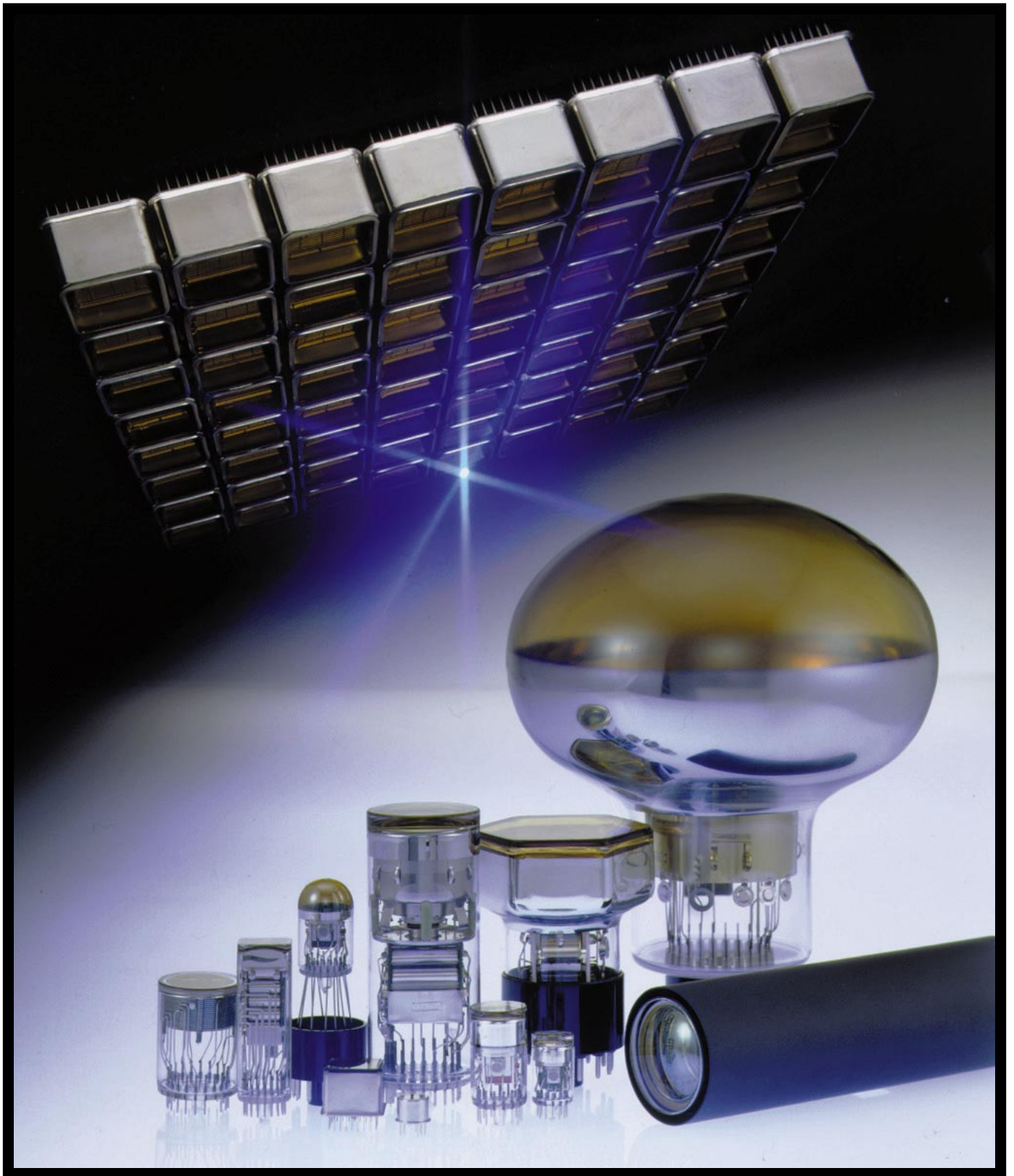


Photomultiplier Tubes and Assemblies For Scintillation Counting & High Energy Physics



