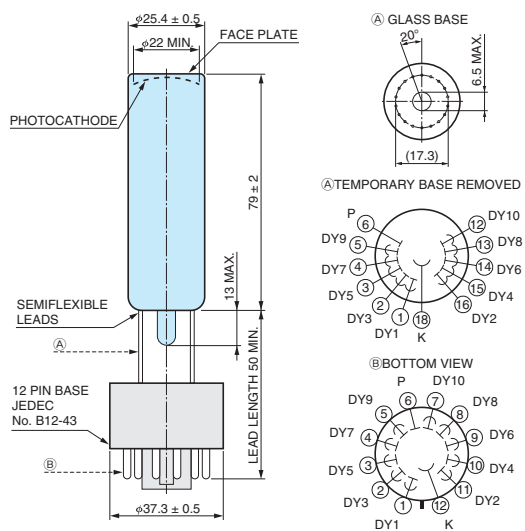
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11 R7899-01



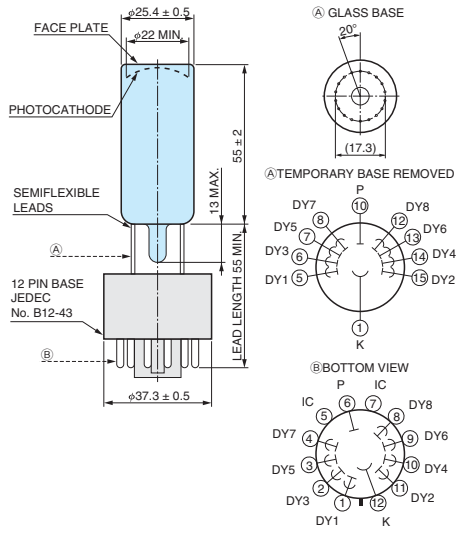
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12 R8619



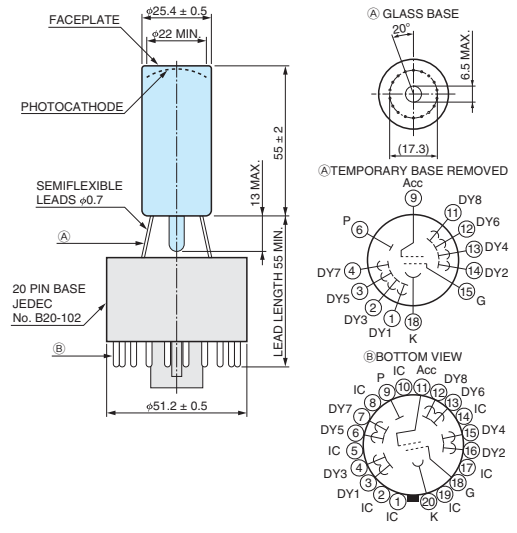
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**13 R9800, R9800-100**



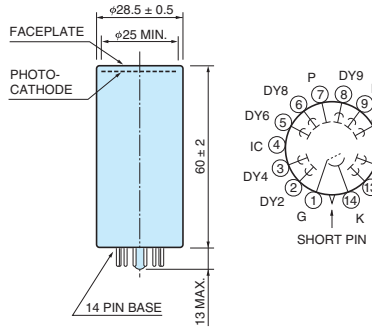
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**14 R13478**



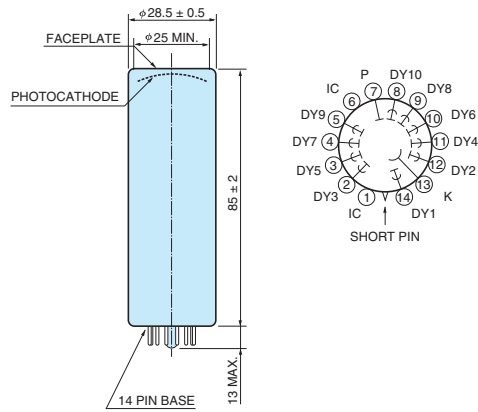
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**15 R3998-02, R3998-100-02**



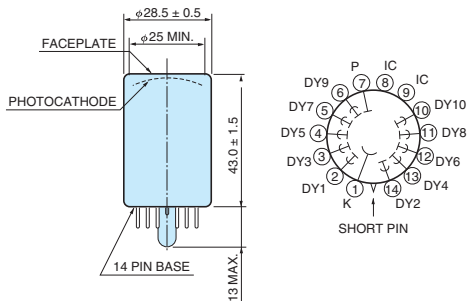
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**16 R6427**



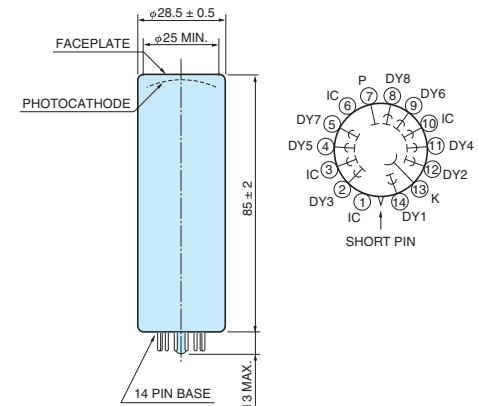
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**17 R7111**



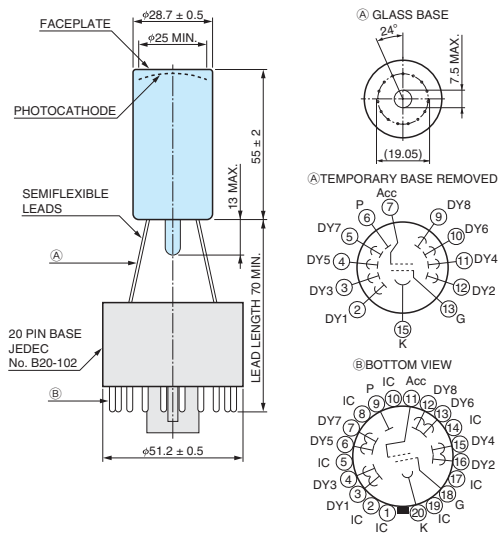
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**18 R7525**



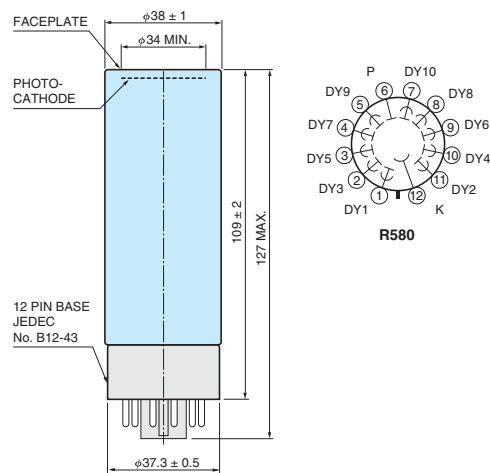
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19 R13449



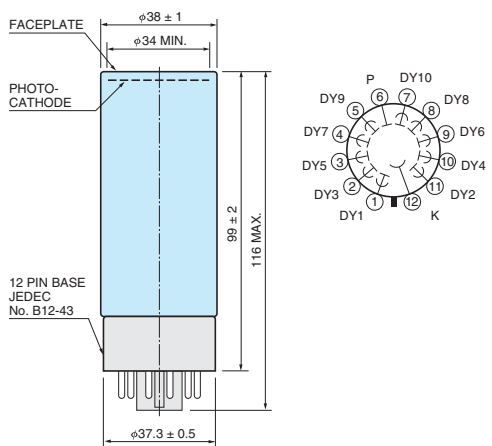
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20 R580



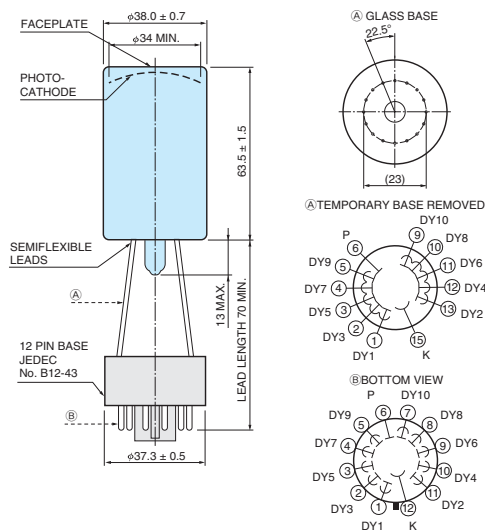
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21 R11102



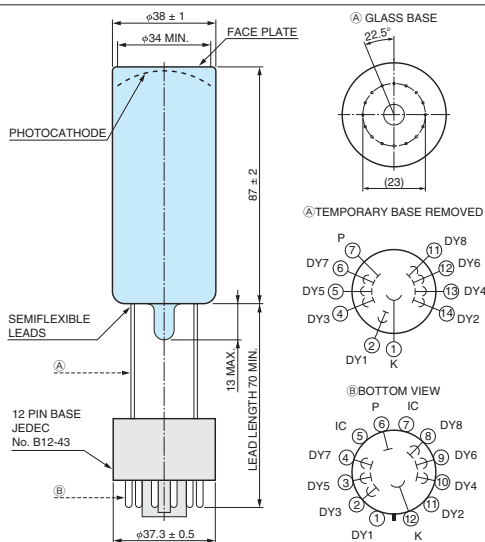
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22 R3886A



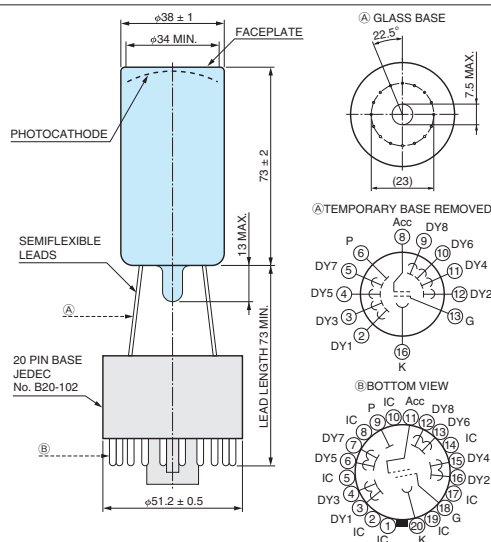
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23 R9420, R9420-100



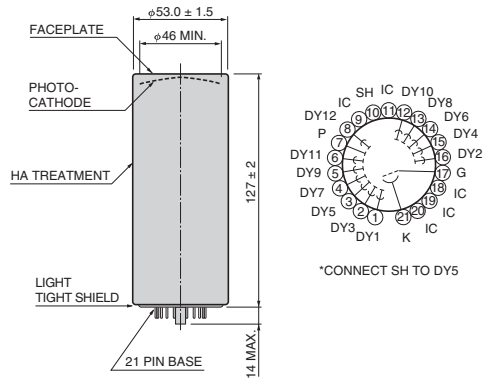
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24 R13408



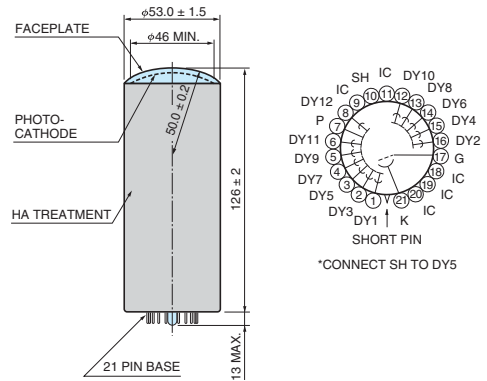
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25 R329-02



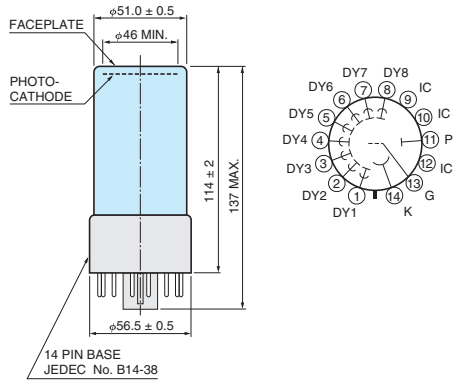
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26 R331-05



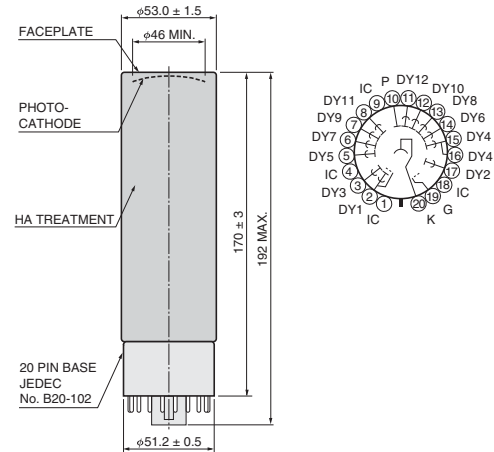
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27 R1306



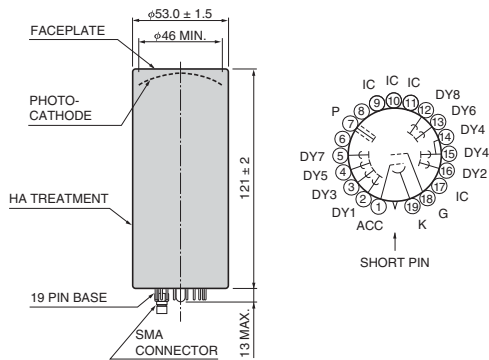
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28 R1828-01



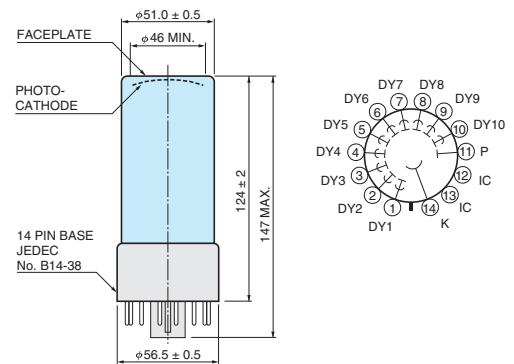
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29 R2083



TPMHA0185EE

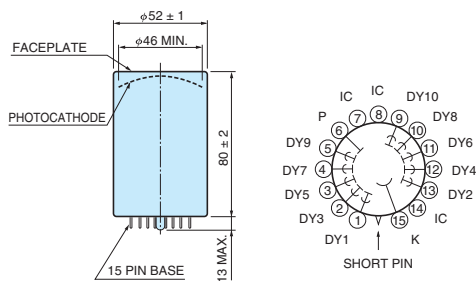
30 R2154-02



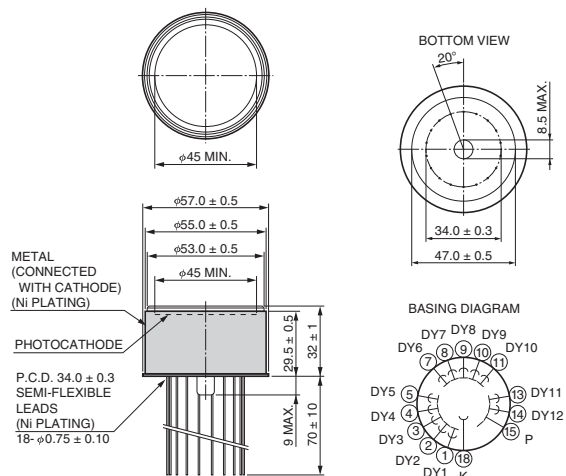
TPMHA0296EB

(Unit: mm)

31 R4607A-06



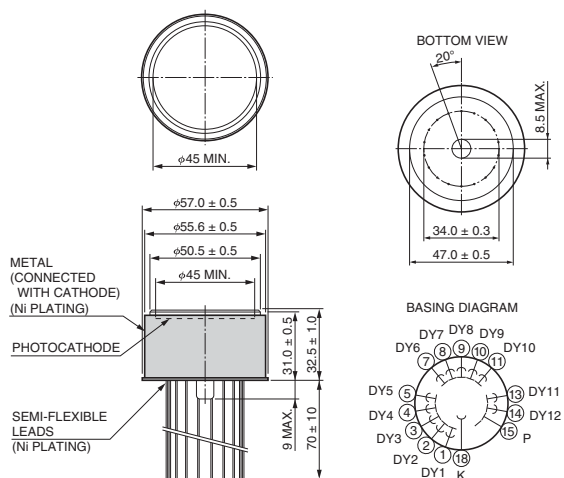
32 R6041



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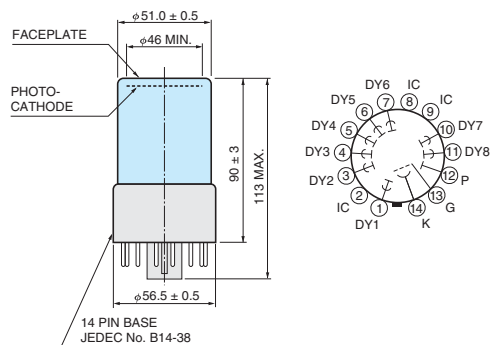
33 R6041-406, R6041-506



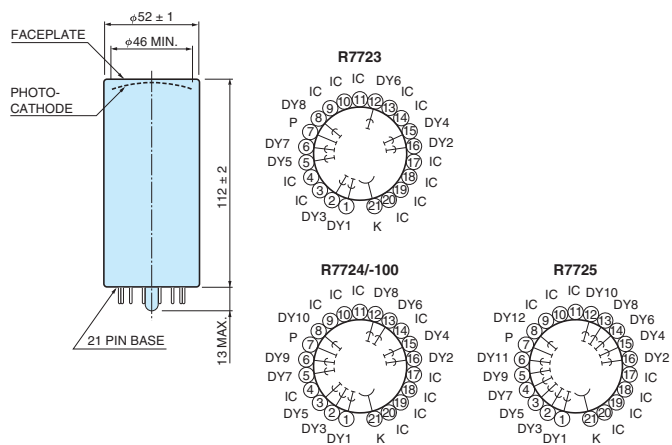
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TPMHA0388EB

34 R6231, R6231-100

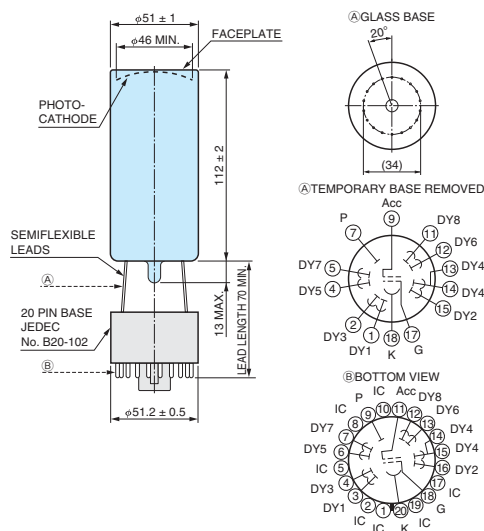


35 R7723, R7724, R7724-100, R7725



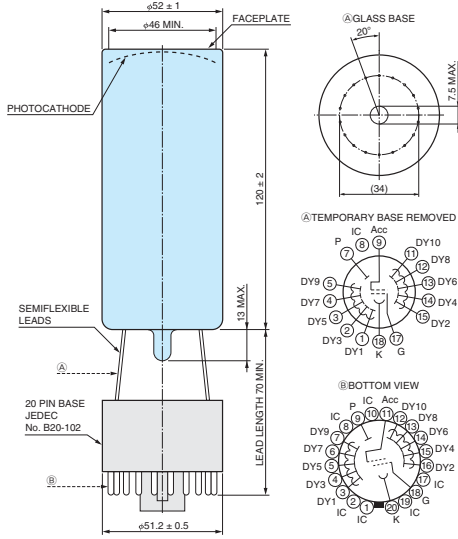
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36 R13089



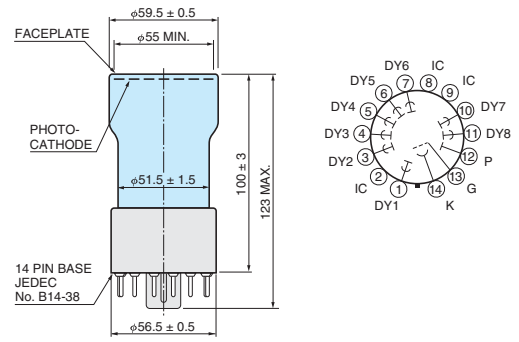
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37 R13435



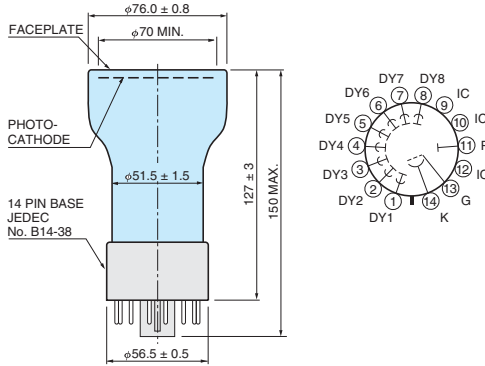
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38 R6232



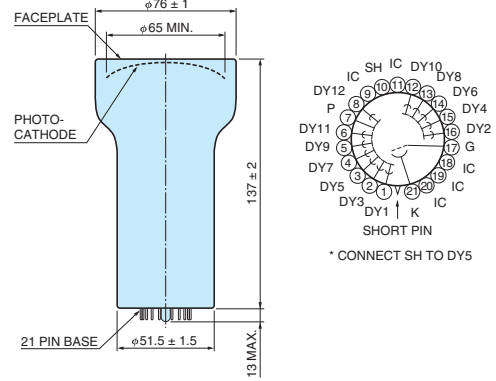
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39 R1307



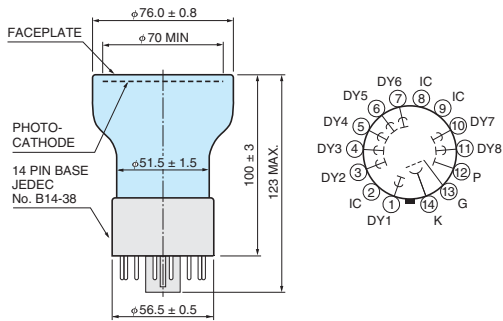
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40 R6091



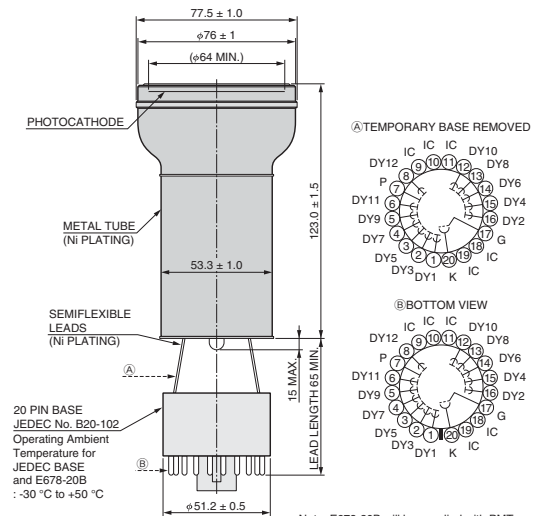
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41 R6233, R6233-100



TPMHA0389EB

42 R11065, R11410

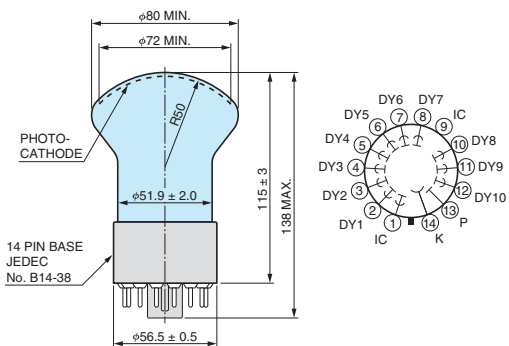


Note: E678-20B will be supplied with PMT

TPMHA0573EA

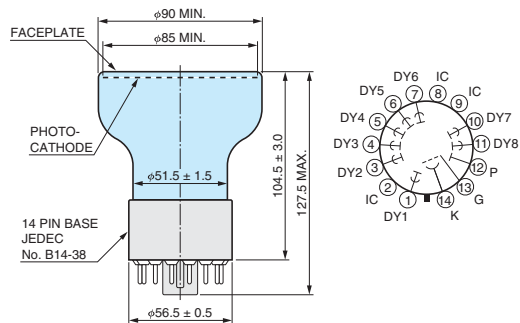
(Unit: mm)

43 R12199



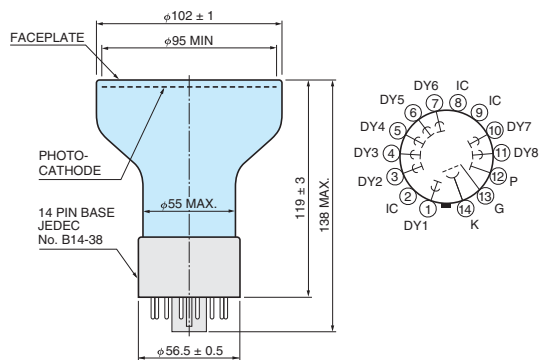
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44 R10233, R10233-100