HAMAMATSU

INTRODUCTION

In ionizing 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 ionizing 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 (TTS), high stability & reliability, and to be operatable in high magnetic field environment or at high temperature condition. 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
and High Energy Physics

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Operating Characteristics

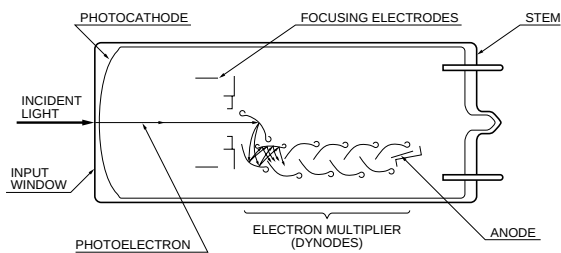
This section describes the prime features of photomultiplier tube construction and basic operating characteristics.

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



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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 λ 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 300nm.

For scintillation counting application, the low noise borosilicate glass (this is called K-free glass) may be used. It contains very little amount of potassium (K_2O and ^{40}K) which can cause unwanted background noise because of its radioisotopes.

(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 185nm.

(3) Synthetic silica

This material transmits ultraviolet light down to 160nm. 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.

(3) Extended Green Bialkali

This is a variant of bialkali photocathode and has especially high sensitivity in a green region. It's suitable for scintillating tile or fiber calorimeters with wavelength shifters and for CsI(Tl) scintillators.

As stated above, the spectral response range is determined by the materials of the photocathode and the window as shown in Figure 20.

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 2856K.

The cathode luminous sensitivity is expressed in the unit of $\mu A/lm$ (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).

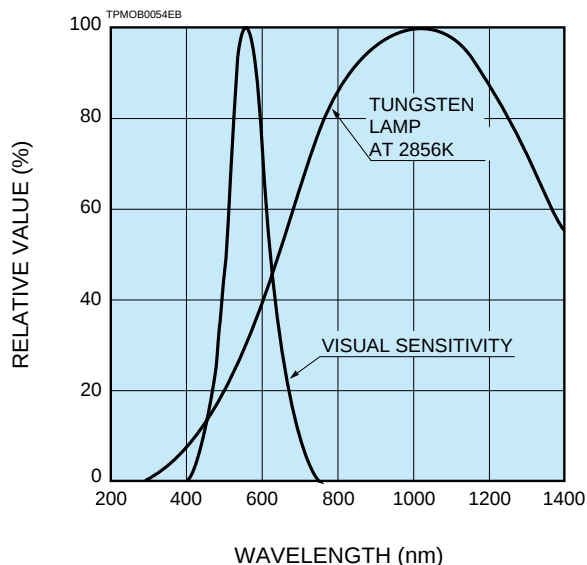
The cathode blue sensitivity is the photoelectric current from the photocathode per incident light flux of a tungsten filament lamp at 2856K passing through a blue filter. Corning CS-5-58 filter which is polished to half stock thickness is used for the measurement of this sensitivity. This filter is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

Since the light flux, once transmitted through the blue filter, can not be expressed in lumen, the blue sensitivity is usually represented in $\mu A/lm-b$ (micro ampere per lumen-blue).

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 may dominate the 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 2856K 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 cage 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) Coarse mesh

Immunity to magnetic fields, high pulse linearity, position detection possible.

(8) Metal channel type

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

Also hybrid dynodes combining two of the above dynodes have been developed. These hybrid dynodes are designed to provide the merits of each dynode type.

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 2856K. This is expressed in the unit of 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 δ^n , where n is the number of dynode stage and δ is an average secondary emission ratio.