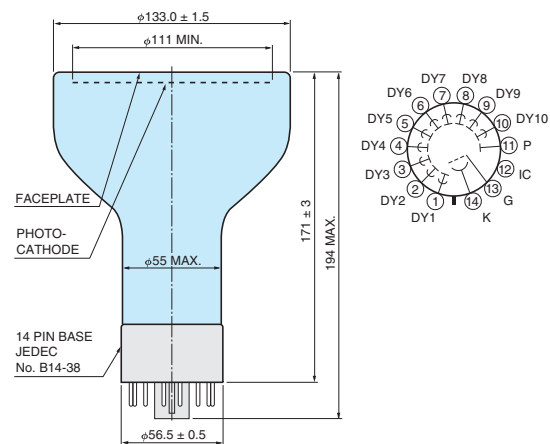
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45 R10806, R10806-100



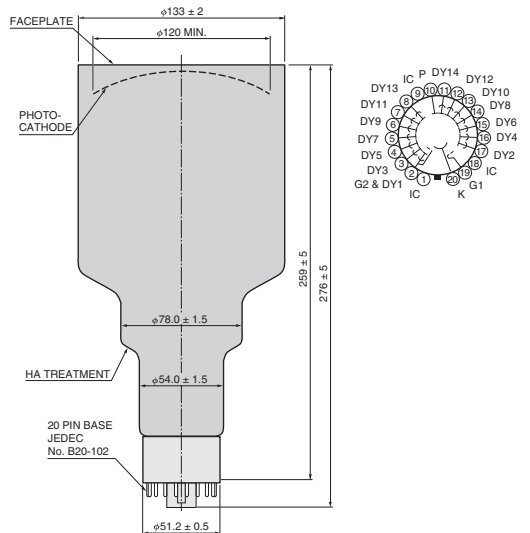
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46 R877, R877-100



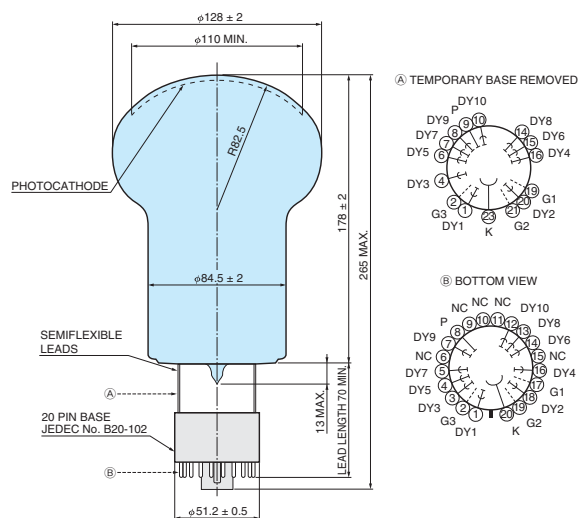
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47 R1250



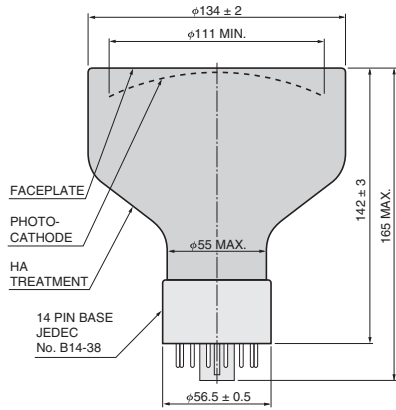
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48 R6594



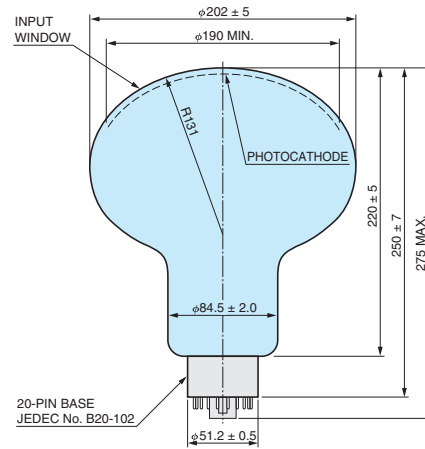
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49 R11833-03, R11833-100-03



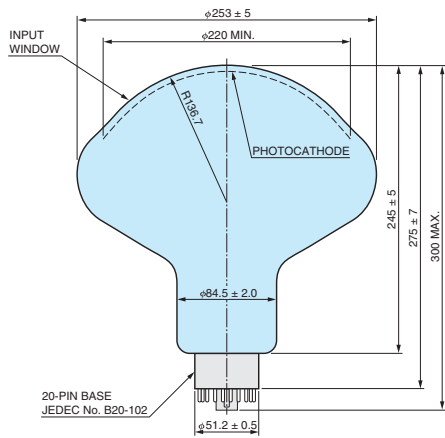
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50 R5912, R5912-20, R5912-100



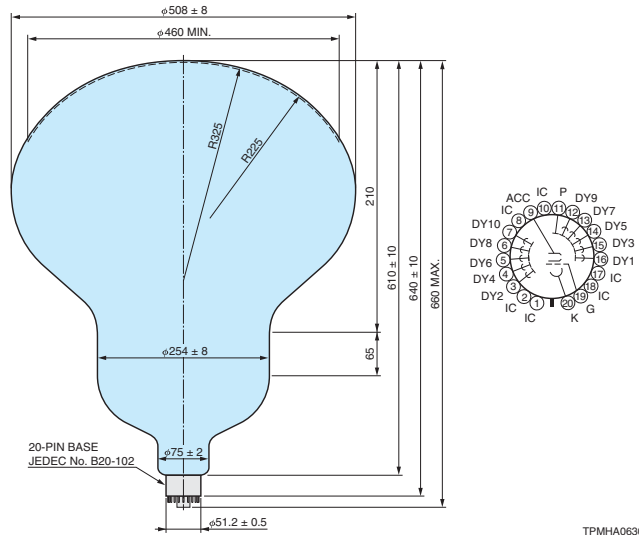
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51 R7081, R7081-20, R7081-100



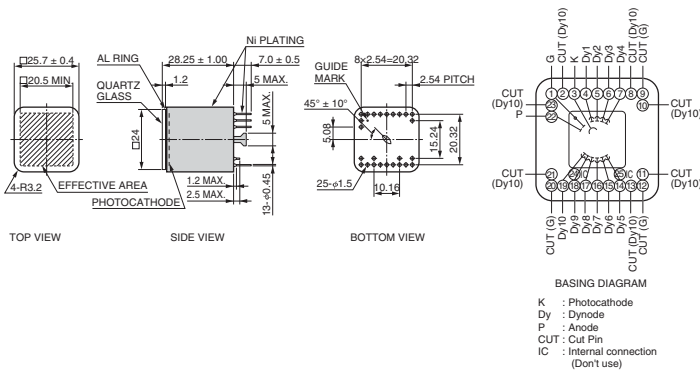
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52 R12860



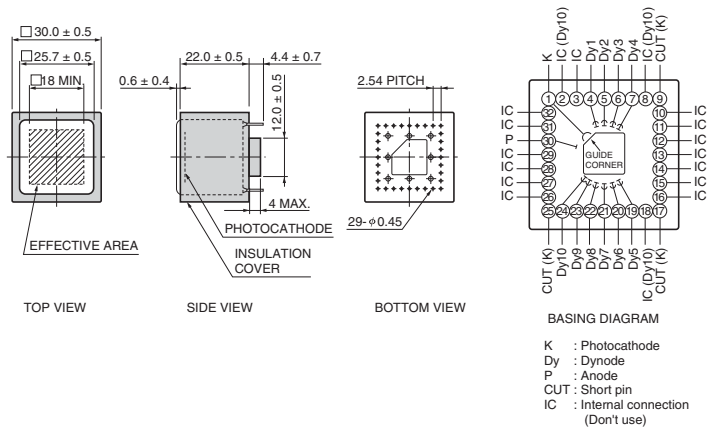
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53 R8520-406, -506



TPMHA0575EA

54 R7600U, R7600U-100/-200/-300

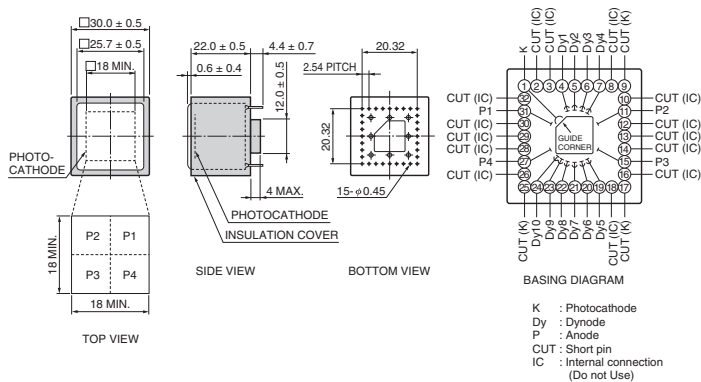


TPMHA0278EJ



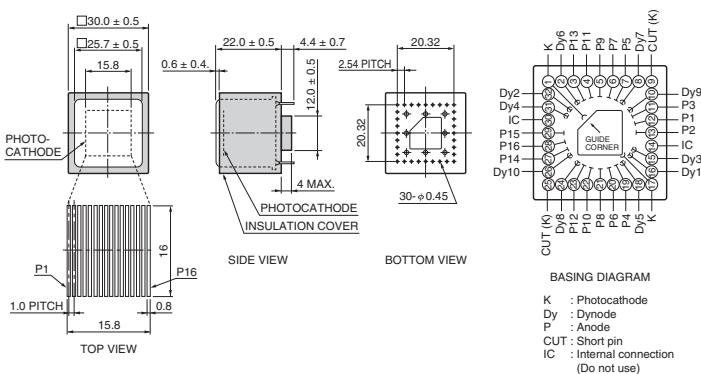
(Unit: mm)

55 R7600U-00-M4, R7600U-100-M4/-200-M4/-300-M4



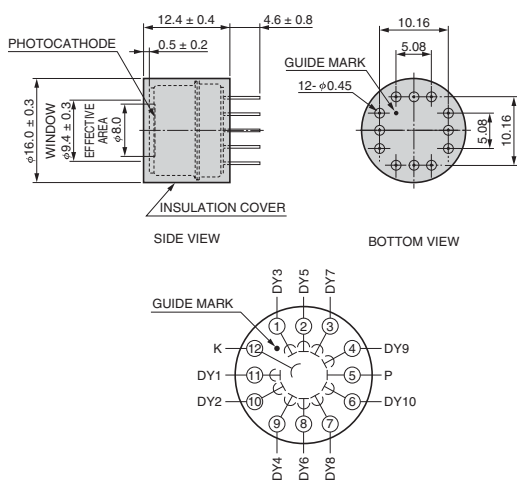
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56 R5900U-00-L16, R5900U-100-L16/-200-L16



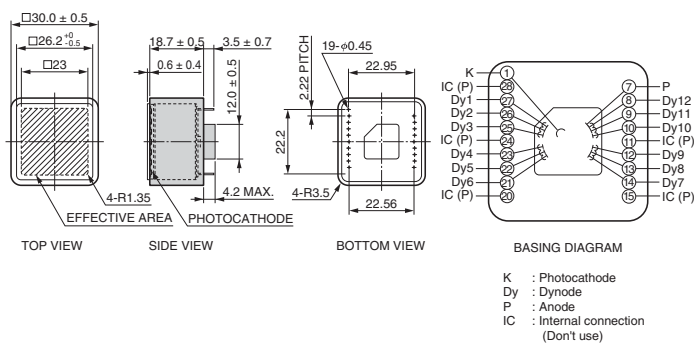
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57 R9880U-110, R9880U-210



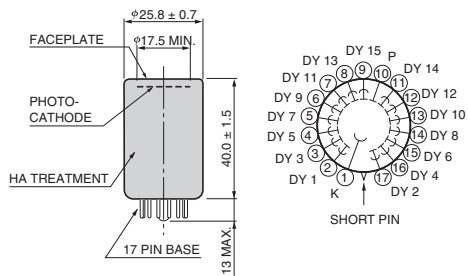
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58 R11265U-100, R11265U-200, R11265U-300



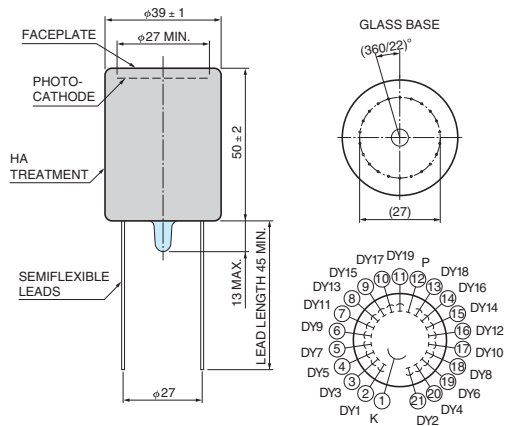
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59 R5505-70



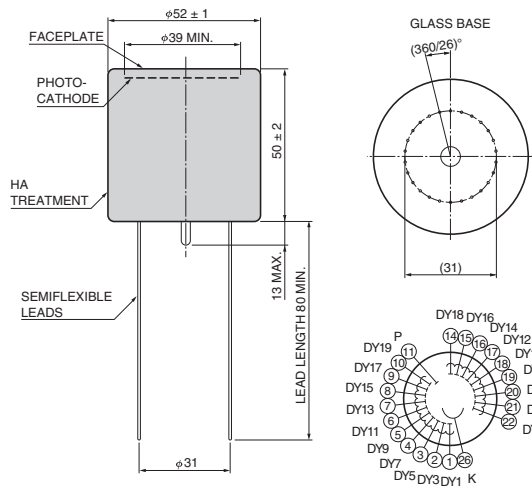
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60 R7761-70



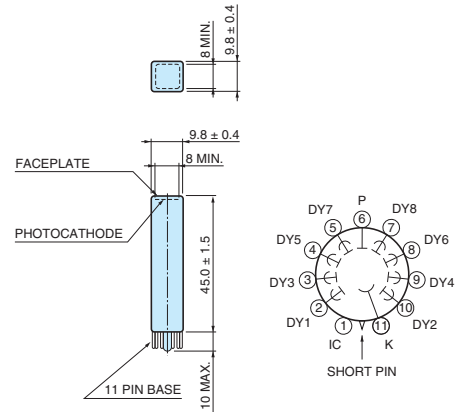
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61 R5924-70



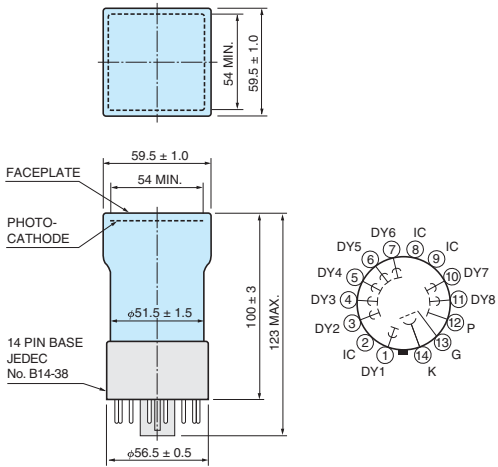
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62 R2248



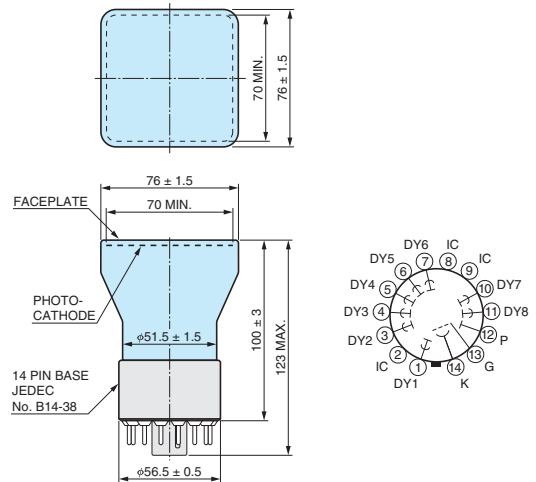
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63 R6236



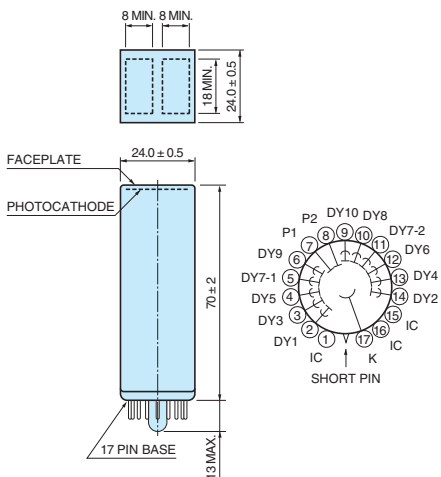
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64 R6237



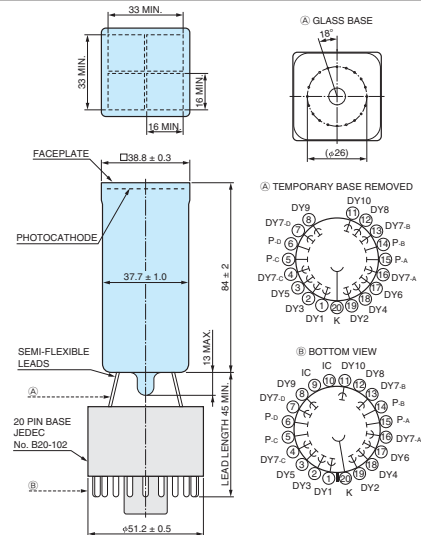
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65 R1548-07



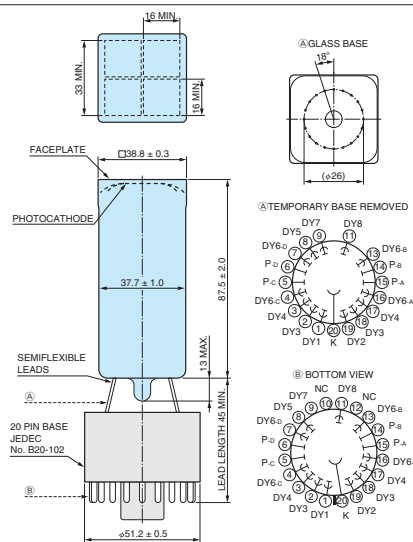
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66 R8997



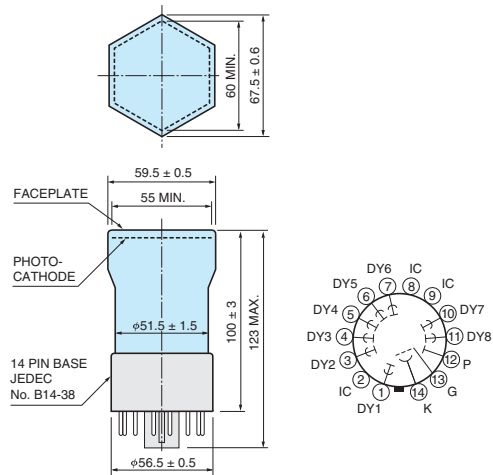
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67 R10550



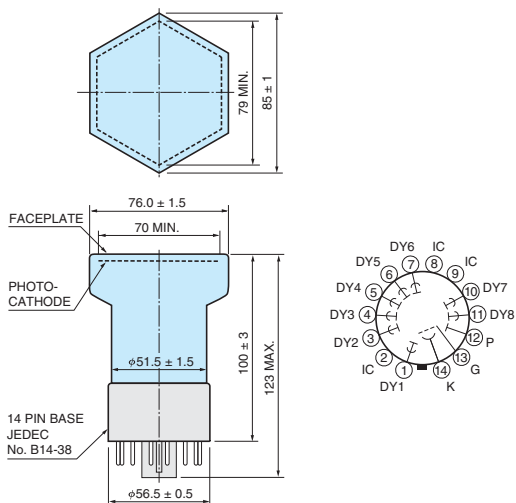
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68 R6234



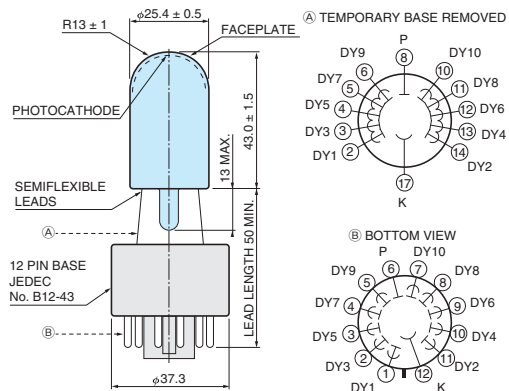
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69 R6235



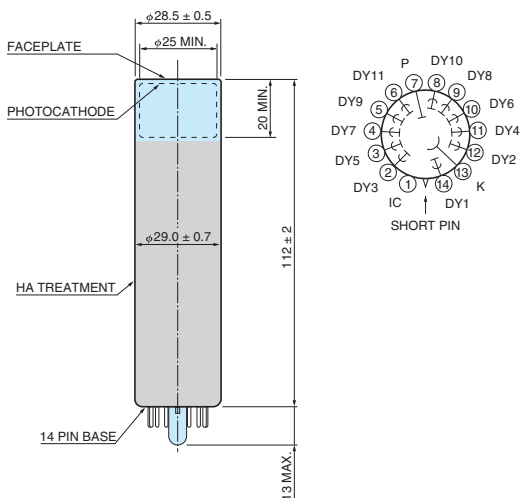
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70 R7373A-01



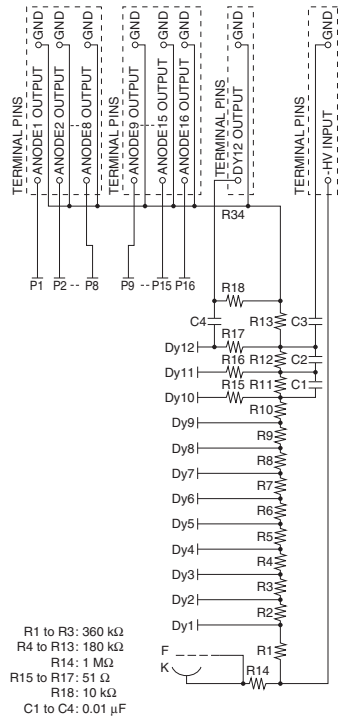
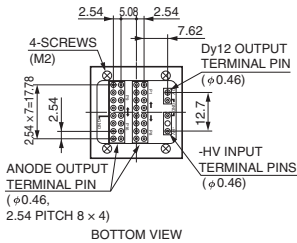
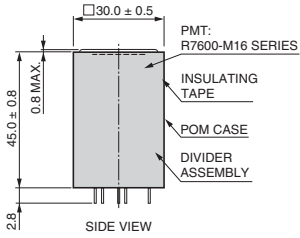
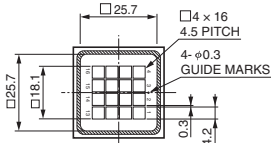
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71 R8143



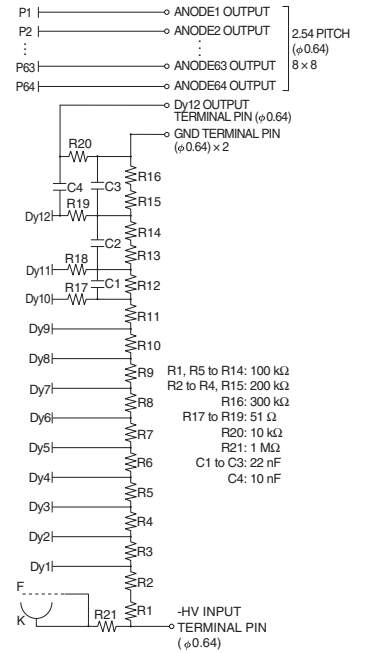
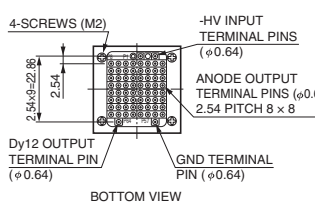
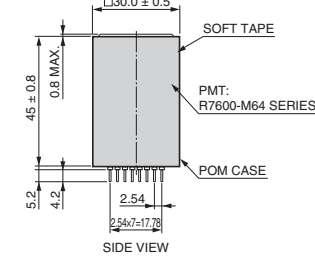
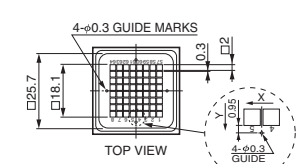
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**72 H8711, H8711-100, H8711-200, H8711-300**



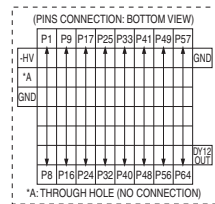
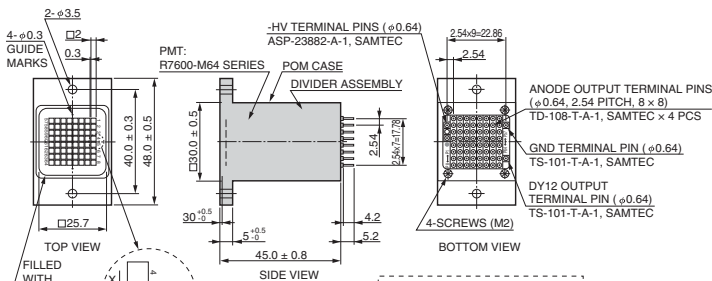
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**73 H7546B, H7546B-100, H7546B-200, H7546B-300**

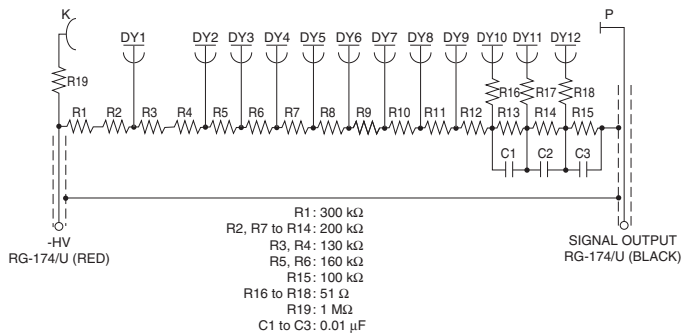
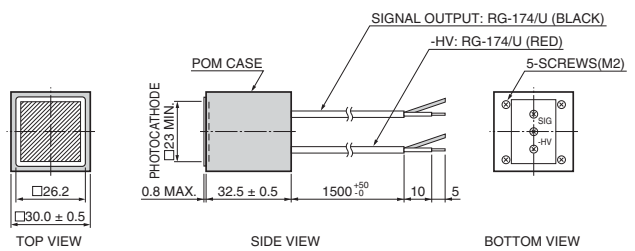


TPMHA0223EC

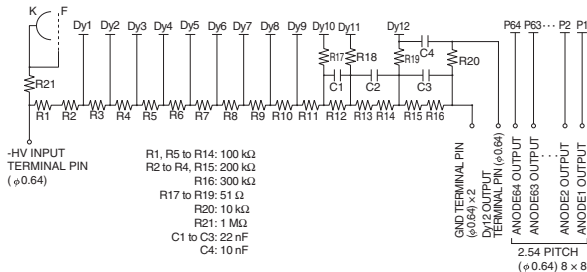
**74 H8804, H8804-100, H8804-200, H8804-300**



**75 H11934-100, H11934-200, H11934-300**



NOTE: DIVIDER RATIO=2.5: 1.3: 0.8: 0.8: 1: 1: .....: 1: 0.5  
TOTAL RESISTANCE=2.78 MΩ, DIVIDER CURRENT=359.7 μA at -1000 V (MAX.)

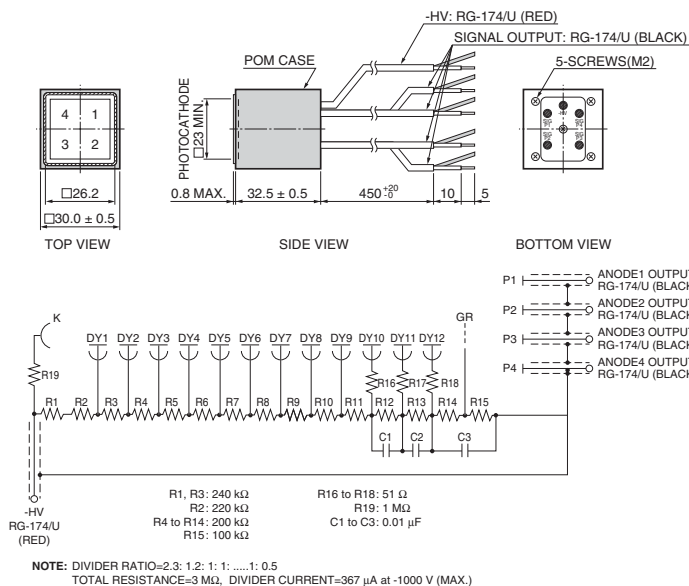


TPMHA0505EB

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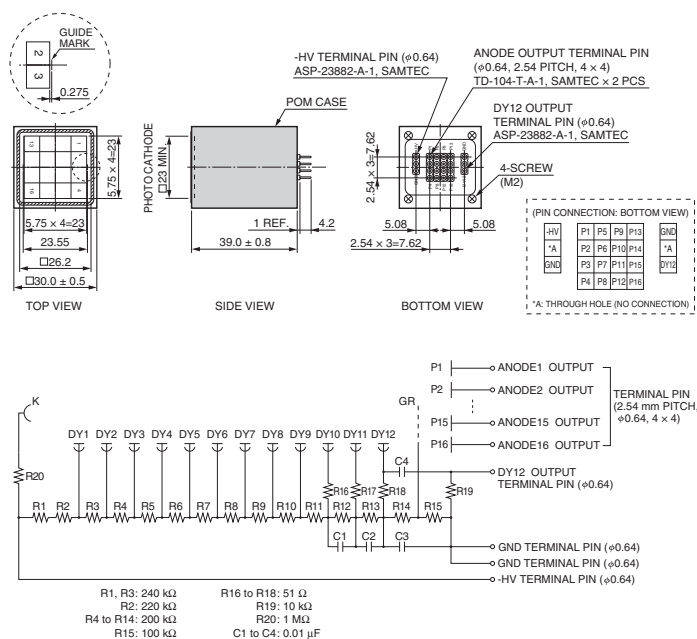
(Unit: mm)

### 76 H13226A-100, H13226A-200



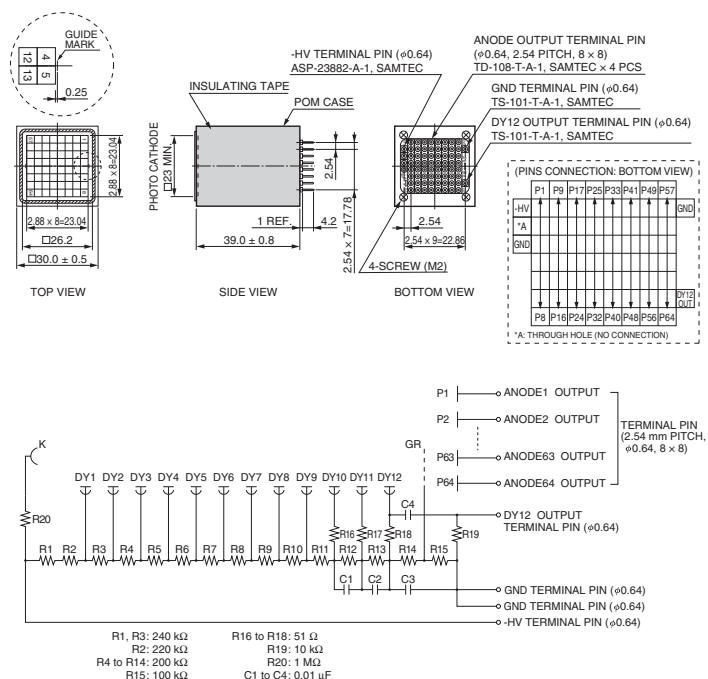
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### 77 H12445-100, H12445-200



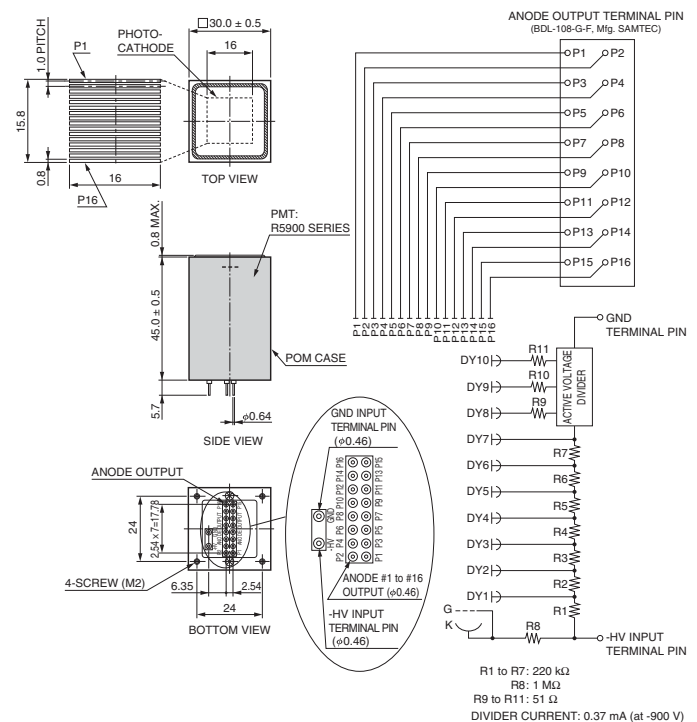
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### 78 H12428-100, H12428-200



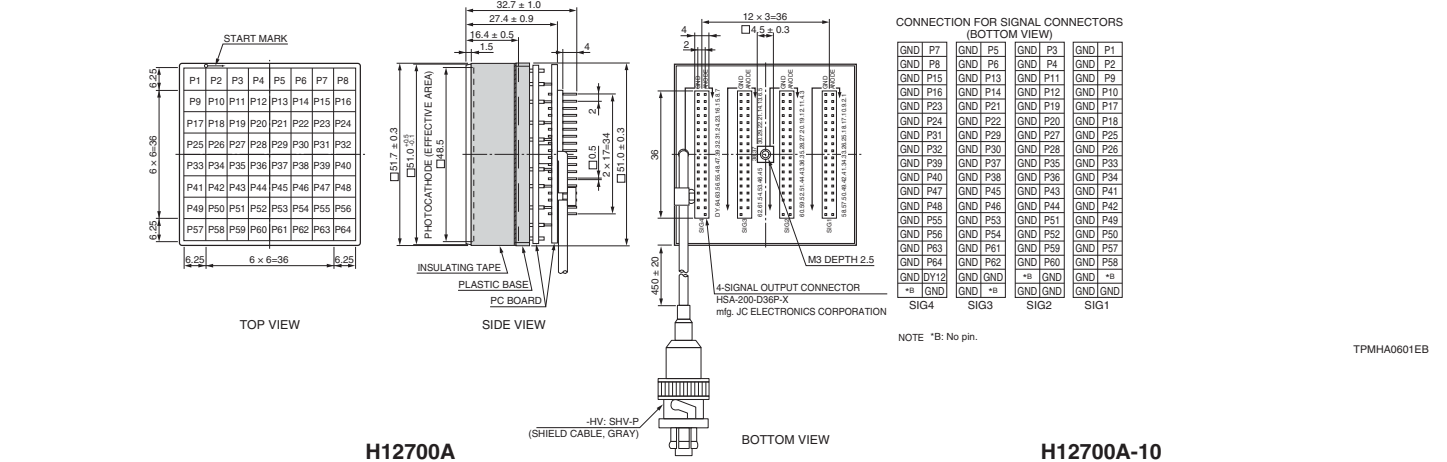
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### 79 H10515B-100, H10515B-200

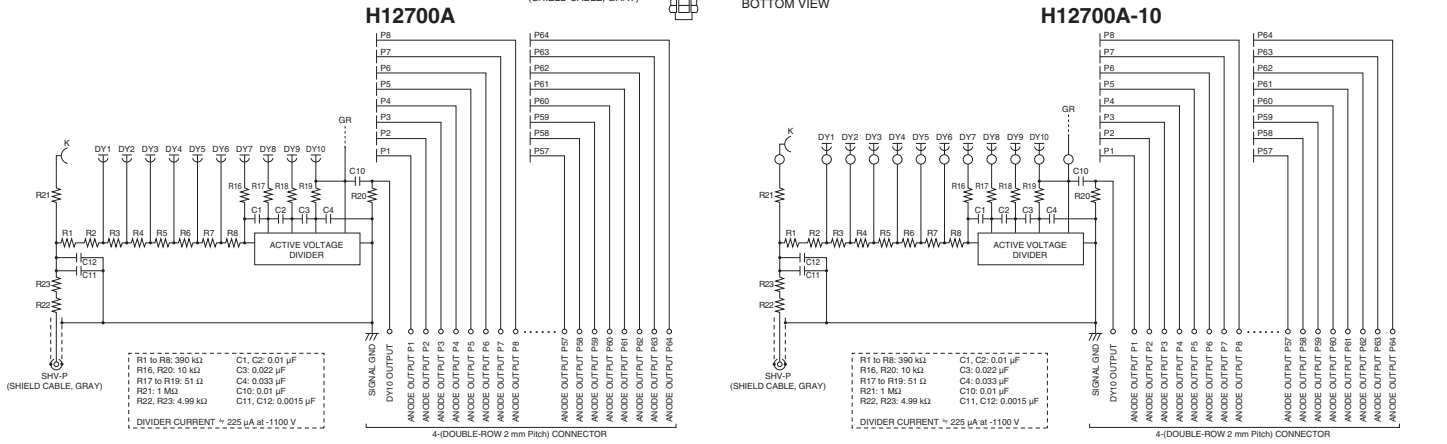


TPMHA0534EB

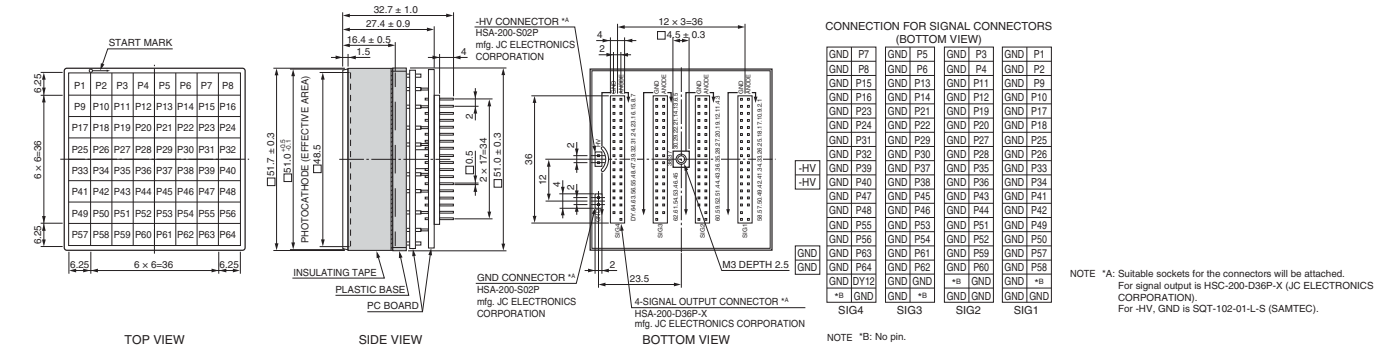
## 80 H12700A, H12700A-10



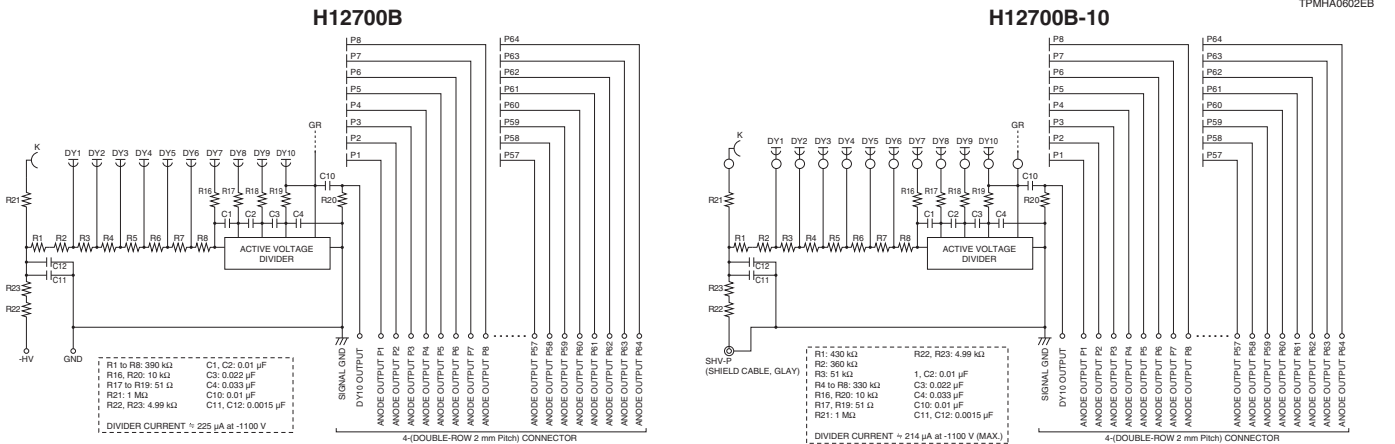
TPMHA0601EB



## 81 H12700B, H12700B-10

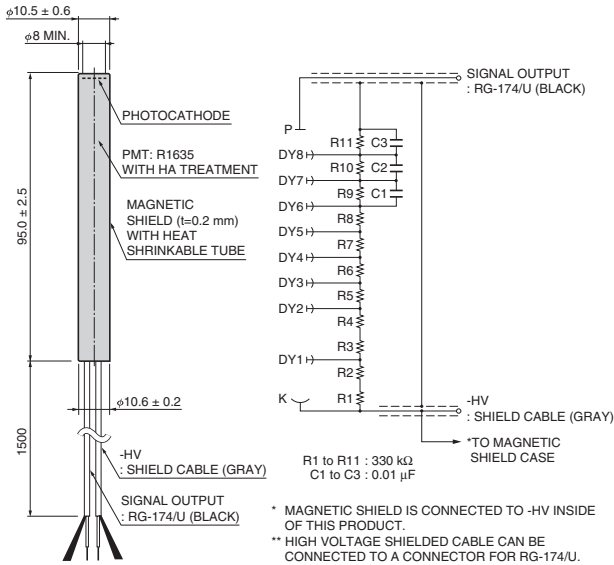


TPMHA0602EB



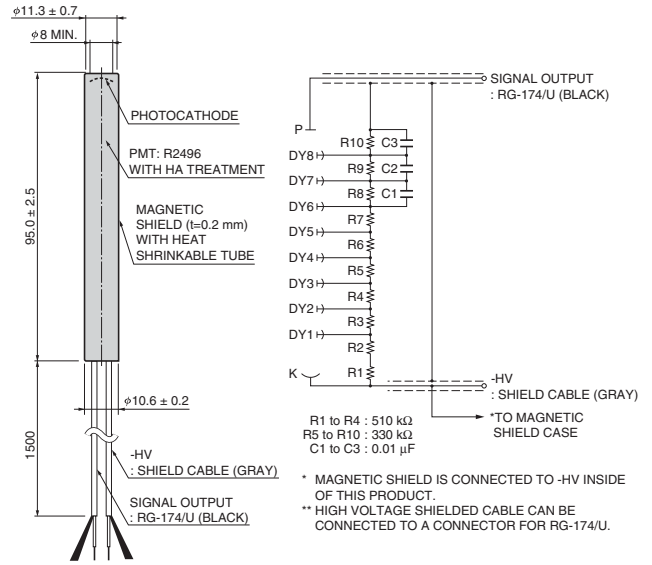


### 85 H3164-10



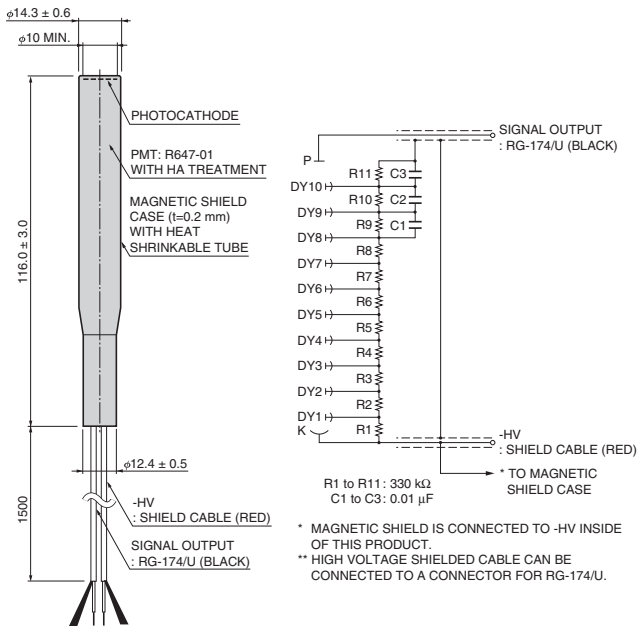
TPMHA0309EE

### 86 H3695-10



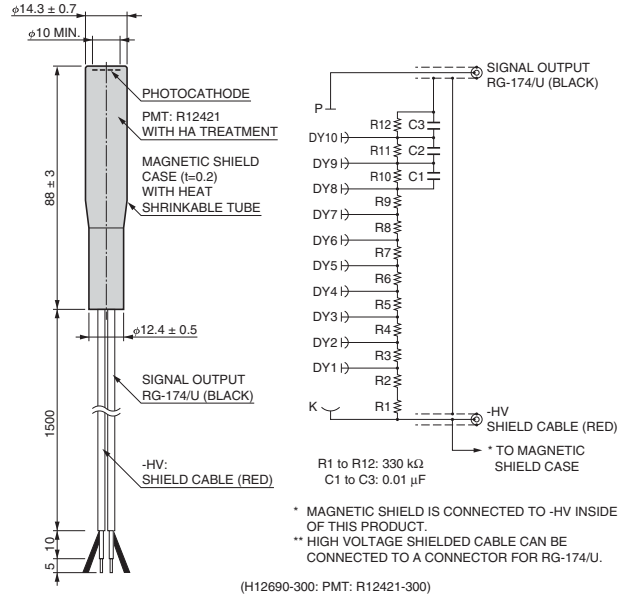
TPMHA0310EE

### 87 H3165-10



TPMHA0311EE

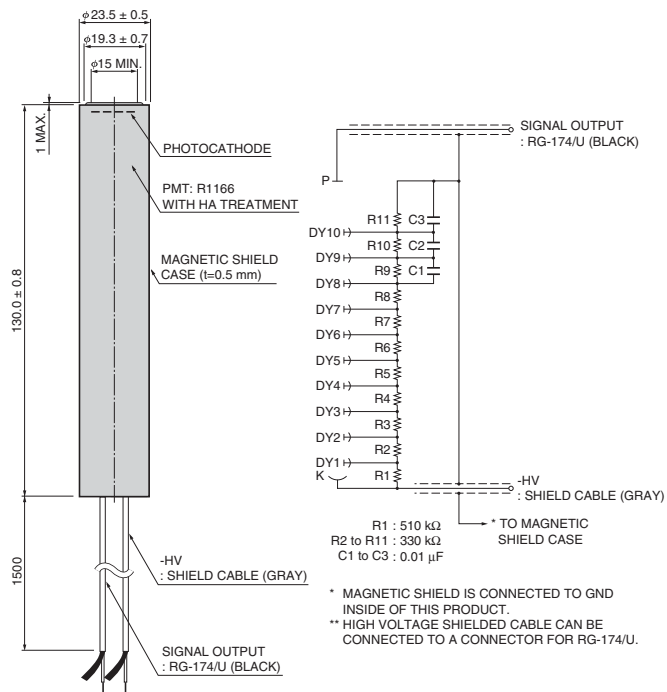
### 88 H12690, H12690-300



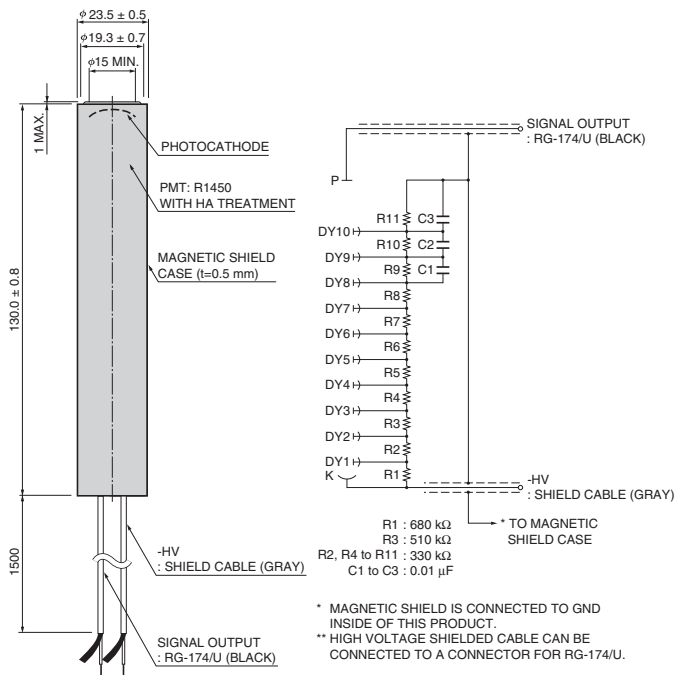
TPMHA0596EA



89 H6520



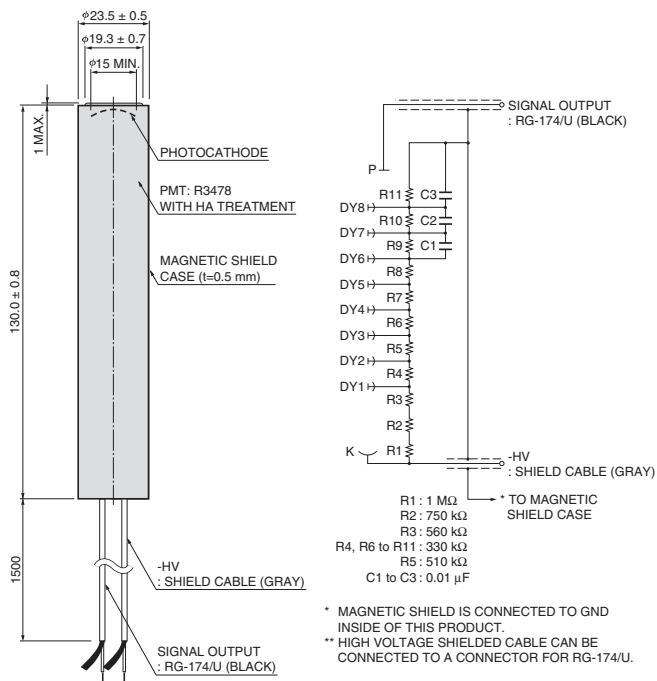
90 H6524



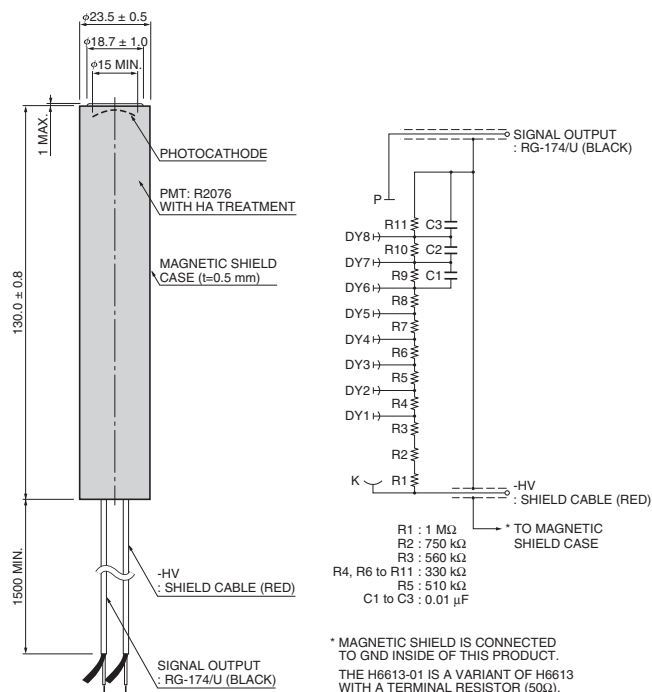
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TPMHA0313EC