While the secondary electron emission ratio δ is given by

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

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

When a voltage V is applied between the cathode and the anode of 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

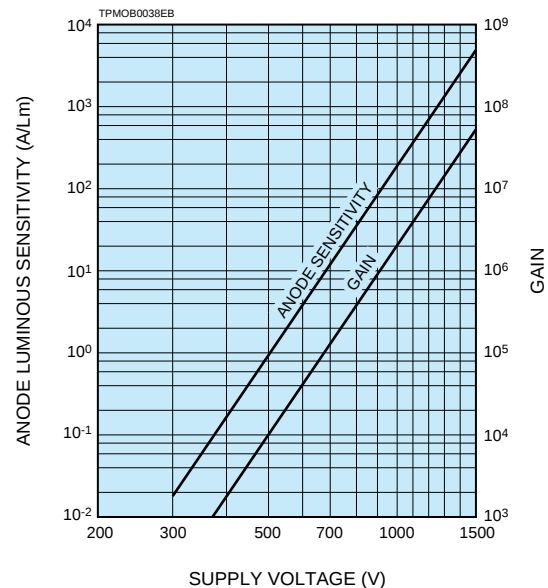


Figure 3 shows gain characteristics.

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 coating: see page 9).

(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 200 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.

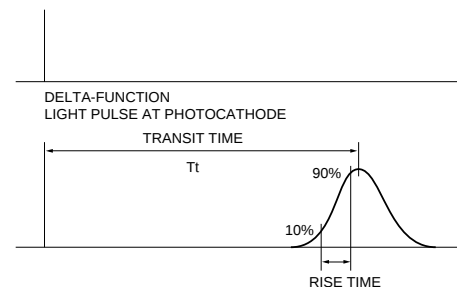
(2) Electron Transit Time (refer to Figure 4)

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)

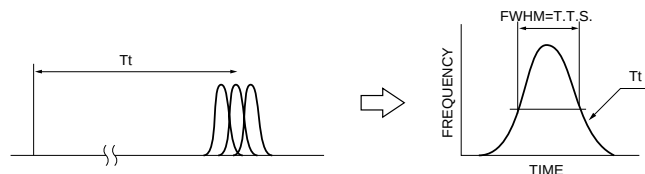
This is also called the transit time jitter. This is the fluctuation in transit time between individual pulses, and may be defined as the FWHM of the frequency distribution of electron transit times. T.T.S. depends on the number of incident photons. The values in this catalog are measured in the single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

Figure 4 : Definition of Rise Time and Transit Time



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Figure 5 : Definition of T.T.S.



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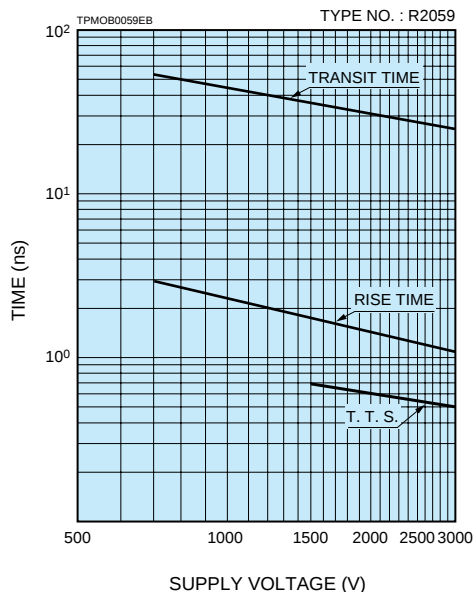
(4) C.R.T. (Coincident Resolving Time)

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}Na). The scintillators used are CsF, BGO or BaF₂ 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 or circular cage 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 (51mm dia. head-on, 12-stage, linear-focused type).

Figure 6 : Time Response Characteristics vs. Supply Voltage



7. PULSE LINEARITY

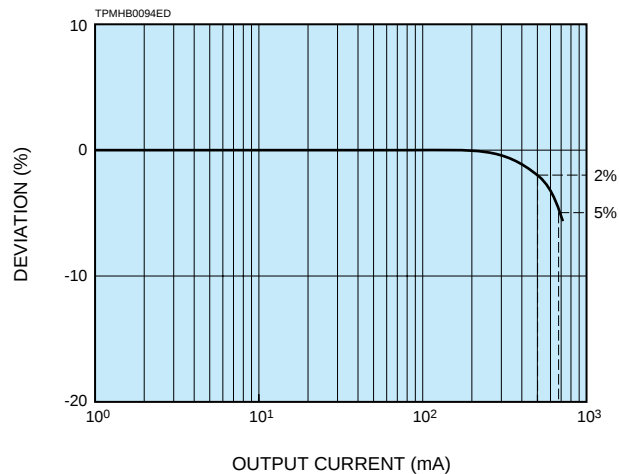
The definition of the pulse linearity is proportionality between the input light amount and the output current in the pulse operation mode. When intense light pulses are to be measured, it's necessary to know the pulse linearity range of the PMT.