91 H6612



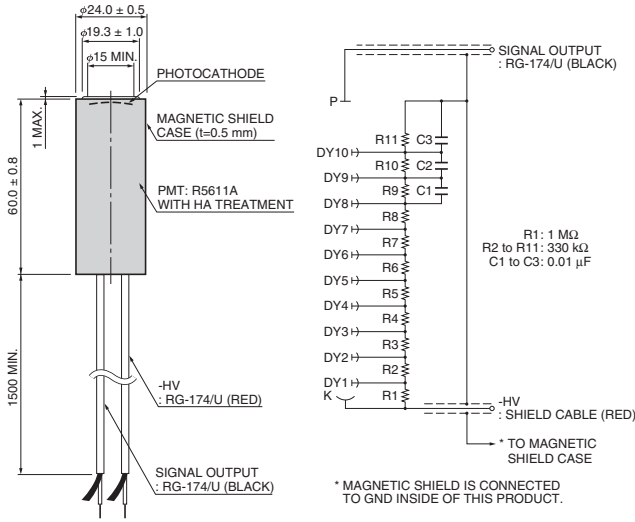
92 H6613



TPMHA0315EC

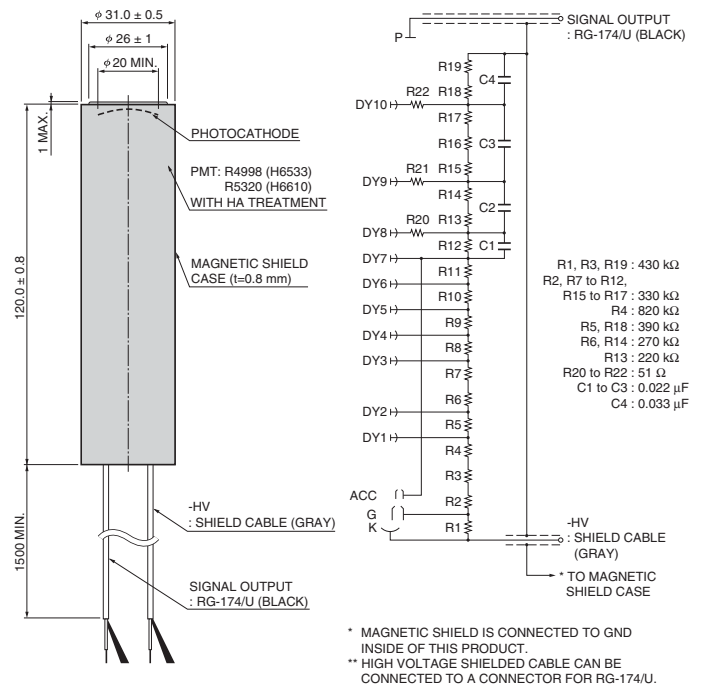
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### 93 H8135



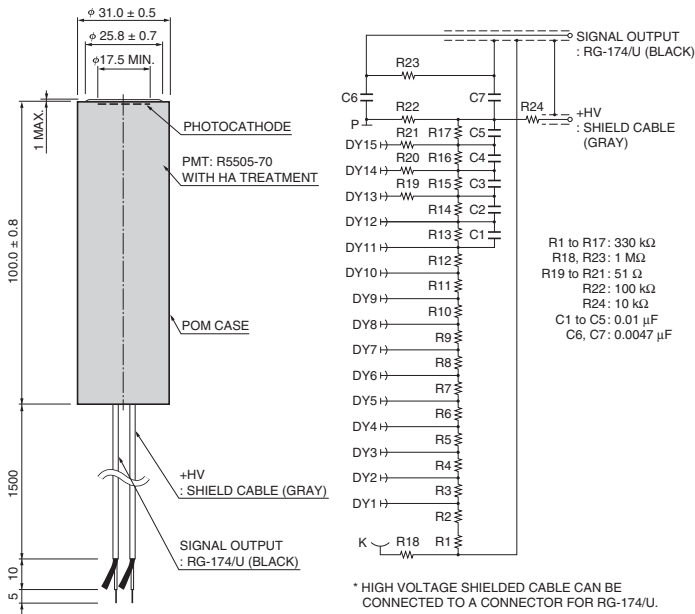
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### 94 H6533



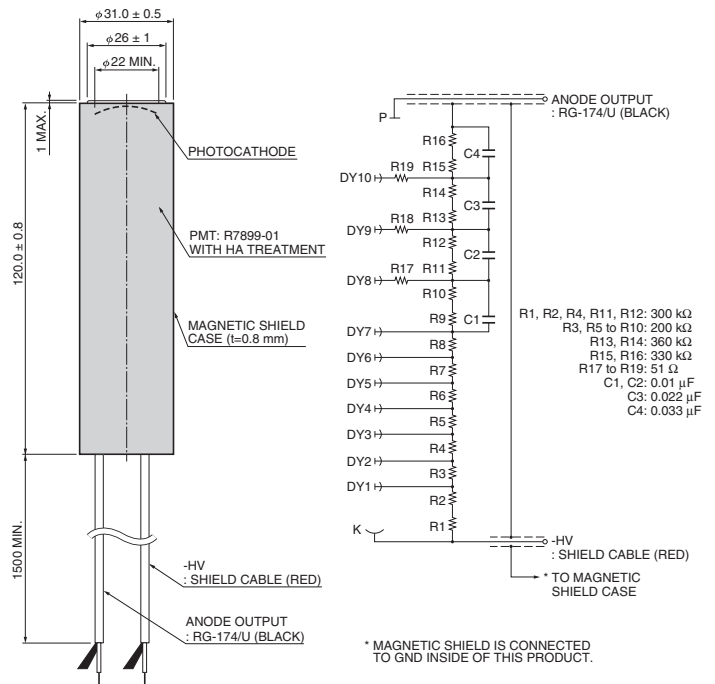
TPMHA0317ED

### 95 H6152-70



TPMHA0470EC

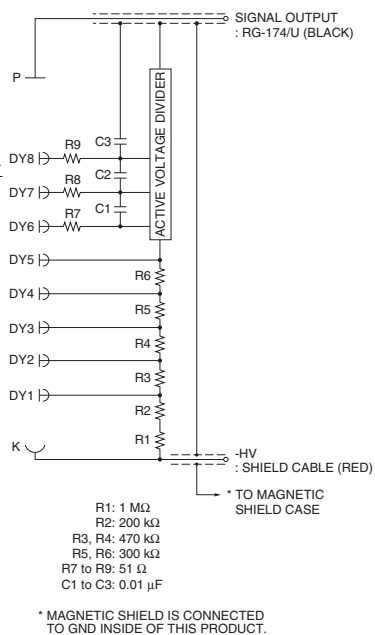
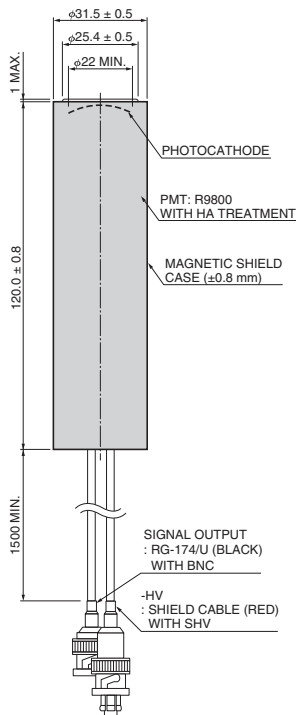
### 96 H8643



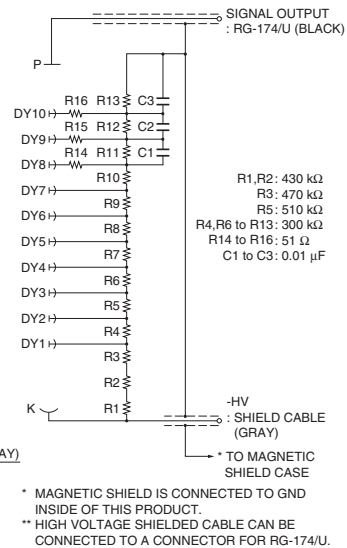
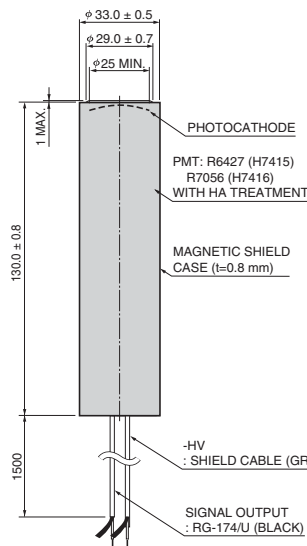
TPMHA0514EB

(Unit: mm)

### 97 H10580



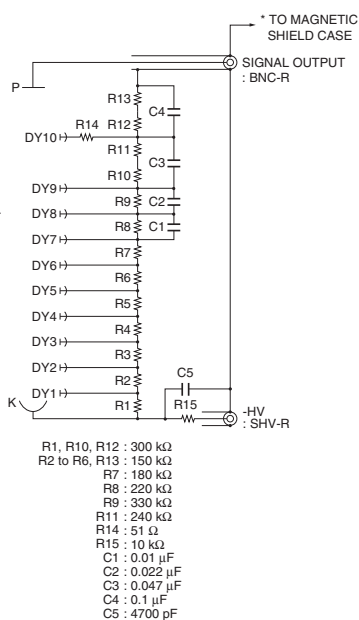
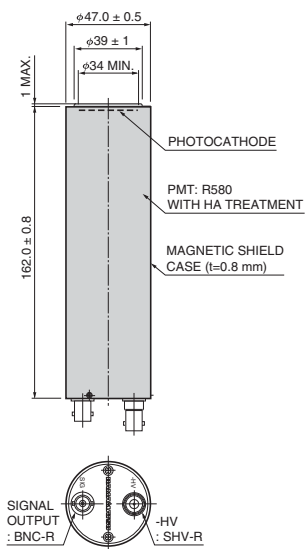
### 98 H7415



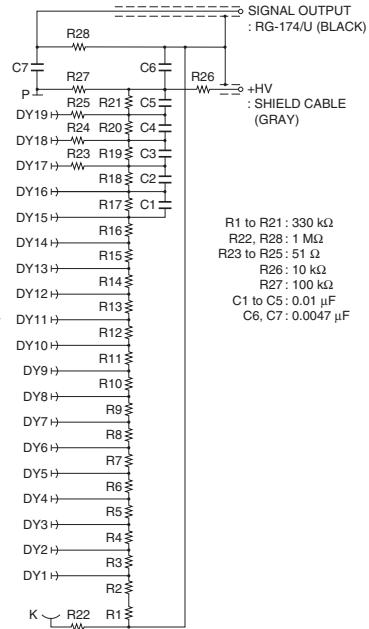
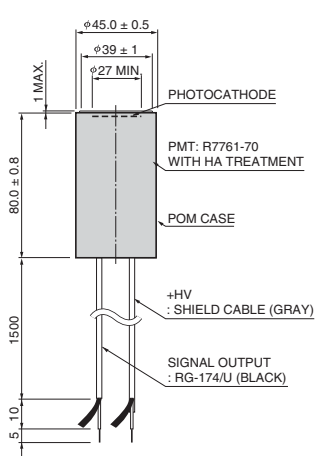
TPMHA054EA

TPMHA0318ED

### 99 H3178-51



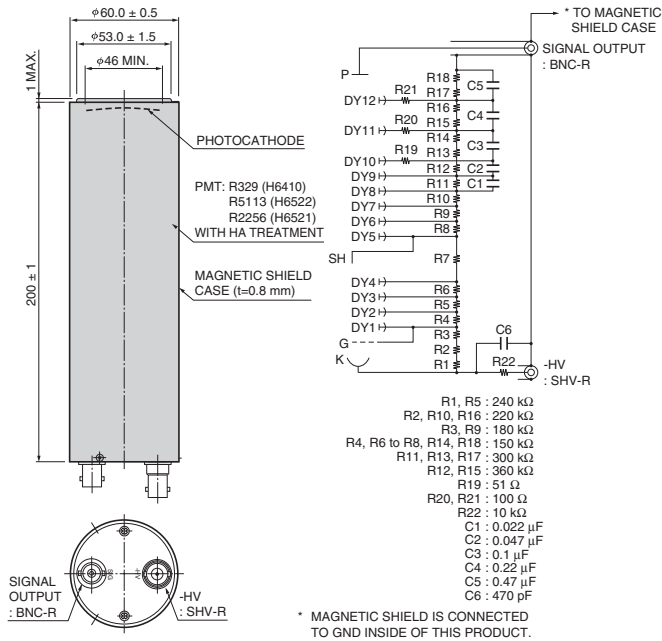
### 100 H8409-70



TPMHA0320EC

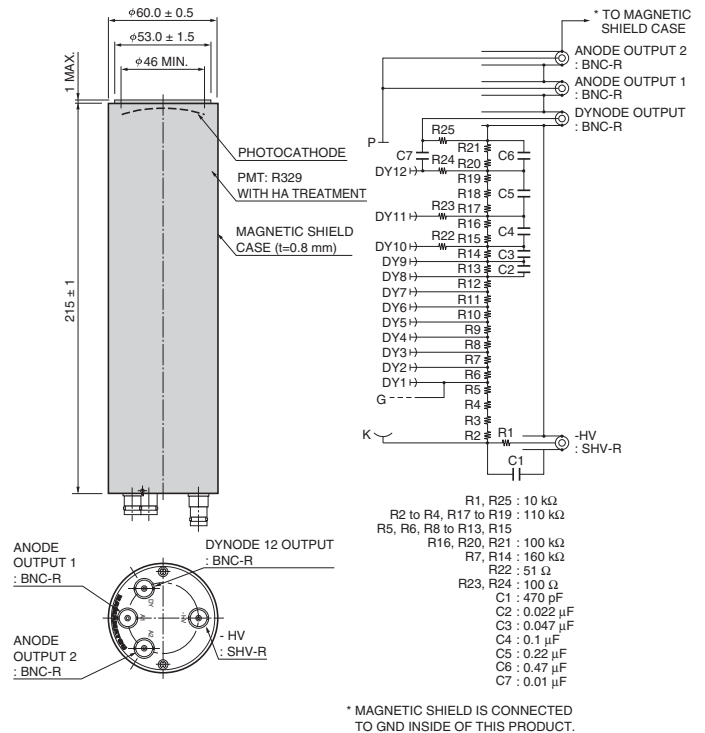
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### 101 H6410



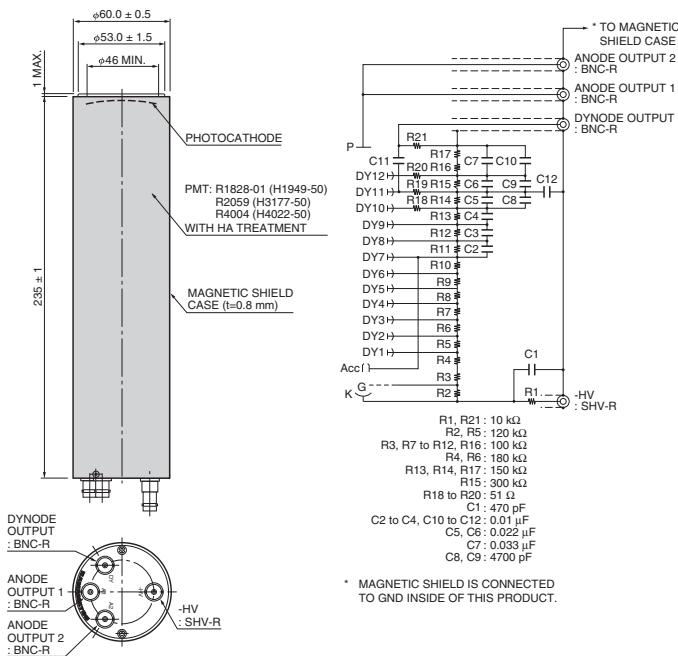
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### 102 H7195



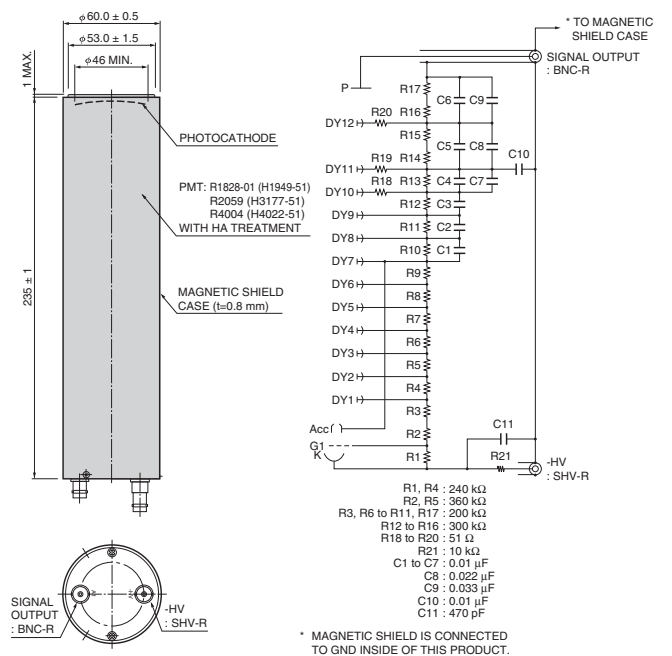
TPMHA0323ED

### 103 H1949-50



TPMHA0325ED

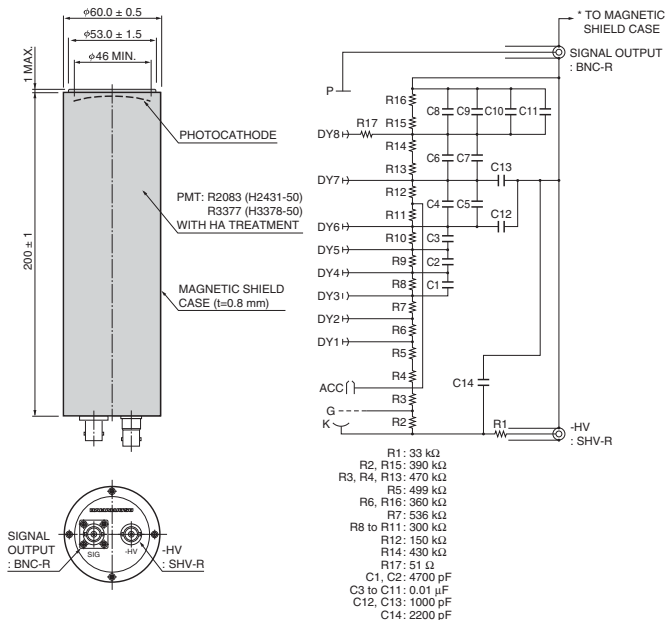
### 104 H1949-51



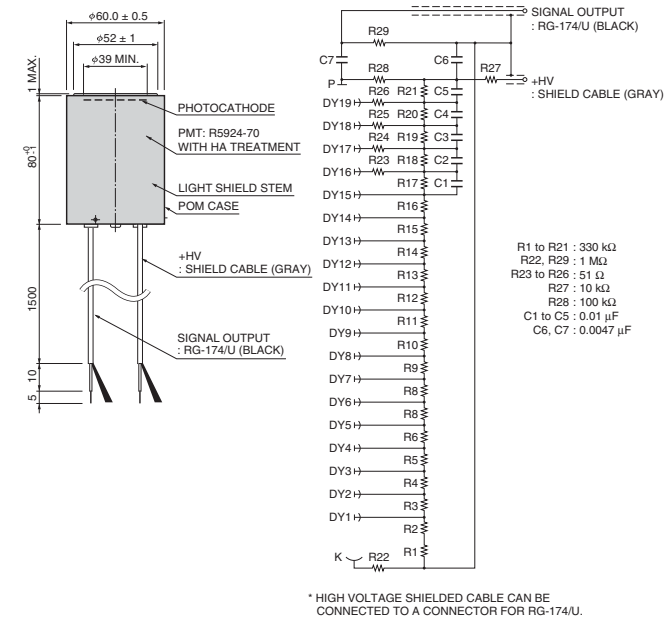
TPMHA0326ED

(Unit: mm)

### 105 H2431-50



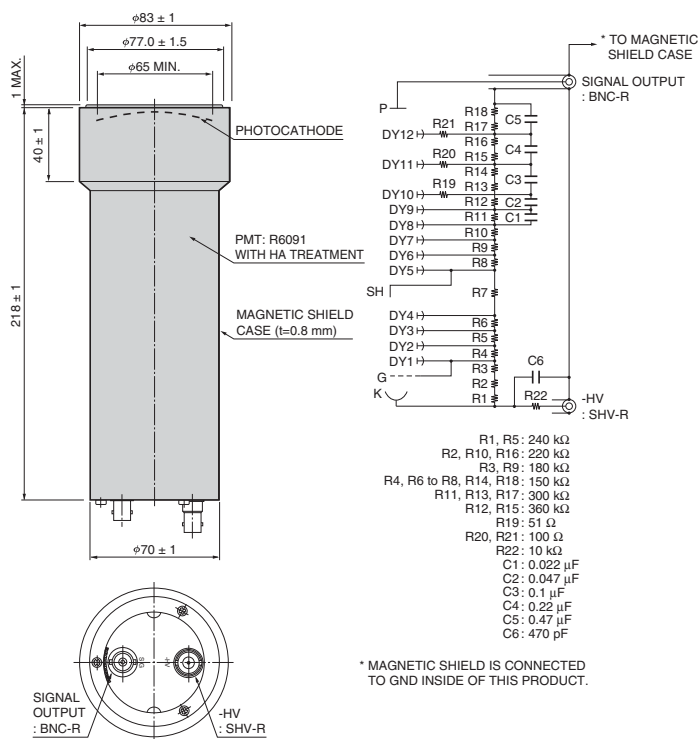
### 106 H6614-70



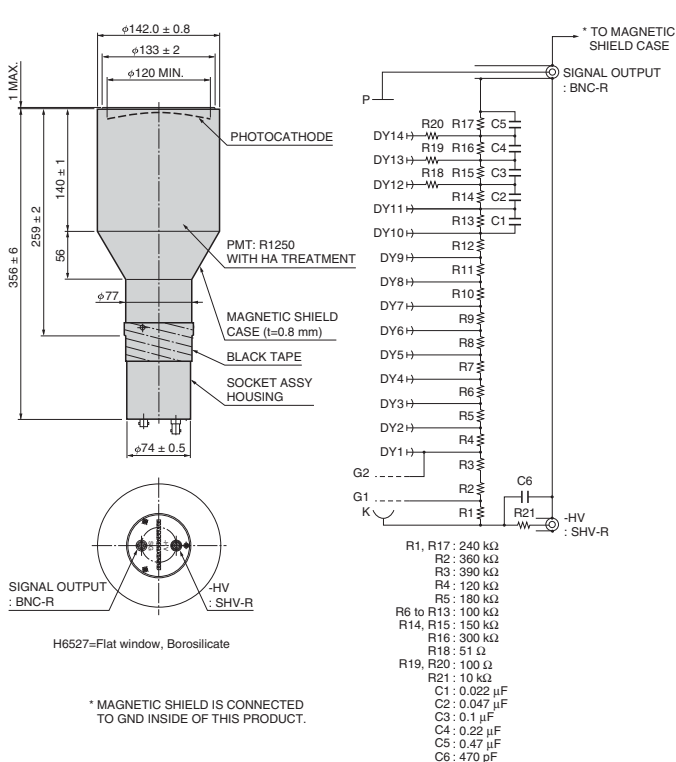
TPMHA0327EC

TPMHA0472EC

### 107 H6559



### 108 H6527

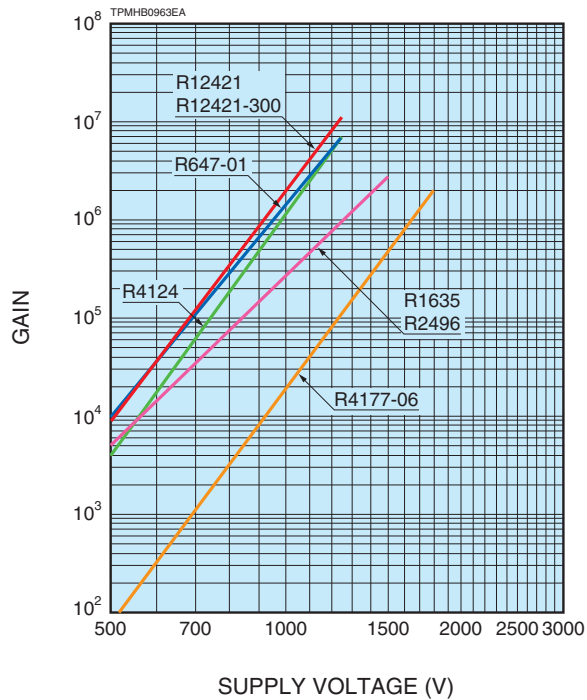


TPMHA0331EC

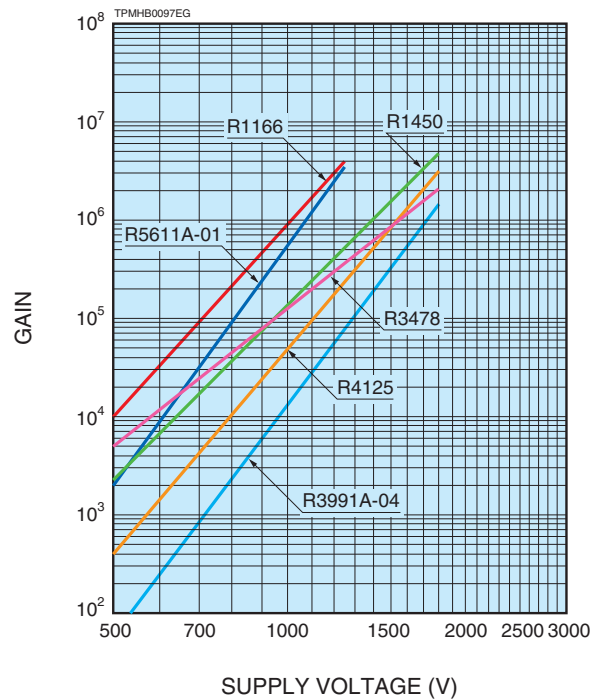
TPMHA0332EF

# Typical gain characteristics

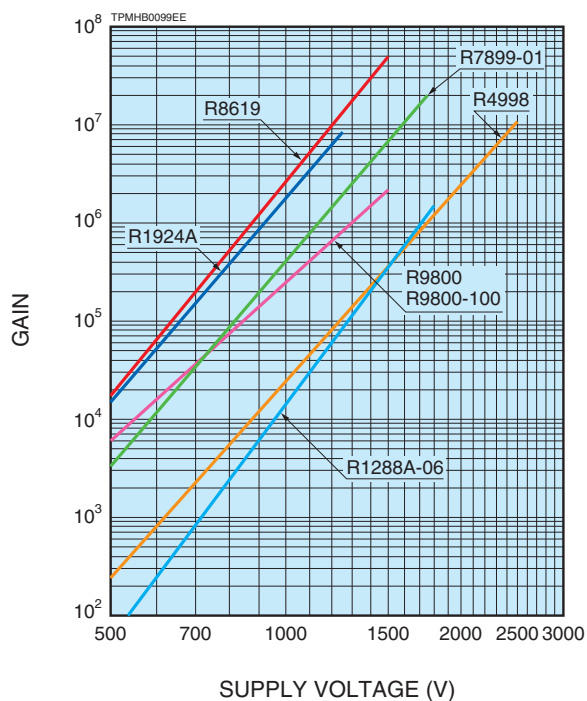
- 10 mm (3/8") Dia. and TO-8 types
- 13 mm (1/2") Dia. types



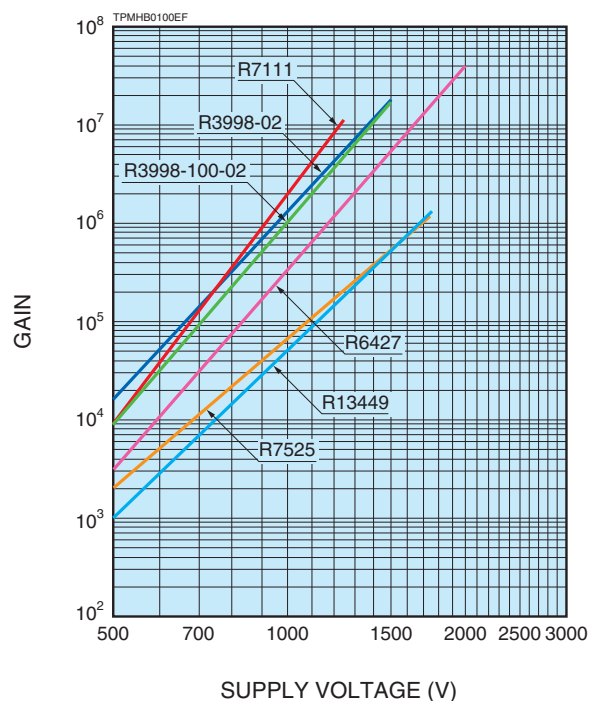
- 19 mm (3/4") Dia. types



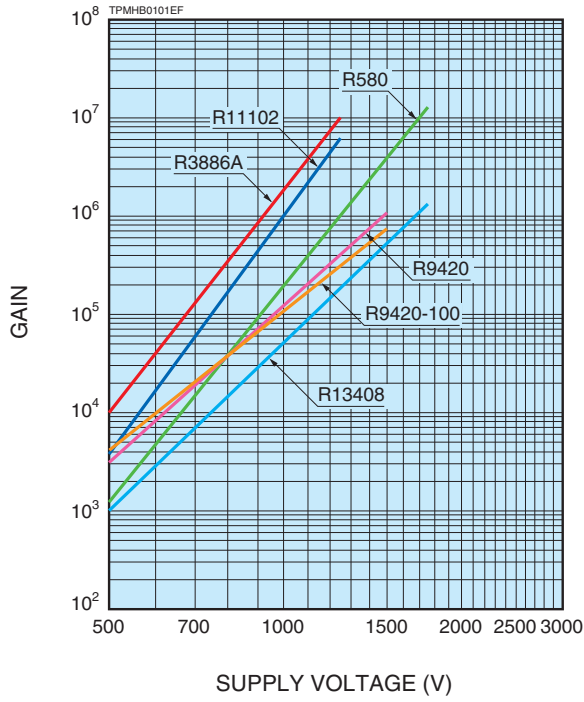
- 25 mm (1") Dia. types



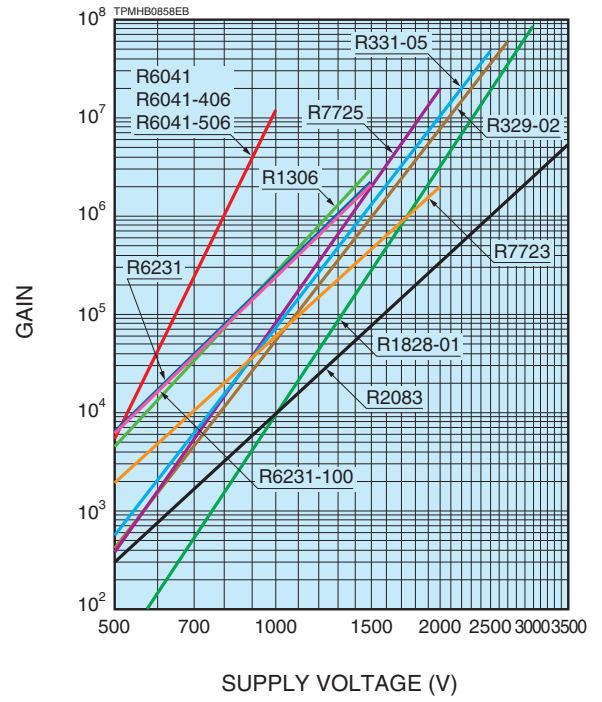
- 28 mm (1-1/8") Dia. types



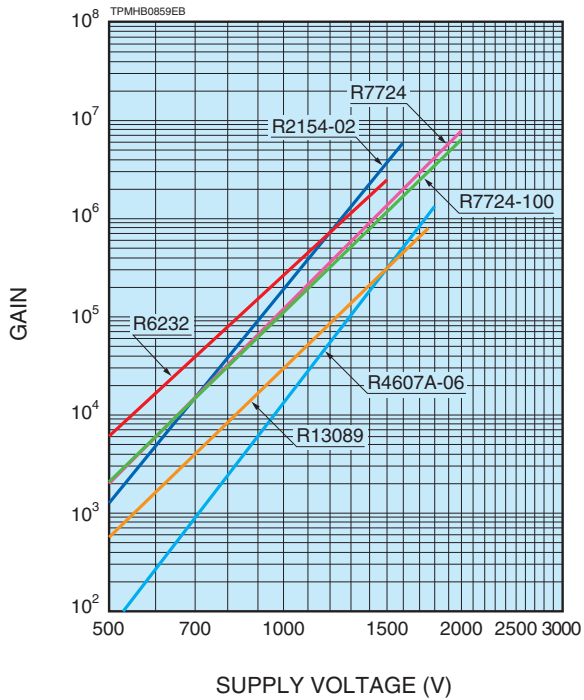
● 38 mm (1-1/2") Dia. types



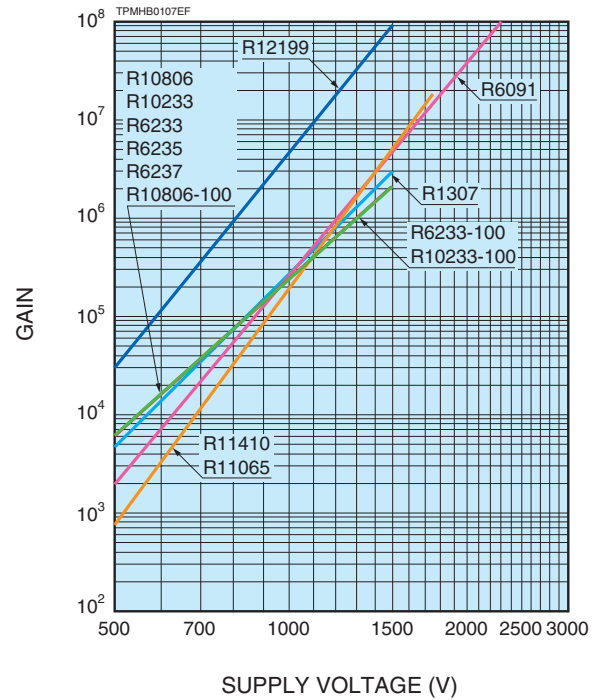
● 51 mm (2") Dia. types



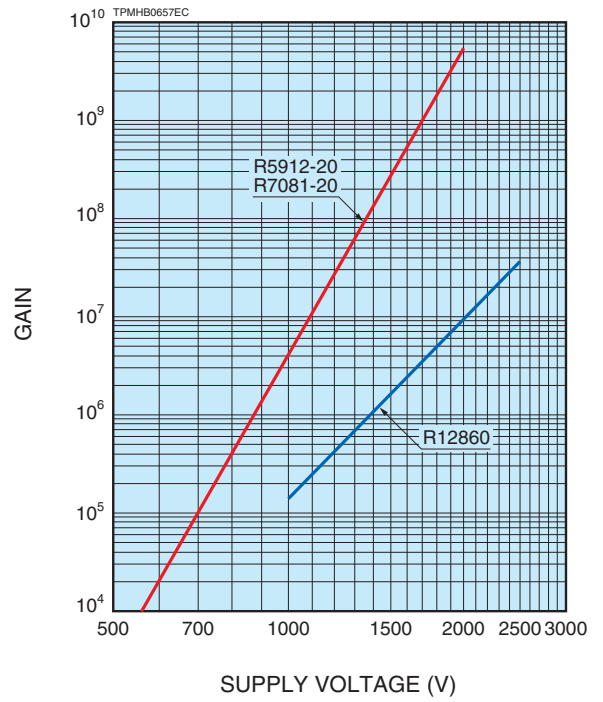
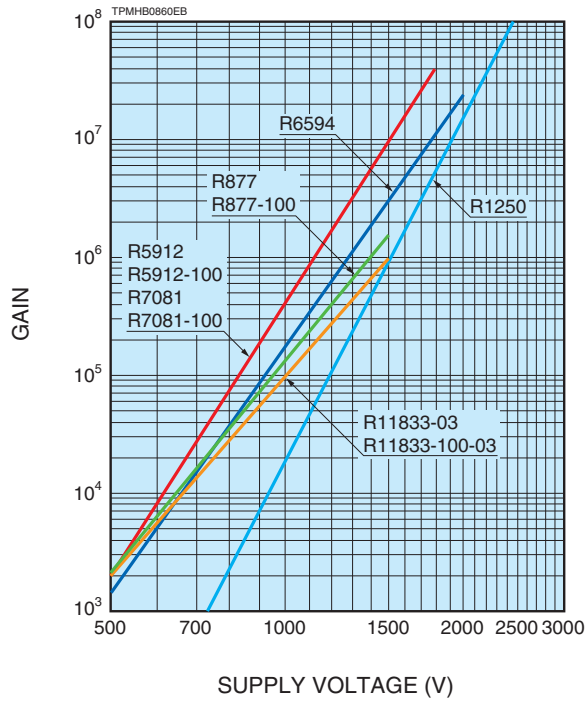
● 51 mm (2") Dia. types  
● 60 mm (2.5") Dia. types



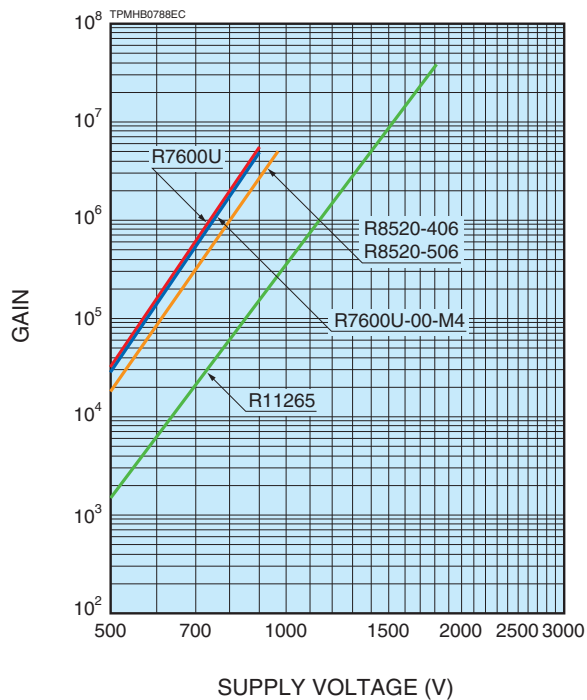
● 76 mm (3") Dia. types  
● 80 mm Dia. types  
● 90 mm (3.5") Dia. types  
● 102 mm (4") Dia. types



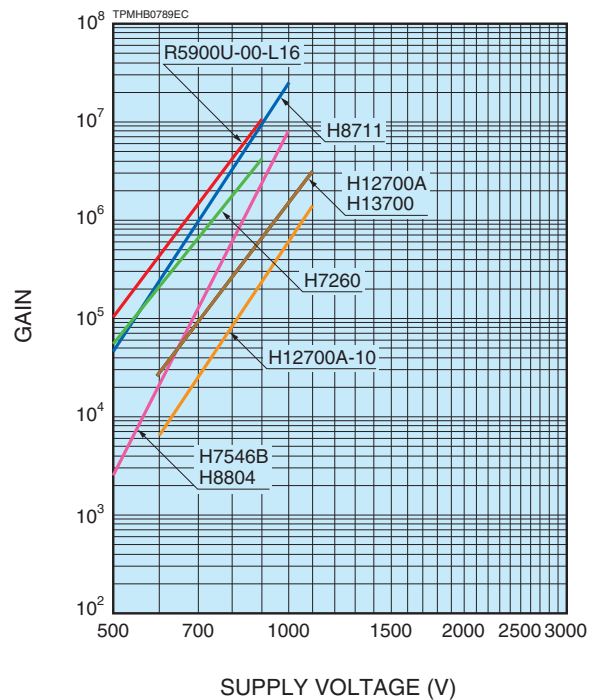
● 127 mm (5"), 204 mm (8"), 254 mm (10") and 508 mm (20") Dia. types



● Metal package types

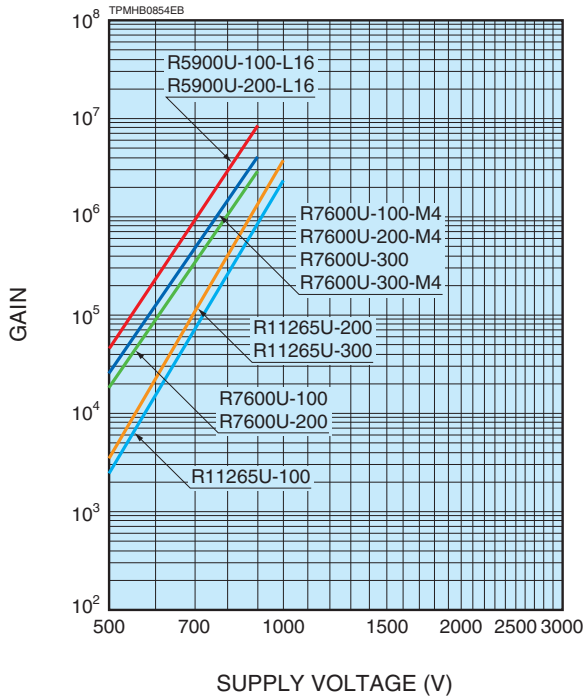


● Metal package types and assembly type

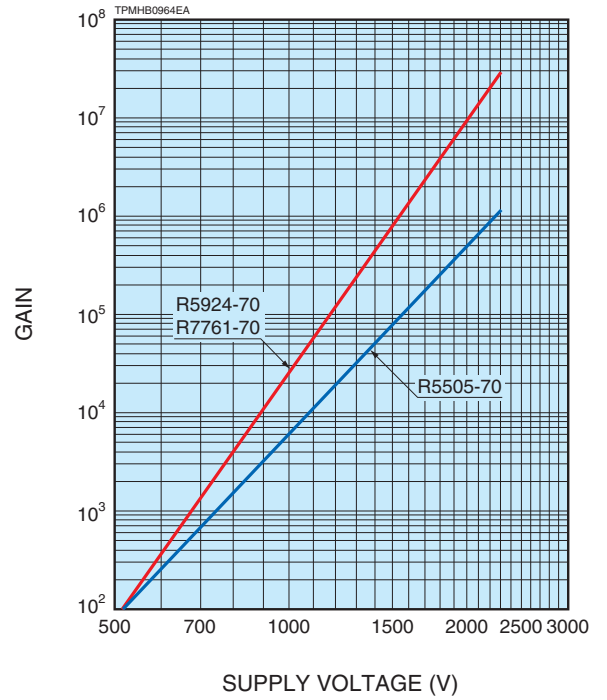




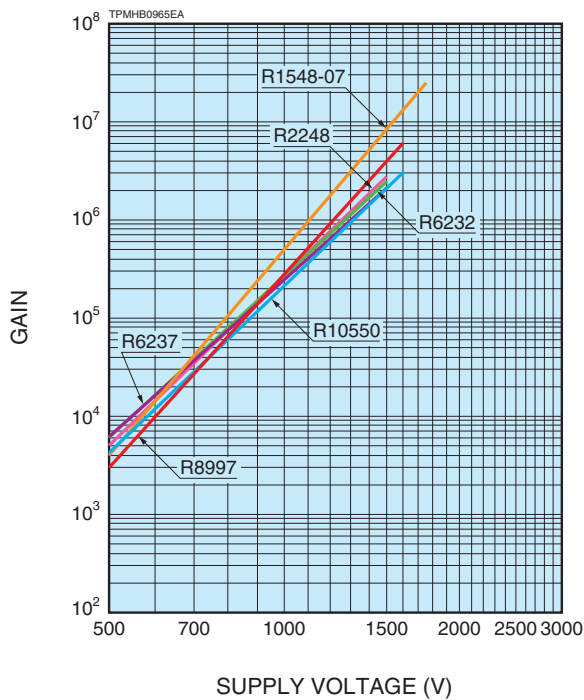
● SBA / UBA / EGBA metal package types



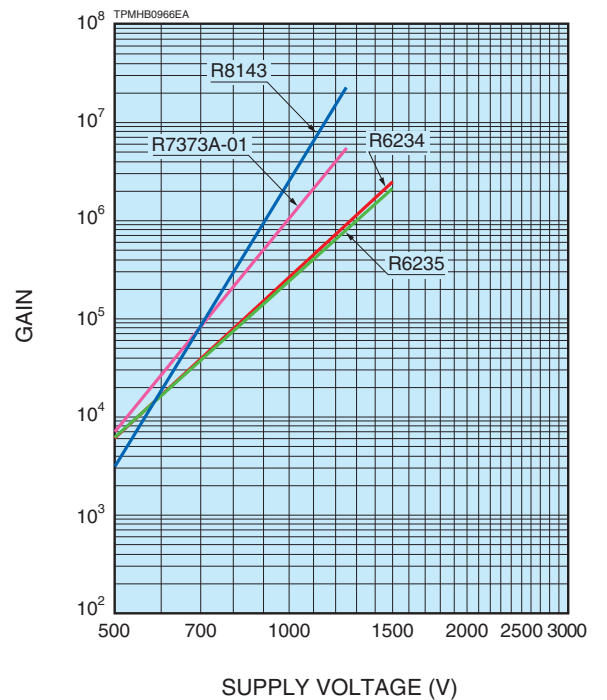
● Fine mesh photomultipliers



● Square, Rectangular shape photomultipliers



● Hexagonal shape photomultipliers  
● 2π shape photomultipliers



# Voltage distribution ratios

Interstages for the dynodes of a PMT are supplied by a voltage divider network consisting of series resistors, as shown on the right page. The cathode ground scheme (1) is usually used in scintillation counting because it reduces noise resulting from glass scintillation. In fast-pulse light applications, use of the anode ground scheme (2) is suggested. Either scheme requires decoupling (charge-storage) capacitors connected to the last few stages of dynodes in order to maintain the dynode

voltage at a constant value during pulse duration. refer to section 11 and 12 on page 8 to 13 for further details.

To free the user from the necessity of designing voltage divider and performing troublesome parts selection, Hamamatsu provides a variety of socket assemblies which enable sufficient performance to be derived from PMT's by making simple connections only.

## Voltage distribution ratio

Voltage distribution No.	Number of stages	Voltage distribution ratios											ΣR
		K	G	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	P	
①	8	1	1	1	1	1	1	1	1	1	1	1	10
②		1.3	4.8	1.5	1.5	1	1	1	1	1	1	1	15.1
③		2	—	2	1	1	1	1	1	1	1	1	11
④		2	2	1	1	1	1	1	1	1	1	1	12
⑤		3	—	1.5	1.5	1	1	1	1	1	1	1	12
⑥		4	—	1	1.5	1	1	1	1	1	1	1	12.5
⑦		4	—	1	1.5	1	1.2	1.5	2	3.3	3		18.5
⑧		4	—	1	2	1	1	1	1	2	1		14
⑨		4	—	1.5	1.5	1	1	1	1	1	1	1	13
⑩		7	—	1	1.5	1	1	1	1	1	1	1	15.5
⑪	4	0	1.2	1.5	1	1	1	1	1	1	1	12.7	

<Symbols>

K: Photocathode G: Grid F: Focusing electrode

Dy: Dynode GR: Guard ring P: Anode

Acc: Accelerating electrode

No.	stages	K	G	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Acc	Dy7	Dy8	P	ΣR
⑫	8	1.3	4.8	1.2	1.8	1	1	1	1	0.5	3	2.5		19.1

Acc: Grid (Accelerating electrode)

No.	stages	K	G	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	P	ΣR
⑬	9	3	1	1	1	1	1	1.5	1	1	1	1		13.5

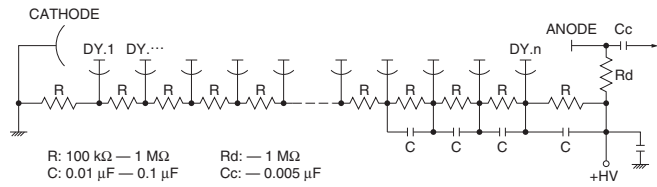
No.	stages	K	G	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	P	ΣR	
⑭	10	1	—	1	1	1	1	1	1	1	1	1	0.5		10.5	
⑮		0.5	1.5	2	1	1	1	1	1	1	1	1	1	0.5		12.5
⑯		1	—	1	1	1	1	1	1	1	1	1	1	1		11
⑰		1	1	1	1	1	1	1	1	1	1	1	1	1		12
⑱		1.3	4.8	1.5	1.5	1	1	1	1	1	1	1	1	1		17.1
⑲		1.3	4.8	1.2	1.8	1	1	1	1	1	1	1.5	3	2.5		21.1
⑳		1.5	—	1	1	1	1	1	1	1	1	1	1	1		11.5
㉑		1.5	—	1	1	1	1	1	1	1	1.2	1.8	3.6	3.3		17.4
㉒		1.5	—	1.5	1.5	1	1	1	1	1	1	1	1	1		12.5
㉓		2	—	1	1	1	1	1	1	1	1	1	1	1		12
㉔		2	—	1	1	1	1	1	1	1.2	1.5	2.2	3.6	3		18.5
㉕		2	—	1	1.5	1	1	1	1	1	1	1	1	0.75		12.25
㉖		3	—	1	1	1	1	1	1	1	1	1	1	1		13
㉗		3	—	1	1.5	1	1	1	1	1	1	1	1	1		13.5
㉘		3	—	1	1.5	1	1	1	1	1	2	3	3.6	3.3		21.4
㉙		3	—	1.5	1	1	1	1	1	1	1	1	1	1		13.5
㉚		4	—	1	1.5	1	1	1	1	1	1	1	1	1		14.5
㉛		4	—	1	1.5	1	1	1	1	1.2	1.5	2	3.3	3		20.5
㉜		4	—	1	2	1	1	1	1	1	1	1	2	1		16

(Note 1)

Note 1: Acc should be connected to Dy7 except R4998.