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 50ns and the repetition rate is 1kHz.

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. Even if the electrical charge is small, the pulse height of the PMT output should be considered.

Figure 7 : Example of Pulse Linearity Characteristic



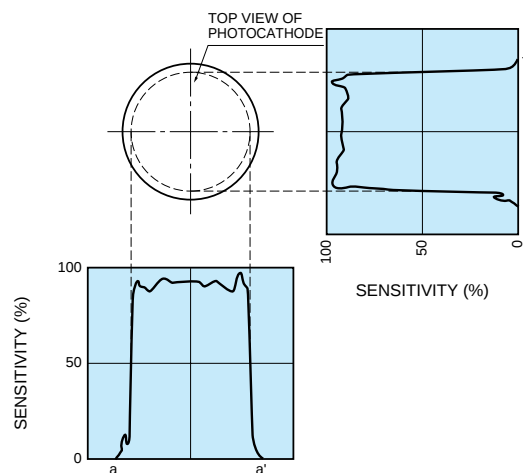
The special voltage distribution ratios are designed to achieve strong electric fields in the later stages of the electron multiplier. Some types are specified with these special voltage dividers.

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.

In general, head-on type PMT's provide better spatial uniformity than side-on type PMT's because of less limitations in the photocathode to first dynode geometry. Tubes 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}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 1k cps:

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

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

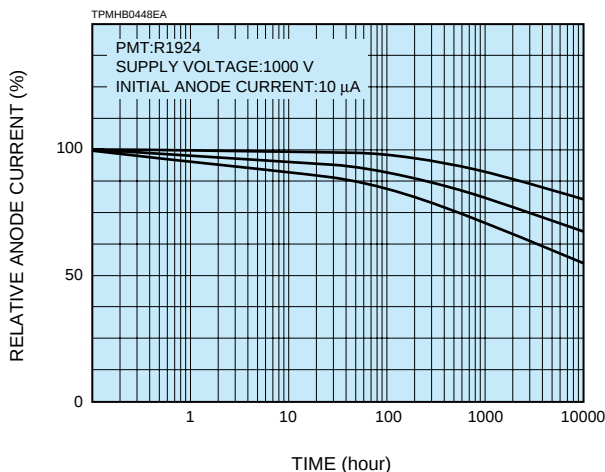
This is the gain shift against count rate change. The tube is initially operated at about 10k cps. The photo-peak count rate is then decreased to approximately 1k cps by increasing the distance between the ^{137}Cs source and the scintillator coupled to the PMT.

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 10^3 to 10^4 hrs 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

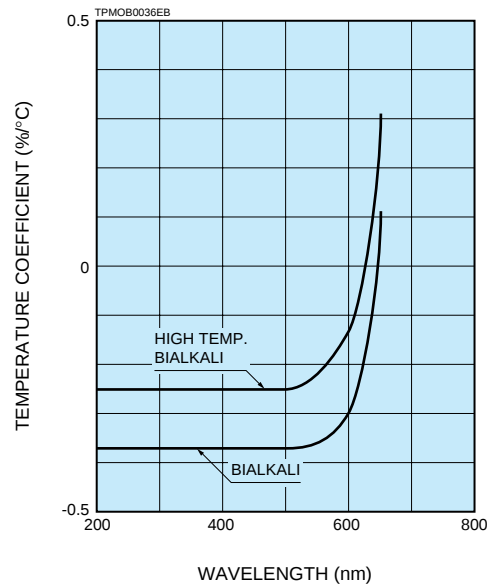


10. ENVIRONMENT

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 60mm and the thickness is 0.8mm, can be used in a magnetic field of around 5mTesla without saturation. If a magnetic field strength is more than 10mTesla, the double shielding method is necessary for a conventional PMT, otherwise proximity mesh types should be used. 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