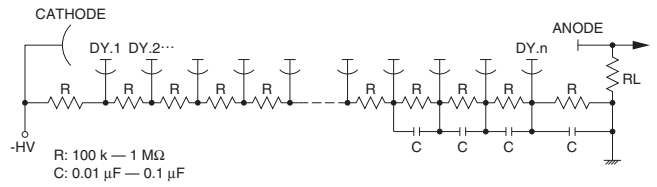
# Schematic diagram of voltage divider networks

(1) Cathode ground scheme (+HV)



TPMOC0043EB

(2) Anode ground scheme (-HV)



TPMOC0044EB

## Voltage distribution ratio

Voltage distribution No.	Number of stages	Voltage distribution ratios															ΣR
		K	Dy1	G1	G3	G2	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	P	
33	10	8	0.18	0	0.17	0.85	1.5	1	1	1	1	1	1	1	1	18.7	
34		8	0.18	0	0.17	0.85	1.5	1	1	1	1.2	1.5	2.1	3	2.4	23.9	

No.	stages	K	Dy1	G	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7(Acc)	Dy8	Dy9	Dy10	P	ΣR
35	10	11.5	1	3.5	4	2	2	1	1	1	1	1	1	1	30

No.	stages	K	G	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	Dy11	P	ΣR
36	11	2	—	1	1	1	1	1	1	1	1	1	1	1	1	13

No.	stages	K	G	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	Dy11	Dy12	P	ΣR
37	12	1	3	1.2	1.8	1	1	1	1	1.5	2.5	3.6	4.5	8.6	4	35.7	
38		1.2	2.8	1.2	1.8	1	1	1	1	1	1	1.5	1.5	3	2.5	21.5	
39		2	—	2	2	1	1	1	1	1	1	1	1	1	1	16	
40		2	—	2	2	1	1	1	1	1	1	1	1	1	1.2	16.2	
41		2.5	—	1.3	0.8	0.8	1	1	1	1	1	1	1	1	0.5	13.9	
42		3	—	2	2	1	1	1	1	1	1	1	1	2	5	22	
43		3.3	—	1.6	1	1	1	1	1	1	1	1	1	2.7	1.3	17.1	
44		4	0	1	1.4	1	1	1	1	1	1	1	1	1	1	16.4	
45		4	—	1	2	1	1	1	1	1	1	1	1	2	1	18	
46		4	—	1.5	2	1	1	1	1	1	1	1	1	2	1	18.5	
47	4.3	0	1	1.6	1	1	1	1	1.2	1.5	2	2.4	3	3.9	3	26.9	

(Note 2)

(Note 2)

No.	stages	K	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	Dy11	Dy12	P	ΣR
48	12	4	1.5	2	1	1	1	1	1	1	1	1	1	2	1	18.5

No.	stages	K	G	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	Dy11	Dy12	Dy13	Dy14	P	ΣR
49	14	2.5	7.5	1.2	1.8	1	1	1	1	1	1	1	1	1.5	1.5	3	2.5	29.5	
50		2.5	7.5	1.2	1.8	1	1	1	1	1.2	1.5	2	2.8	4	5.7	8	5	47.2	

No.	stages	K	Dy1	G2	G1	G3	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	Dy11	Dy12	Dy13	Dy14	P	ΣR
51	10	16.8	0	0.6	0	3.4	5	3.33	1.67	1	1.2	1.5	2.2	3	—	—	—	—	2.4	42.2	
52	14	11.3	0	0.6	0	3.4	5	3.33	1.67	1	1	1	1	1	1.2	1.5	2.2	3	2.4	40.6	

No.	stages	K	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	Dy11	Dy12	Dy13	Dy14	Dy15	Dy16	Dy17	Dy18	Dy19	P	ΣR	
53	15	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	17
54	19	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	21

No.	stages	K	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	Dy11	Dy12	GR	P	ΣR
55	10	2	1	1	1	1	1	1	1	1	1	1	1	1	0.5	12.5	
56	12	2.3	1.2	1	1	1	1	1	1	1	1	1	1	1	0.5	15	

Note 2: Shield should be connected to Dy5.

# Quick reference for PMT socket assemblies

Assembly type No.	PMT characteristics				Assembly characteristics						Notes								
	Tube diameter	Tube type No. / Voltage distribution ratio	Reference page for PMT feature	Outline No.	H.V input terminal	Signal output terminal	Standard rating		Maximum rating										
							Overall voltage (V)	Divider current (mA)	Overall voltage (V)										
E1761-21	10 mm (3/8")	R1635	③	20	1	SHV	BNC	-1250	0.35	-1500									
E1761-22		R2248		24															
E849-90	13 mm (1/2")	R2496	⑤	20	1	SHV	BNC	-1250	0.32	-1500									
E849-99		R647-01	⑩	20								2	SHV	BNC	-1000	0.28	-1250		
E849-68		R12421	⑬	20														3	AWG22
E974-17	19 mm (3/4")	R4124	⑰	20	3	AWG22	RG-174/U	-1000	0.23	-1250									
E974-22		R1166	⑳	20								4	SHV	BNC	-1000	0.27	-1800		
E2253-05		R1450	㉑	20														5	SHV
E974-19		R3478	㉒	20								6	SHV	BNC	-1700	0.34	-1800		
E2037-02	25 mm (1")	R4125	㉓	20	7	AWG22	RG-174/U	-1500	0.27	-1800									
E6133-04		R1548-07	③①	24								8	AWG24	AWG24	-1250	0.13	-1750	6 μA is for total of 2 anodes.	
E990-29	25 mm (1")	R5505-70	⑤③	24	9	SHV	BNC	+2000	0.36	+2300									
E2924-500		28 mm (1-1/8")	R3998-02	⑬								20	10	AWG22	RG-174/U	-1000	0.23	-1500	
E2624-14	28 mm (1-1/8")		R3998-100-02		26	11	SHV	BNC	-1000	0.24	-1250								
E2624-04		R1924A	⑳	20	12								SHV	BNC	-1500	0.32	-2000		
E2183-500	38 mm (1-1/2")	R7111	㉔	20		13	AWG22	RG-174/U	-1500	0.37	-2000	E2624-14 without connector and flange, tapered circuit voltage							
E2183-501		R6427	③②	20	14								SHV	BNC	-1250	0.32	-1750		
E1198-07		51 mm (2")	R580	㉕														20	14
E2979-500			R11102		20								15	AWG22	RG-174/U	-1250	0.32	-1750	
E1198-05	51 mm (2")	R3886A	㉖	20	14	SHV	BNC	-1000	0.36	-1250									
E1198-20		R2154-02	㉗	22								16	SHV	BNC	-2500	0.58	-3000	with shield case	
E1198-26	60 mm (2.4")	R1828-01	③⑧	22	17	AWG22	RG-174/U	-1000	0.31	-1500	-HV type								
E1198-27		76 mm (3")	R1306	①								22	18	SHIELD CABLE	RG-174/U	+1000	0.31	+1500	+HV type
	90 mm (3.5")		R1307	①	22	19	SHIELD CABLE	RG-174/U	-1000	0.25	-1500	-HV type							
		102 mm (4")	R6231		22								19	SHIELD CABLE	RG-174/U	+1000	0.25	+1500	+HV type
			R6231-100		22														
		R6232		22															
		R6233		22															
		R6233-100		22															
		R6234	④	24															
		R6235		24															
		R6236		24															
		R6237		24															
		R10233		22															
		R10233-100		22															
		R10806		22															
		R10806-100		22															

Note:

①: When overall voltage is negative (-HV), DC and pulse signals are obtained. When it's positive (+HV), pulse signal is obtained.

②: The maximum average anode current is defined as 5 % of divider current.

Assembly type No.	PMT characteristics			Assembly characteristics						Notes	
	Tube diameter	Tube type No. / Voltage distribution ratio	Reference page for PMT feature	Outline No.	H.V input terminal	Signal output terminal	Standard rating		Maximum rating		
							Overall voltage <sup>①</sup> (V)	Divider current <sup>②</sup> (mA)	Overall voltage (V)		
E5859	51 mm (2") 76 mm (3")	R329-02 R6091	④⑦	22 22	⑳	SHV	BNC	-2000	0.5	-2700 -2500	shield case is available. +HV type (E5859-02) is available.
E5859-01		R329-02 R331-05 R6091	④④	22 22 22	⑳	SHV	BNC	-1500	0.42	-2700 -2500	shield case is available. +HV type (E5859-03) is available.
E5859-11		R7725	④⑤	22	⑳	SHV	BNC	-1750	0.45	-2000	
E5859-15		R7723	⑧	22	⑳	SHV	BNC	-1750	0.38	-2000	
E5859-19		R7724 R7724-100	③②	22	⑳	SHV	BNC	-1750	0.5	-2000	
E1198-22	127 mm (5")	R877 R877-100	①⑦	22	⑳	SHIELD CABLE	RG-174/U	-1250	0.32	-1500	shield case is available. -HV type
E1198-23					⑳	SHIELD CABLE	RG-174/U	+1250	0.32	+1500	shield case is available. +HV type
E6316-01					㉒	SHV	BNC	-1250	0.32	-1500	-HV type with rear panel connector
E7693		R1250	④⑨	22	㉓	SHV	BNC	-2000	0.68	-3000	
E7694-02	204 mm (8") 254 mm (10")	R5912 R7081	⑤①	22 22	㉔	SHV	BNC	-1500	0.36	-2000	+HV type, (E7694-03) is available
E13416	26 mm square type	R8520-406 R8520-506	①⑤	25	㉕	SHIELD CABLE	SHIELD CABLE	+800	0.036	+900	
E5996	30 mm square type	R7600U R7600U-03 R7600U-100 R7600U-200 R7600U-300	②②	24	㉖	SHIELD CABLE	RG-174/U	-800	0.3	-900	
E7083		R7600U-00-M4 R7600U-100-M4 R7600U-200-M4 R7600U-300-M4	②②	24	㉗	SHIELD CABLE	0.8D-QEV	-800	0.3	-900	Active base type (E6572) is available.
E6736		R5900U-00-L16 R5900U-100-L16 R5900U-200-L16	①⑥	24	㉘	SHIELD CABLE	0.8D-QEV	-800	0.34	-900	
E11807		R11265U R11265U-100 R11265U-200	④①	24	㉙	SHIELD CABLE	RG-174/U	-900	0.33	-1000	
E11807-01		R11265U R11265U-100 R11265U-200	④①	24	㉙	SHIELD CABLE	RG-174/U	-900	0.34	-1000	E11807 with tapered voltage driver circuit.
E10679-02	16 mm TO-8	R9880U-110 R9800U-210	①④	24	③①	AWG22	RG-174/U	-1000	0.29	-1100	SHV / BNC connector type E10679-03 is available

Note:

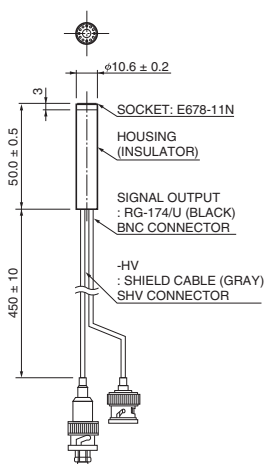
①: When overall voltage is negative (-HV), DC and pulse signals are obtained. When it's positive (+HV), pulse signal is obtained.

②: The maximum average anode current is defined as 5 % of divider current.

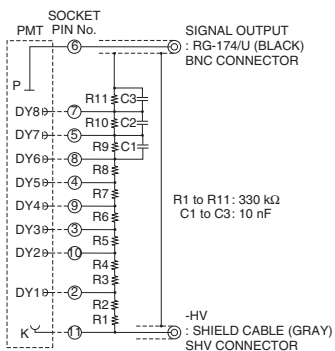
# Dimensional outline and circuit diagrams

For PMT socket assemblies

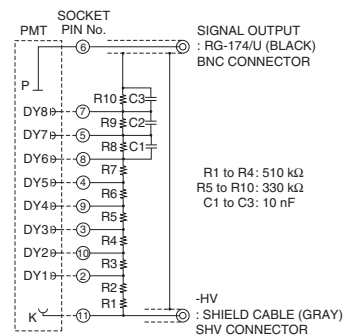
## 1 E1761-21, E1761-22



**E1761-21**  
(For R1635)



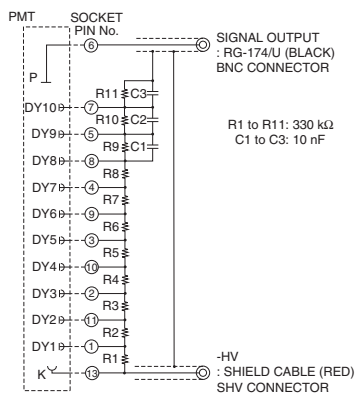
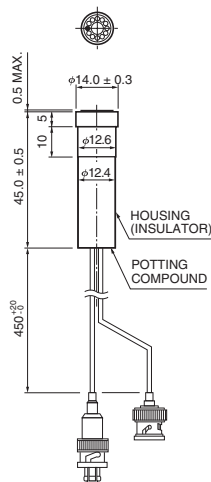
**E1761-22**  
(For R2496)



TACCA0075EB

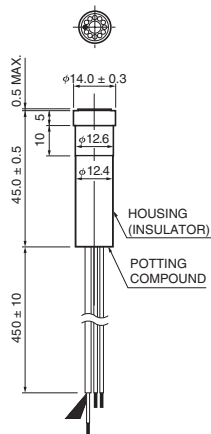
TACCA0078EC

## 2 E849-90

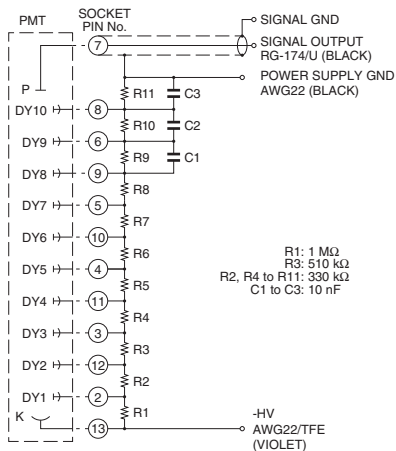


TACCA0077ED

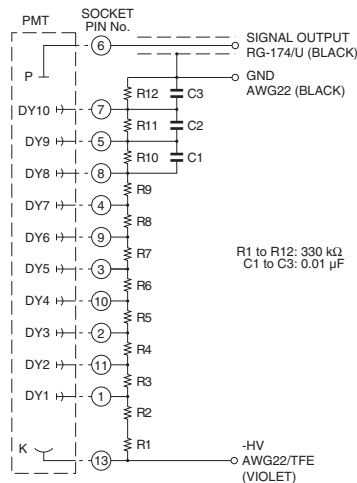
## 3 E849-68, E849-99



**E849-68**  
(For R4124)



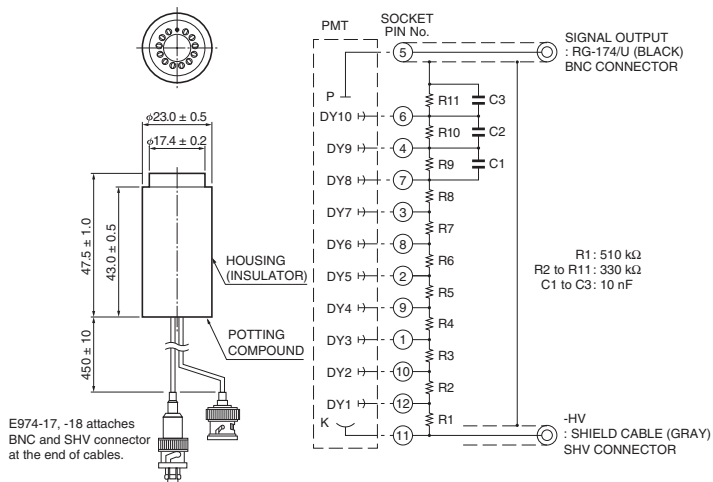
**E849-99**  
(For R12421)



TACCA0210EB

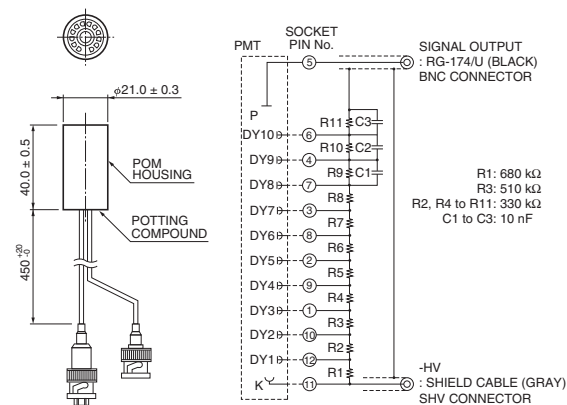
(Unit: mm)

### 4 E974-17



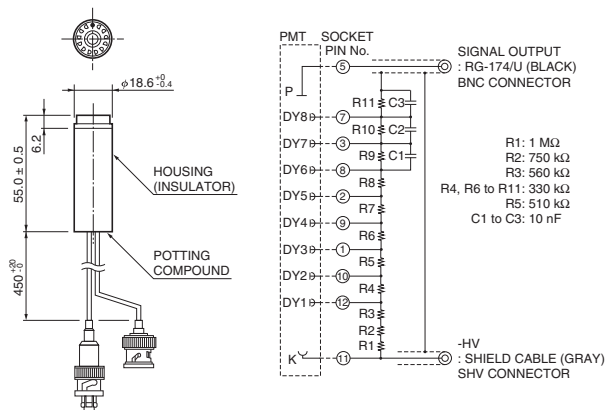
TACCA0212EB

### 5 E974-22



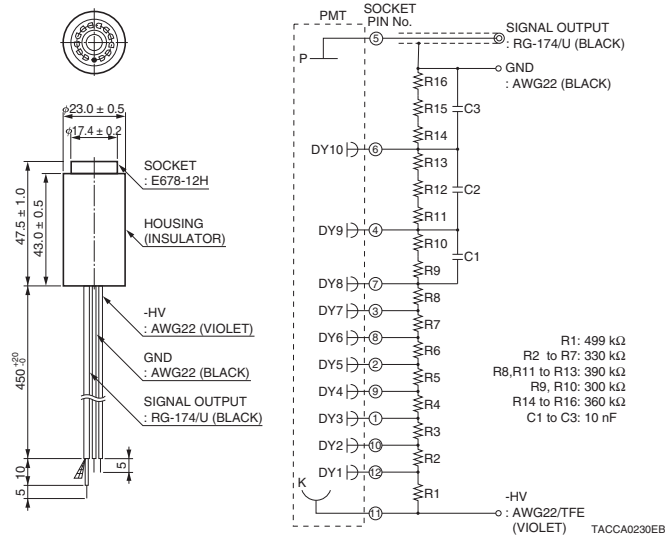
TACCA0078EC

### 6 E2253-05



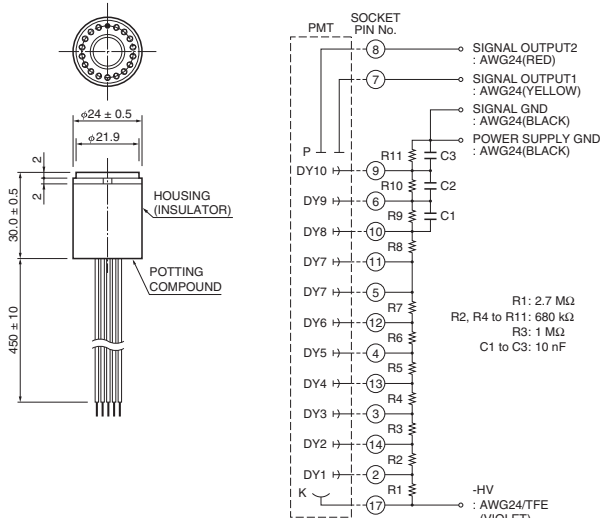
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### 7 E974-19



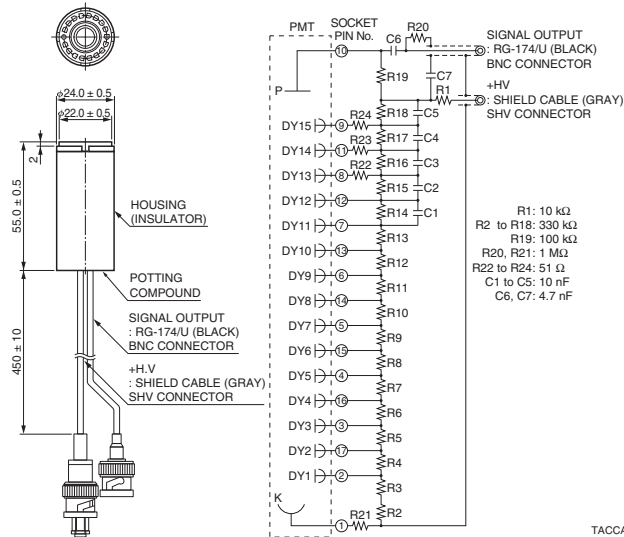
TACCA0230EB

### 8 E2037-02



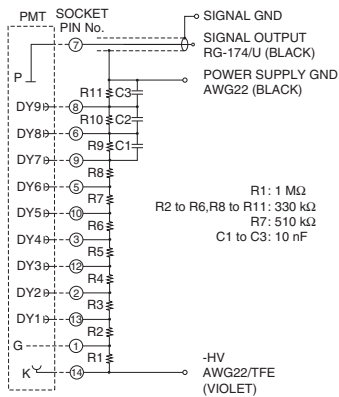
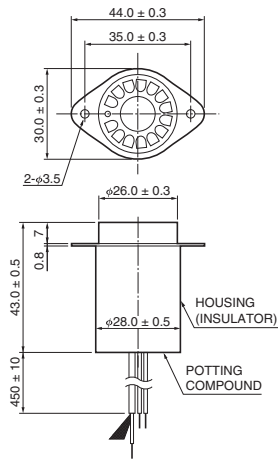
TACCA0028EC

### 9 E6133-04



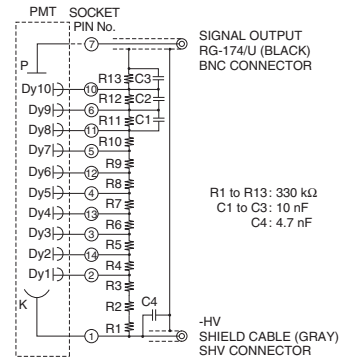
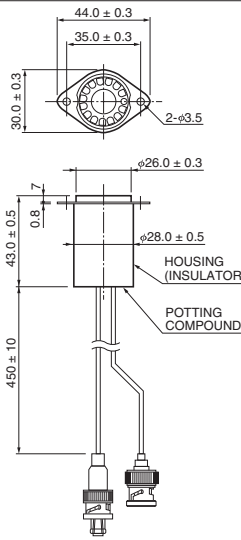
TACCA0231EB

**10 E990-29**



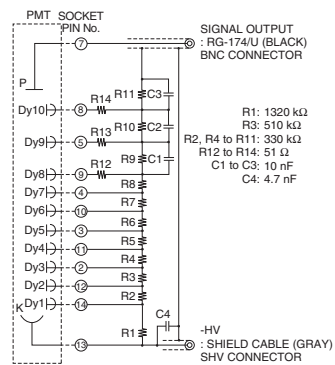
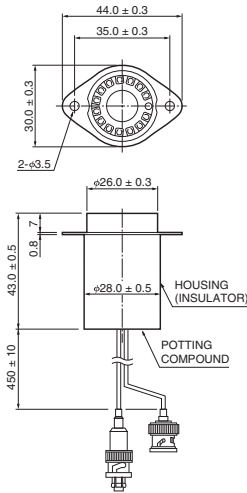
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**11 E2924-500**



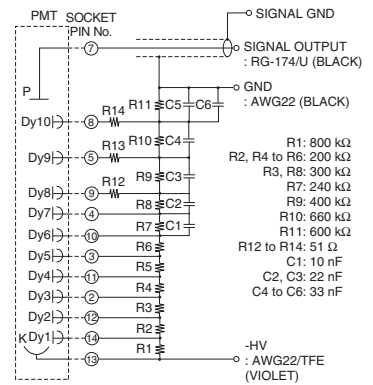
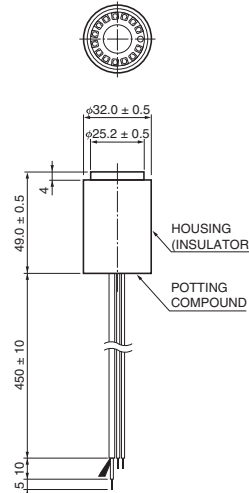
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**12 E2624-14**



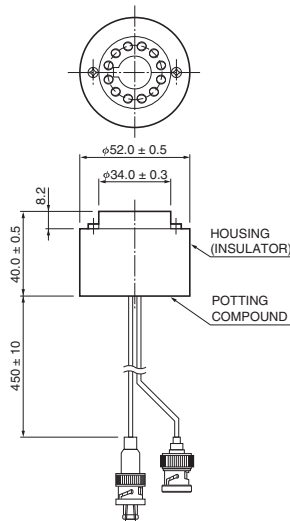
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**13 E2624-04**

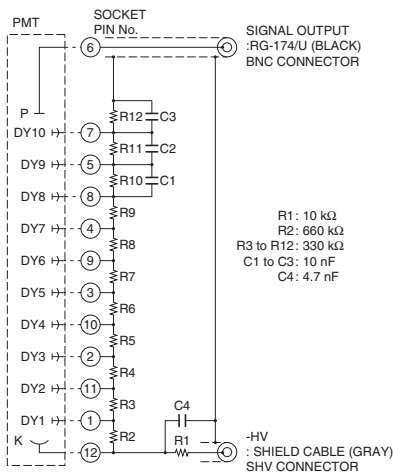


TACCA0084ED

**14 E2183-500, E2183-501**

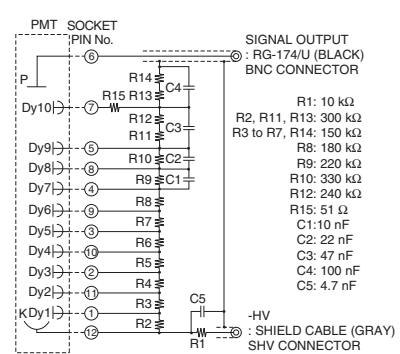


**E2183-500**



TACCA0166EC

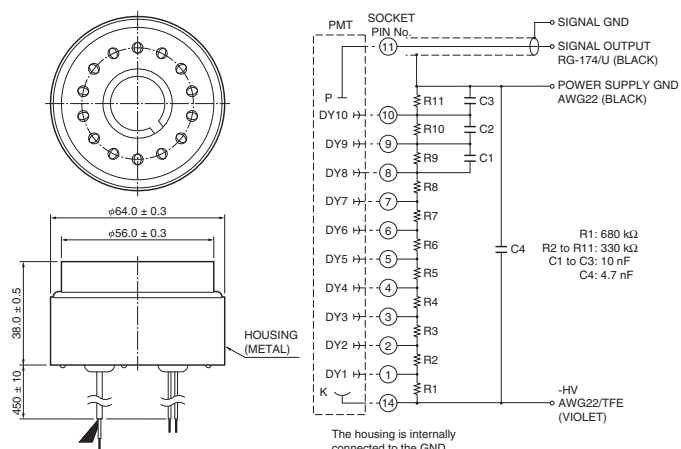
**E2183-501**



TACCA0086EC

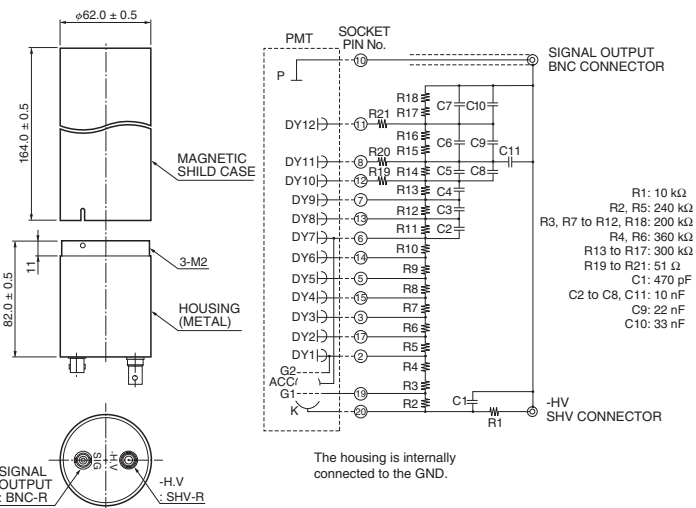


15 E1198-07



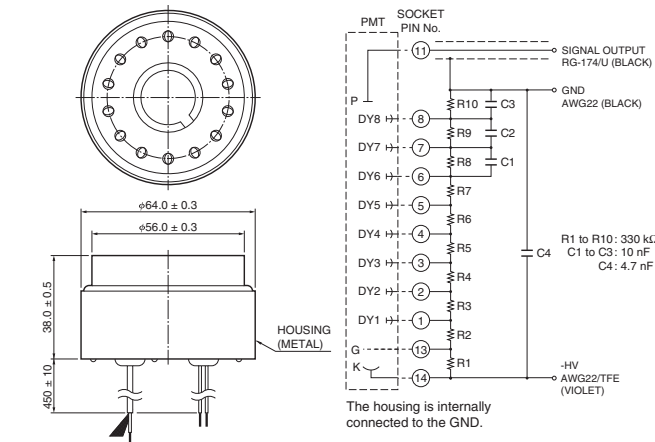
TACCA0220EB

16 E2979-500



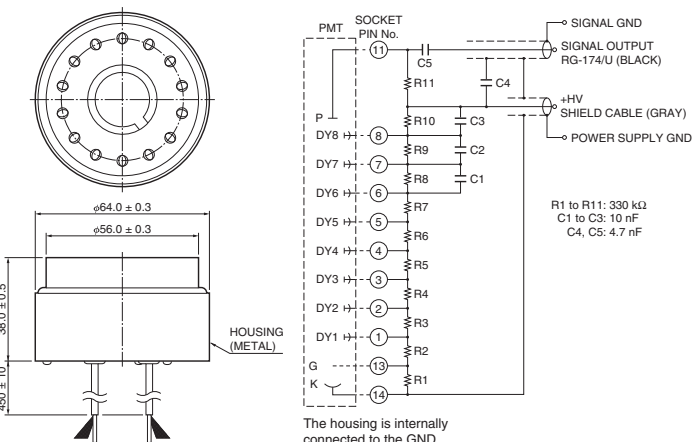
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17 E1198-05



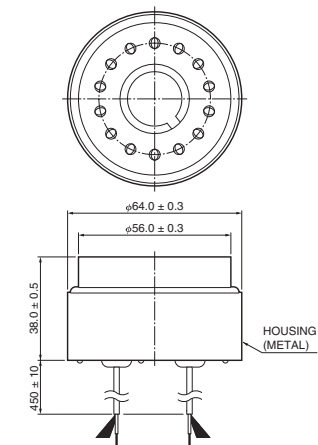
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18 E1198-20

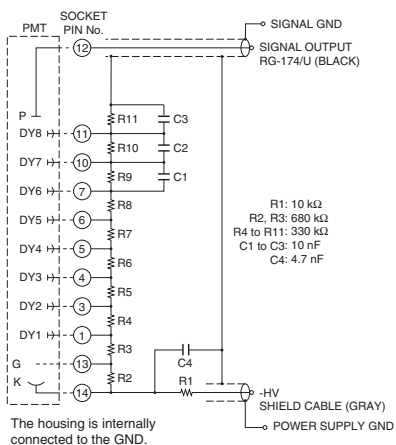


TACCA0223EC

19 E1198-26, E1198-27

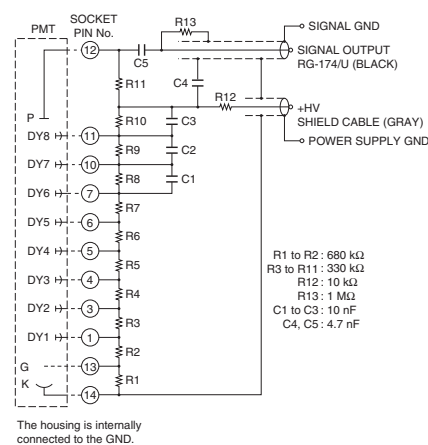


E1198-26

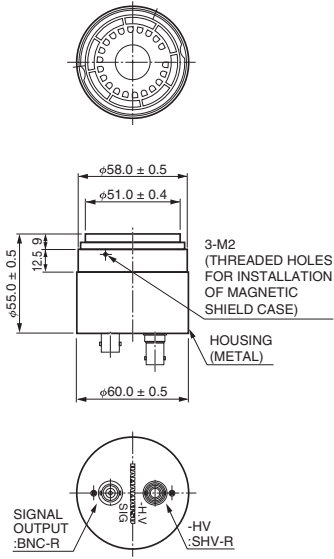


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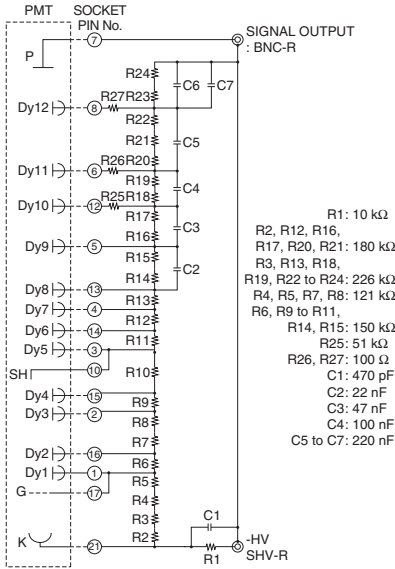
E1198-27



TACCA0225EB



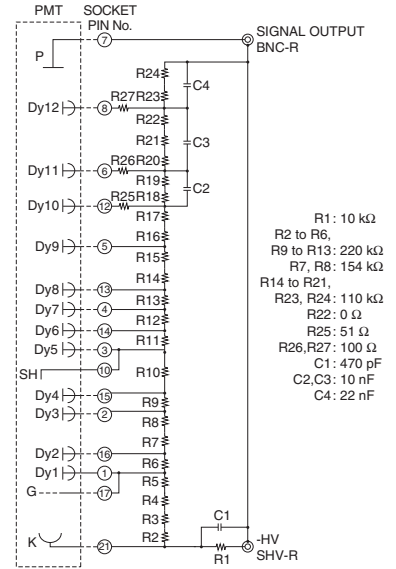
**E5859 taper bleeder circuit**  
(For R329/R331-05/R6091)



The housing is internally connected to the GND.

TACCA0176EC

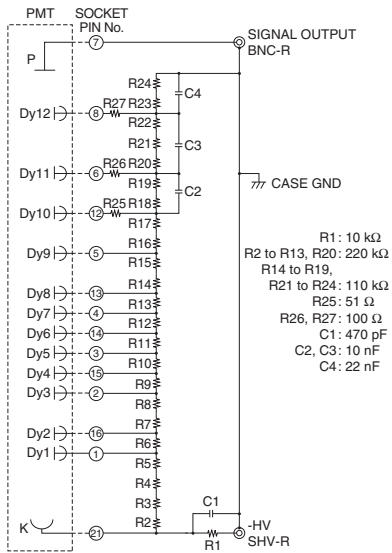
**E5859-01 standard bleeder circuit**  
(For R329/R6091)



The housing is internally connected to the GND.

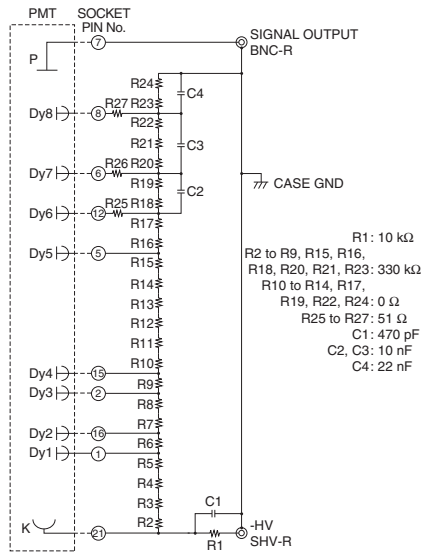
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**E5859-11**  
(For R7725)



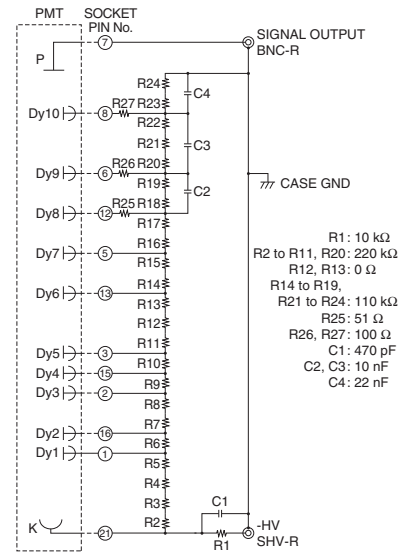
TACCA0359EA

**E5859-15**  
(For R7723)



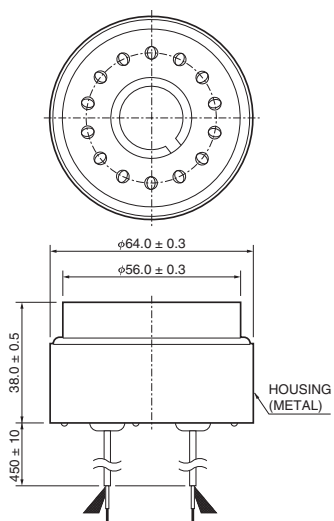
TACCA0360EA

**E5859-19**  
(For R7724)

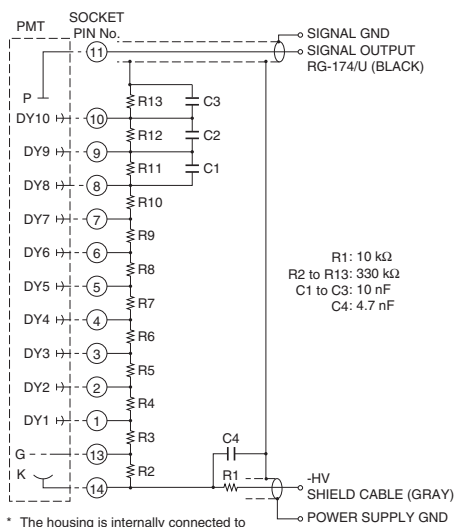


TACCA0361EA

21 E1198-22, E1198-23



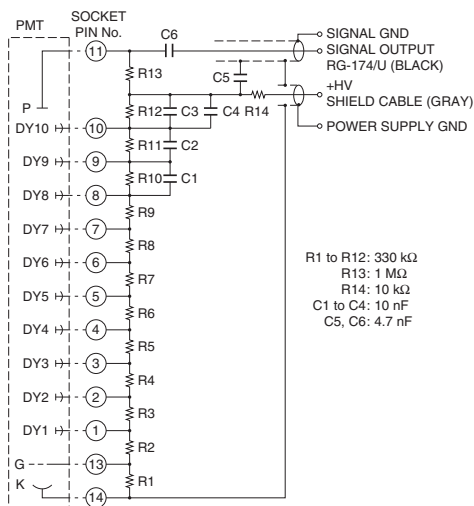
E1198-22



\* The housing is internally connected to the GND.  
 \*\* High voltage shielded cable can be connected to a connector for RG-174/U.

TACCA0168EB

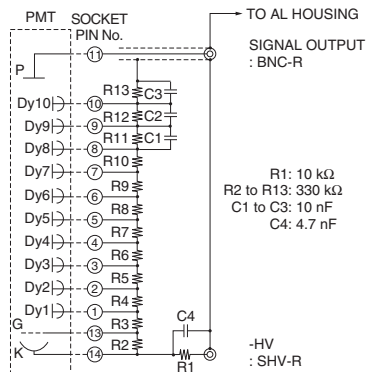
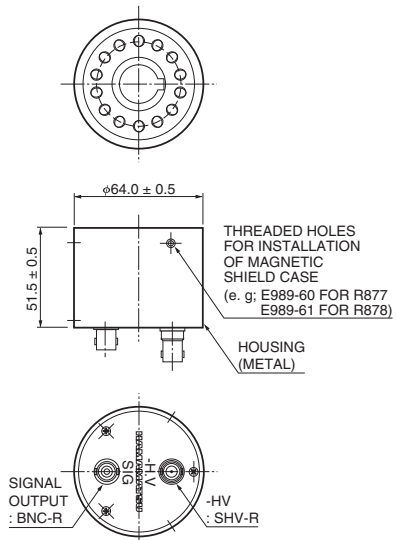
E1198-23



\* The housing is internally connected to the GND.  
 \*\* High voltage shielded cable can be connected to a connector for RG-174/U.

TACCA0169EC

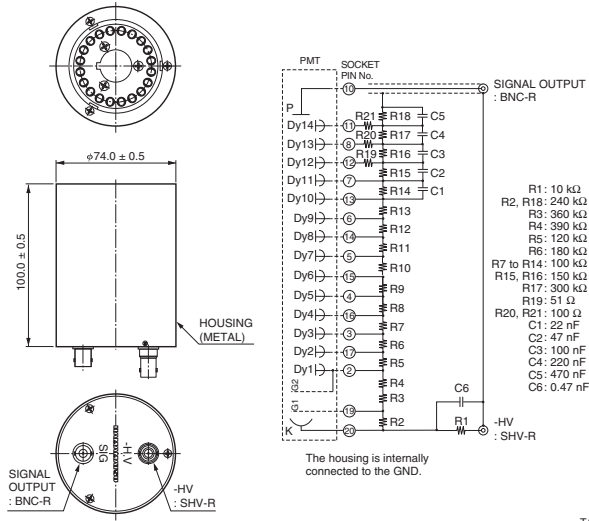
22 E6316-01



The housing is internally connected to the GND.  
 Note: Magnetic shield case is available to order separately.

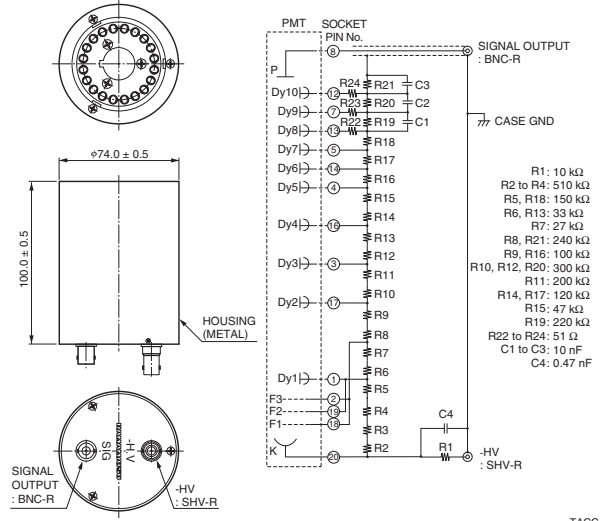
TACCA0089EB

23 E7693



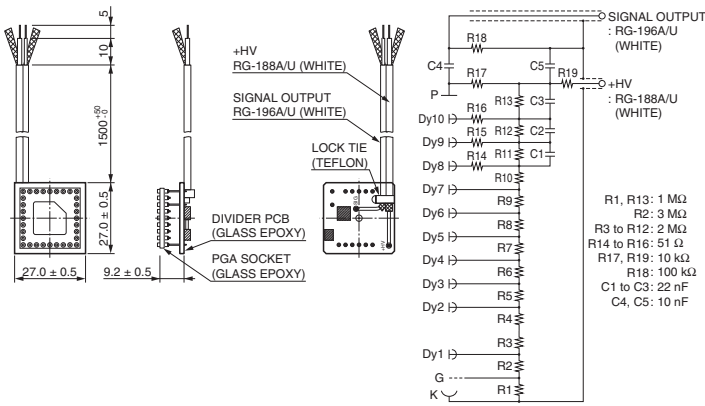
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24 E7694-02



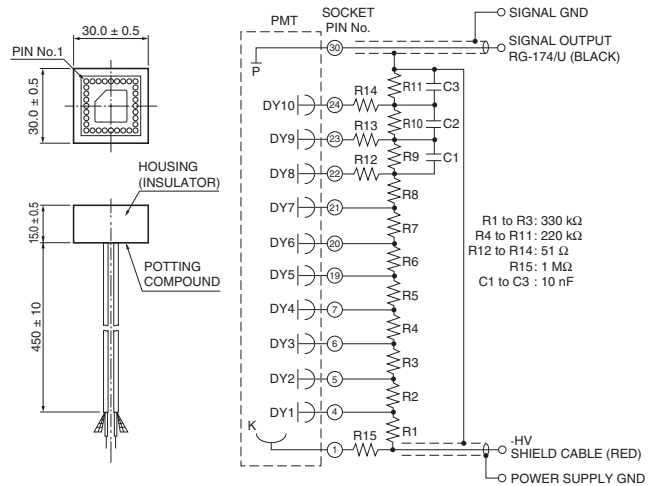
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25 E13416



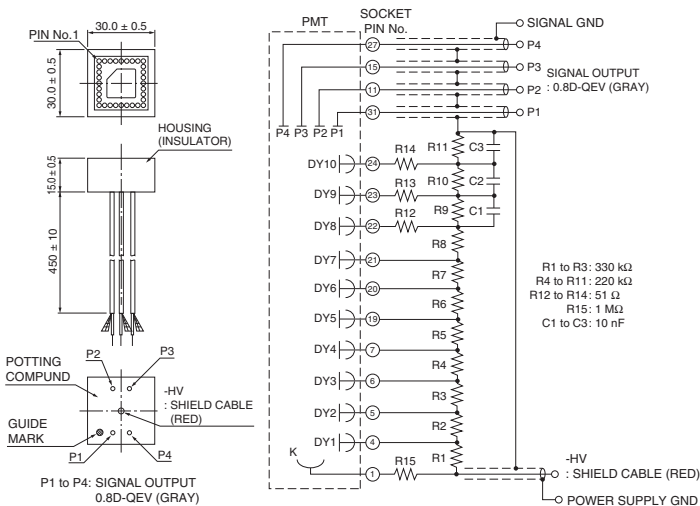
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26 E5996



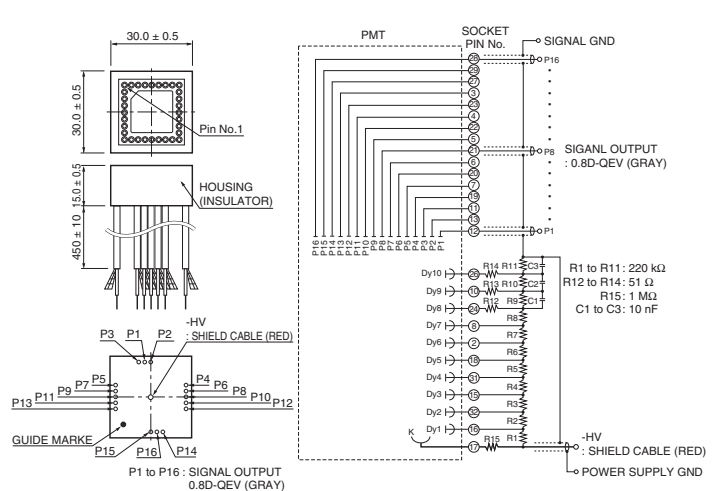
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27 E7083



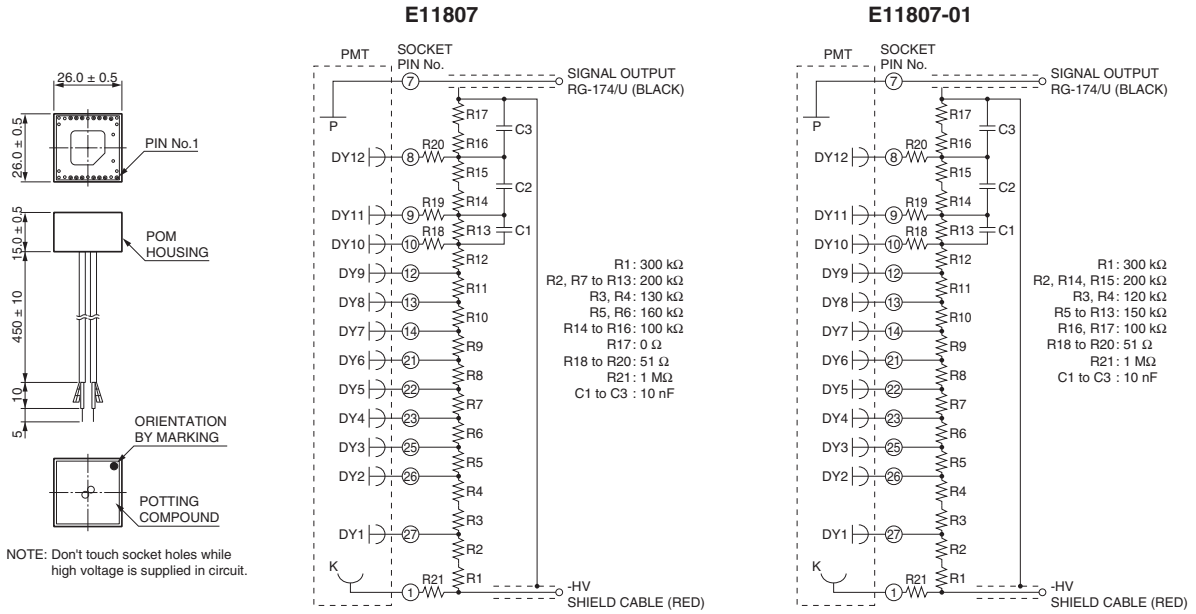
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28 E6736



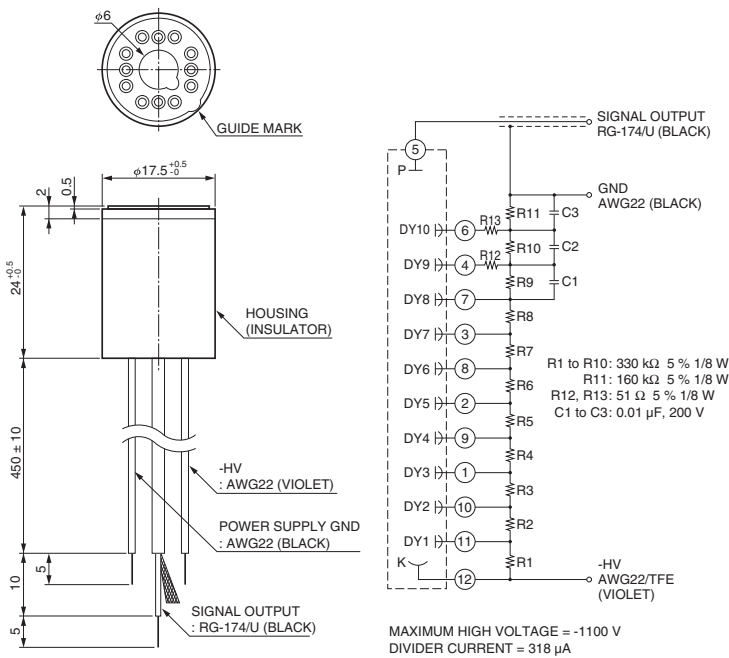
TACCA0158EE

29 E11807, E11807-01



TACCA0314EA

30 E10679-02



\* E10679-02 with SHV / BNC connector type (E10679-03) is also available.

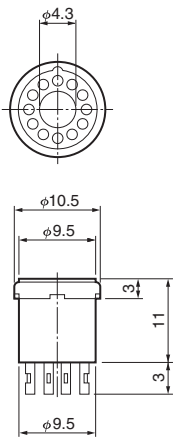
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TACCO0165EA

# Dimensional outlines

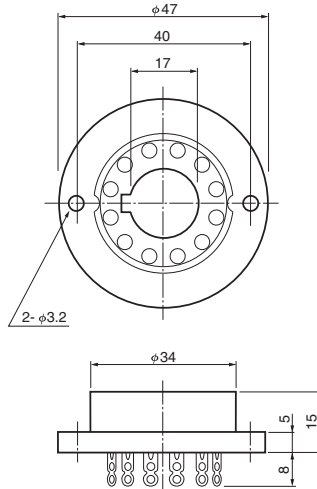
For E678 series sockets

E678-11N



TACCA0043EA

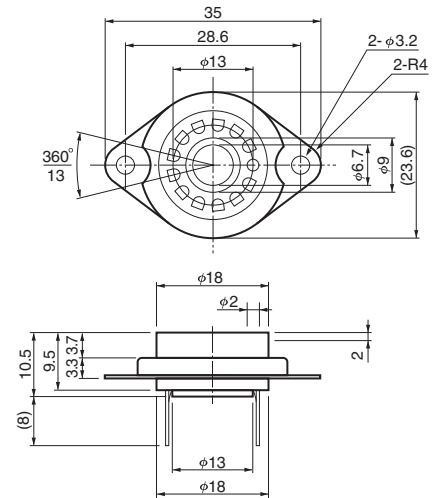
E678-12A, E678-12R\*



\* Gold plating type

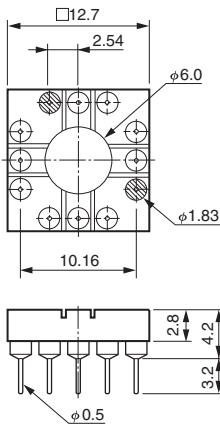
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E678-12L



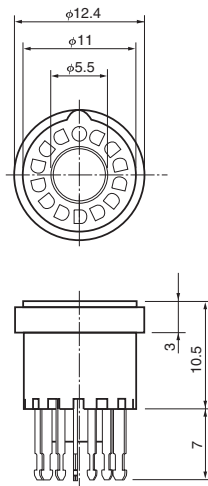
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E678-12V



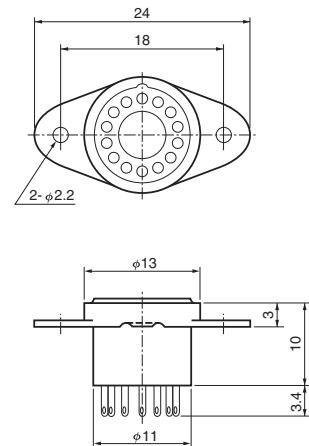
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E678-13E



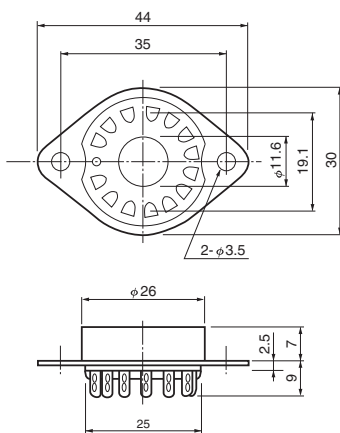
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E678-13F



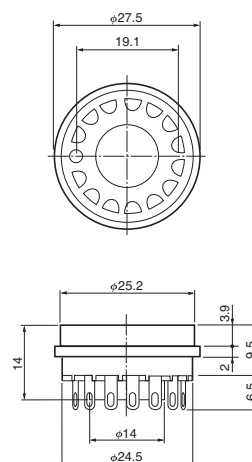
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E678-14C



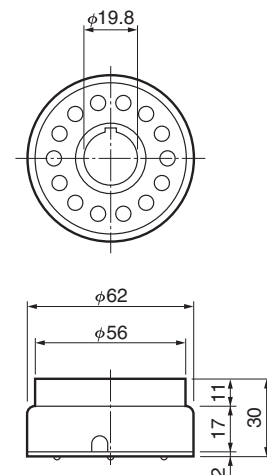
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E678-14-03



TACCA0184EA

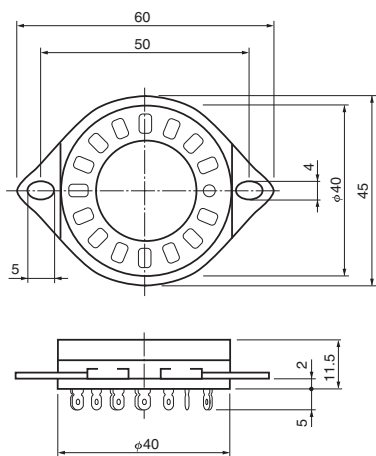
E678-14W



TACCA0200EA

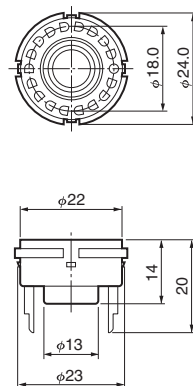
(Unit: mm)

### E678-15C



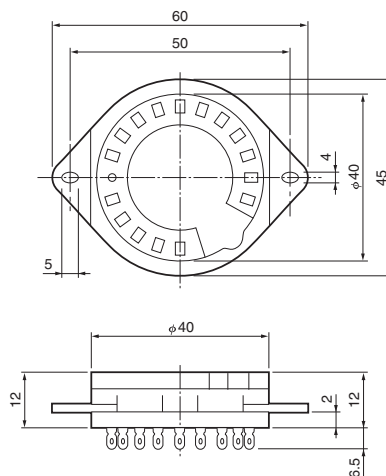
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### E678-17D



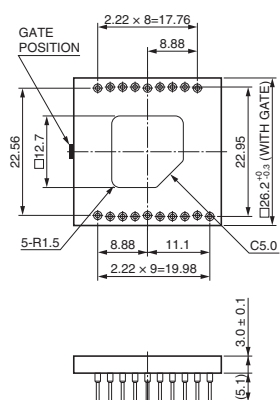
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### E678-19J



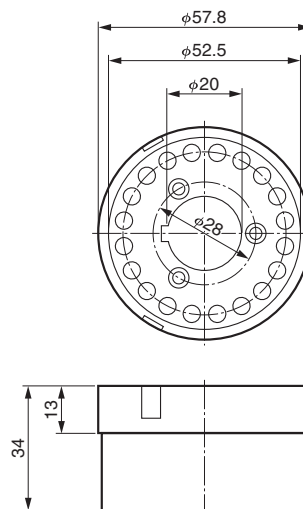
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### E678-19K



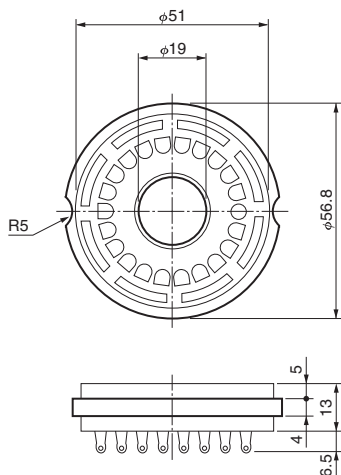
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### E678-20B



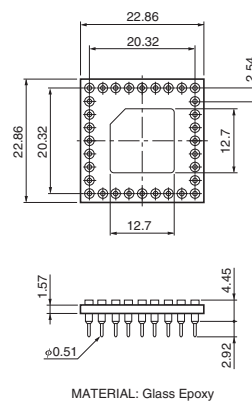
TACCA0309EA

### E678-21C



TACCA0066EC

### E678-32B



MATERIAL: Glass Epoxy

TACCA0094ED

# Index by type No.

Type number	Product	Page	Type number	Product	Page
R329-02	51 mm (2") dia. PMT	22	R3377	51 mm (2") dia. PMT	23
R331-05	51 mm (2") dia. PMT	22	R3478	19 mm (3/4") dia. PMT	20
R580	38 mm (1-1/2") dia. PMT	20	R3479	19 mm (3/4") dia. PMT	21
R647-01	13 mm (1/2") dia. PMT	20	H3695-10	Hybrid assembly	28
E678 SERIES	Socket	68, 69	R3878	10 mm (3/8") dia. PMT	21
R750	19 mm (3/4") dia. PMT	21	R3886A	38 mm (1-1/2") dia. PMT	20
R760	13 mm (1/2") dia. PMT	21	R3991A-04	19 mm (3/4") dia. PMT	20
R762	19 mm (3/4") dia. PMT	21	R3998-02	28 mm (1-1/8") dia. PMT	20
E849-68	Socket assembly	58	R3998-100-02	28 mm (1-1/8") dia. PMT (SBA type)	20
E849-90	Socket assembly	58	R4004	51 mm (2") dia. PMT	23
E849-99	Socket assembly	58	R4124	13 mm (1/2") dia. PMT	20
R877	127 mm (5") dia. PMT	22	R4125	19 mm (3/4") dia. PMT	20
R877-01	127 mm (5") dia. PMT	23	R4141	13 mm (1/2") dia. PMT	21
R877-100	127 mm (5") dia. PMT (SBA type)	22	R4177-04	13 mm (1/2") dia. PMT	21
R960	13 mm (1/2") dia. PMT	21	R4177-06	13 mm (1/2") dia. PMT	20
E974-17	Socket assembly	58	R4607A-06	51 mm (2") dia. PMT	22
E974-19	Socket assembly	58	R4998	25 mm (1") dia. PMT	20
E974-22	Socket assembly	58	R5113-02	51 mm (2") dia. PMT	23
E990-29	Socket assembly	58	R5320	25 mm (1") dia. PMT	21
R1166	19 mm (3/4") dia. PMT	20	R5505-70	Fine mesh PMT	24
E1198 SERIES	Socket assembly	58, 59	R5611A	19 mm (3/4") dia. PMT	21
R1250	127 mm (5") dia. PMT	22	R5611A-01	19 mm (3/4") dia. PMT	20
R1288A-04	25 mm (1") dia. PMT	21	E5859 SERIES	Socket assembly	59
R1288A-06	25 mm (1") dia. PMT	20	R5900U-00-L16	Metal package PMT	24
R1306	51 mm (2") dia. PMT	22	R5900U-100-L16	Metal package PMT (SBA type)	24
R1306-15	51 mm (2") dia. PMT	23	R5900U-200-L16	Metal package PMT (UBA type)	24
R1307	76 mm (3") dia. PMT	22	R5912	204 mm (8") dia. PMT	22
R1307-07	76 mm (3") dia. PMT	23	R5912-20	204 mm (8") dia. PMT	22
R1450	19 mm (3/4") dia. PMT	20	R5912-100	204 mm (8") dia. PMT (SBA type)	22
R1548-07	25 mm (1" Dual) square PMT	24	R5924-70	Fine mesh PMT	24
R1635	10 mm (3/8") dia. PMT	20	E5996	Socket assembly	59
E1761-21	Socket assembly	58	R6041	51 mm (2") dia. PMT	22
E1761-22	Socket assembly	58	R6041-406	51 mm (2") dia. PMT	22
R1828-01	51 mm (2") dia. PMT	22	R6041-506	51 mm (2") dia. PMT	22
R1924A	25 mm (1") dia. PMT	20	R6091	76 mm (3") dia. PMT	22
R1924A-01	25 mm (1") dia. PMT	21	E6133-04	Socket assembly	58
H1949-50	Hybrid assembly	28	H6152-70	Hybrid assembly	28
H1949-51	Hybrid assembly	28	R6231	51 mm (2") dia. PMT	22
E2037-02	Socket assembly	58	R6231-01	51 mm (2") dia. PMT	23
R2059	51 mm (2") dia. PMT	23	R6231-100	51 mm (2") dia. PMT (SBA type)	22
R2076	19 mm (3/4") dia. PMT	21	R6232	60 mm (2.5") dia. PMT	22
R2083	51 mm (2") dia. PMT	22	R6232-01	60 mm (2.5") dia. PMT	23
R2154-02	51 mm (2") dia. PMT	22	R6233	76 mm (3") dia. PMT	22
E2183-500	Socket assembly	58	R6233-01	76 mm (3") dia. PMT	23
E2183-501	Socket assembly	58	R6233-100	76 mm (3") dia. PMT (SBA type)	22
R2248	10 mm (3/8") square PMT	24	R6234	60 mm (2.5") hexagon PMT	24
E2253-05	Socket assembly	58	R6234-01	60 mm (2.5") hexagon PMT	25
R2256-02	51 mm (2") dia. PMT	23	R6235	76 mm (3") hexagon PMT	24
H2431-50	Hybrid assembly	28	R6235-01	76 mm (3") hexagon PMT	25
R2496	10 mm (3/8") dia. PMT	20	R6236	60 mm square PMT	24
E2624-04	Socket assembly	58	R6236-01	60 mm square PMT	25
E2624-14	Socket assembly	58	R6237	76 mm (3") square PMT	24
E2924-500	Socket assembly	58	R6237-01	76 mm (3") square PMT	25
E2979-500	Socket assembly	58	E6316-01	Socket assembly	59
R3149	51 mm (2") dia. PMT	23	H6410	Hybrid assembly	28
H3164-10	Hybrid assembly	28	R6427	28 mm (1-1/8") dia. PMT	20
H3165-10	Hybrid assembly	28	H6520	Hybrid assembly	28
H3177-50	Hybrid assembly	29	H6524	Hybrid assembly	28
H3178-51	Hybrid assembly	28	H6527	Hybrid assembly	28



Type number	Product	Page
H6533	Hybrid assembly	28
H6559	Hybrid assembly	28
E6572	Socket assembly	59
R6594	127 mm (5") dia. PMT	22
H6612	Hybrid assembly	28
H6613	Hybrid assembly	28
H6614-70	Hybrid assembly	28
E6736	Socket assembly	59
R7056	28 mm (1-1/8") dia. PMT	21
R7081	254 mm (10") dia. PMT	22
R7081-20	254 mm (10") dia. PMT	22
R7081-100	254 mm (10") dia. PMT (SBA type)	22
E7083	Socket assembly	59
R7111	28 mm (1-1/8") dia. PMT	20
H7195	Hybrid assembly	28
H7260	Hybrid assembly	26
H7260-100	Hybrid assembly (SBA type)	26
H7260-200	Hybrid assembly (UBA type)	26
R7373A-01	2 $\pi$ shape PMT	24
H7415	Hybrid assembly	28
R7525	28 mm (1-1/8") dia. PMT	20
H7546B	Hybrid assembly	26
H7546B-100	Hybrid assembly (SBA type)	26
H7546B-200	Hybrid assembly (UBA type)	26
H7546B-300	Hybrid assembly (EGBA type)	26
R7600U	Metal package PMT	24
R7600U-100	Metal package PMT (SBA type)	24
R7600U-200	Metal package PMT (UBA type)	24
R7600U-300	Hybrid assembly (EGBA type)	24
R7600U-00-M4	Metal package PMT	24
R7600U-100-M4	Metal package PMT (SBA type)	24
R7600U-200-M4	Metal package PMT (UBA type)	24
R7600U-300-M4	Hybrid assembly (EGBA type)	24
R7600U-03	Metal package PMT	25
E7693	Socket assembly	59
E7694-02	Socket assembly	59
E7694-03	Socket assembly	59
R7723	51 mm (2") dia. PMT	22
R7724	51 mm (2") dia. PMT	22
R7724-100	51 mm (2") dia. PMT (SBA type)	22
R7725	51 mm (2") dia. PMT	22
R7761-70	Fine mesh PMT	24
R7899	25 mm (1") dia. PMT	21
R7899-01	25 mm (1") dia. PMT	20
H8135	Hybrid assembly	28
R8143	2 $\pi$ shape PMT	24
H8409-70	Hybrid assembly	28
R8520-406	Metal package PMT	24
R8520-506	Metal package PMT	24
R8619	25 mm (1") dia. PMT	20
H8643	Hybrid assembly	28
H8711	Hybrid assembly	26
H8711-100	Hybrid assembly (SBA type)	26
H8711-200	Hybrid assembly (UBA type)	26
H8711-300	Hybrid assembly (EGBA type)	26
H8804	Hybrid assembly	26
H8804-100	Hybrid assembly (SBA type)	26
H8804-200	Hybrid assembly (UBA type)	26
H8804-300	Hybrid assembly (EGBA type)	26

Type number	Product	Page
R8997	38 mm (1-1/2") dia. PMT	24
R9420	38 mm (1-1/2") dia. PMT	20
R9420-100	38 mm (1-1/2") dia. PMT (SBA type)	20
R9800	25 mm (1") dia. PMT	20
R9800-100	25 mm (1") dia. PMT (SBA type)	20
R9800U-110	Metal package PMT (SBA type)	24
R9800U-210	Metal package PMT (UBA type)	24
R10233	90 mm (3.5") dia. PMT	22
R10233-01	90 mm (3.5") dia. PMT	23
R10233-100	90 mm (3.5") dia. PMT (SBA type)	22
H10515B-100	Hybrid assembly (SBA type)	26
H10515B-200	Hybrid assembly (UBA type)	26
R10550	38 mm (1-1/2" quadrant) square PMT	24
H10580	Hybrid assembly	28
E10679-02	Socket assembly	59
R10806	102 mm (4") dia. PMT	22
R10806-100	102 mm (4") dia. PMT (SBA type)	22
R11065	76 mm (3") dia. PMT	22
R11102	38 mm (1-1/2") dia. PMT	20
R11265U-100	Metal package PMT (SBA type)	24
R11265U-200	Metal package PMT (UBA type)	24
R11265U-300	Metal package PMT (EGBA type)	24
R11410	76 mm (3") dia. PMT	22
E11807	Socket assembly	59
E11807-01	Socket assembly	59
R11833-03	127 mm (5") dia. PMT	22
R11833-100-03	127 mm (5") dia. PMT (SBA type)	22
H11934-100	Hybrid assembly (SBA type)	26
H11934-200	Hybrid assembly (UBA type)	26
H11934-300	Hybrid assembly (EGBA type)	26
R12199	80 mm dia. PMT	22
R12421	13 mm (1/2") dia. PMT	20
R12421-03	13 mm (1/2") dia. PMT	21
R12421-300	13 mm (1/2") dia. PMT (EGBA type)	20
H12428-100	Hybrid assembly (SBA type)	26
H12428-200	Hybrid assembly (UBA type)	26
H12445-100	Hybrid assembly (SBA type)	26
H12445-200	Hybrid assembly (UBA type)	26
H12690	13 mm (1/2") dia. PMT assembly	28
H12690-300	13 mm (1/2") dia. PMT assembly (EGBA type)	28
H12700A	Hybrid assembly	26
H12700A-10	Hybrid assembly	26
H12700A-03	Hybrid assembly	27
H12700B	Hybrid assembly	26
H12700B-10	Hybrid assembly	26
R12860	508 mm (20") dia. PMT	22
R13089	51 mm (2") dia. PMT	22
H13226A-100	Hybrid assembly (SBA type)	26
H13226A-200	Hybrid assembly (UBA type)	26
R13408	38 mm (1-1/2") dia. PMT	20
E13416	Socket assembly	59
R13435	51 mm (2") dia. PMT	22
R13449	28 mm (1-1/8") dia. PMT	20
R13478	25 mm (1") dia. PMT	20
H13700	Hybrid assembly	26
H13700A-03	Hybrid assembly	27
H13974-00-1616	Hybrid assembly	26
H13974-03-1616	Hybrid assembly	27

# CAUTIONS AND WARRANTY

## WARNING



### **Take sufficient care to avoid an electric shock hazard**

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

ate interlocks to protect the operator and service personnel. The metal housing of the Metal Package PMT R8520-406 and R8520-506 and R11065 series and R11410 series are connected to the photocathode (potential) so that it becomes a high voltage potential when the product is operated at a negative high voltage (anode grounded).

## PRECAUTIONS FOR USE

### ● **Handle tubes with extreme care**

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

### ● **Keep faceplate and base clean**

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

### ● **Do not expose to strong light**

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

### ● **Handling of tubes with a glass base**

A glass base (also called button stem) is less rugged than a plastic base, so care should be taken in handling this type of

tube. For example, when fabricating the voltage-divider circuit, solder the divider resistors to socket lugs while the tube is inserted in the socket.

### ● **Cooling of tubes**

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

### ● **Helium permeation**

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

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

## WARRANTY

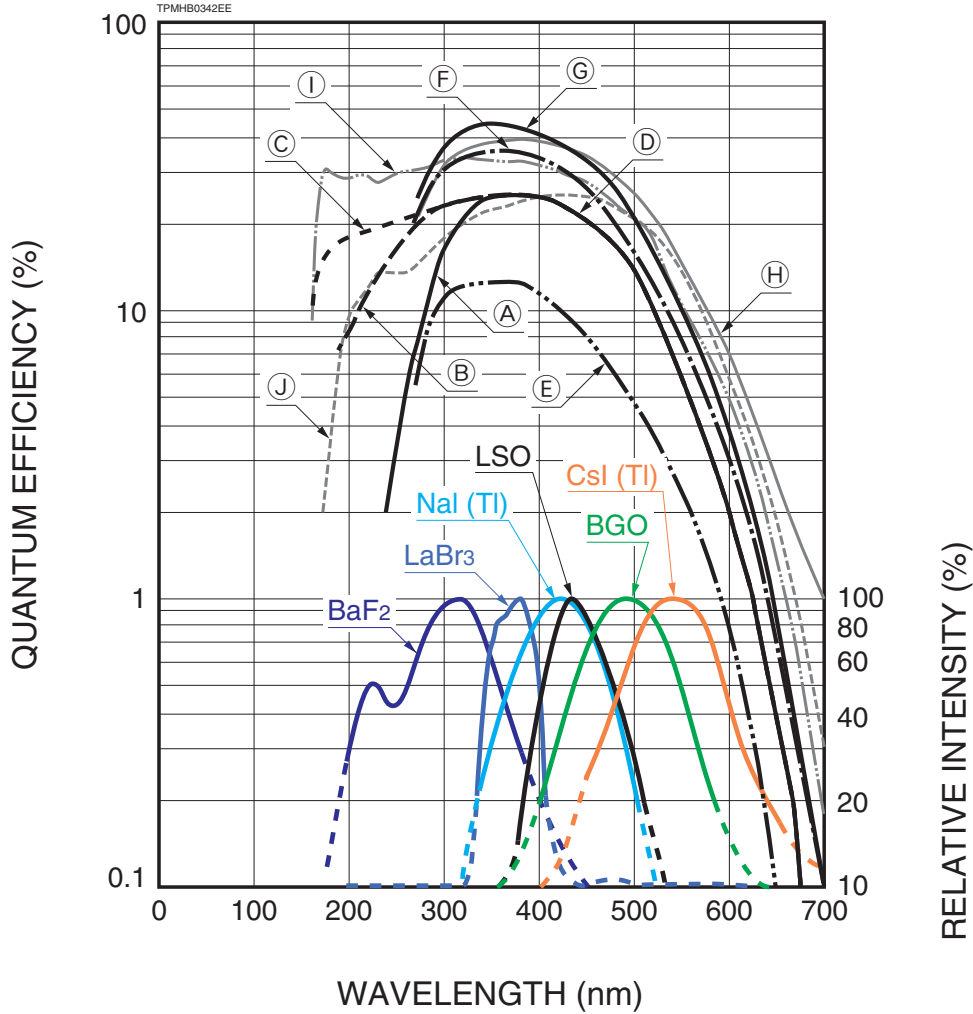
Hamamatsu photomultiplier tubes and related products are warranted to the original purchaser for a period of 12 months after delivery. The warranty is limited to repair or replacement of a defective product due to defects in workmanship or materials used in its manufacture.

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.

# Typical photocathode spectral response and emission spectrum of scintillators



- Ⓐ: Bialkali photocathode (Borosilicate glass)
- Ⓑ: Bialkali photocathode (UV glass)
- Ⓒ: Bialkali photocathode (Silica glass)
- Ⓓ: Bialkali photocathode
- Ⓔ: High temp. bialkali photocathode
- Ⓕ: Super bialkali
- Ⓖ: Ultra bialkali
- Ⓗ: Extended green bialkali
- Ⓙ: Low temp. (down to -110 °C) bialkali photocathode
- ⓰: Low temp. (down to -186 °C) bialkali photocathode

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Photomultiplier Tube Modules  
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Image Intensifiers  
Xenon Lamps / Mercury Xenon Lamps  
Deuterium Lamps  
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Quality, technology and service are part of every product.

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