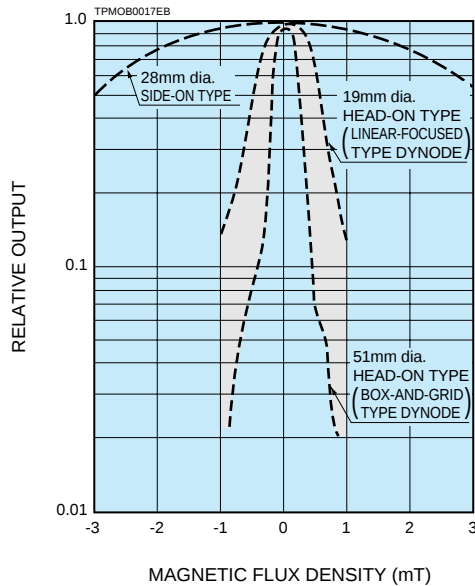
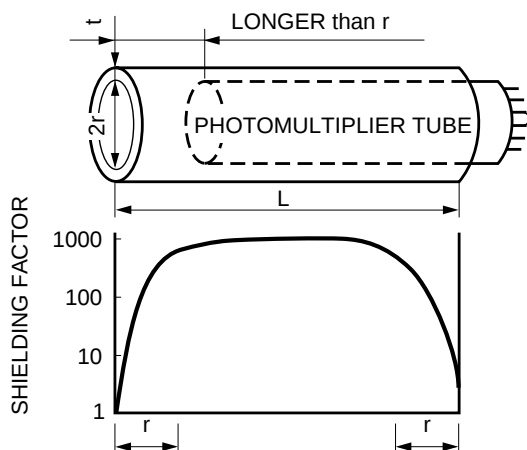


Figure 12 : Edge Effect of Magnetic Shield Case



The proximity mesh made of non-magnetic material has been introduced as alternate dynodes in PMT's. These types (see page 22) exhibit much higher immunity to external magnetic fields than the conventional PMT's. Also triode and tetrode types (see page 22) are useful for applications at high light intensities.

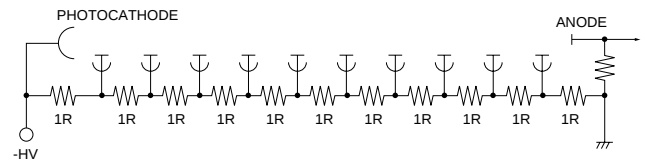
11. VOLTAGE DIVIDER CONSIDERATION

11.1 General

Interstage voltages for PMT dynodes are usually supplied by a voltage divider network consisting of multiple series resistors. Schematic diagrams of typical voltage divider networks are illustrated in Figure 13. Circuit (a) is a basic arrangement and (b) is for pulse operations. Figure 14 shows the response of a PMT using the voltage divider (a) as a function of the input light flux. The deviation from the linearity (over-response, region B) is caused by an increase in dynode voltages resulting from the redistribution of the decreased voltage primarily between the last dynode and the anode. As the input light level increases, the anode output current begins to saturate at near the value of the current flowing through the voltage divider (region C) due to the effect of voltage losses in the last few stages. Therefore, the upper limit of dynamic range of the PMT is determined by the voltage divider current. To prevent this problem, it is suggested that the voltage divider current be maintained at least 20 times the anode output current required from the PMT.

Figure 13 : Schematic Diagrams of Voltage Divider Networks

(a) Basic arrangement for DC operation



(b) For pulse operation

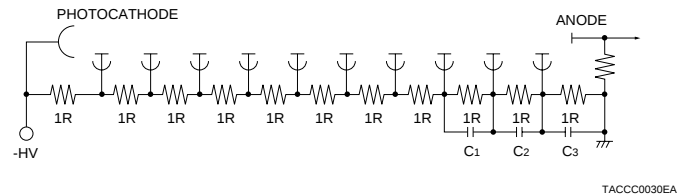
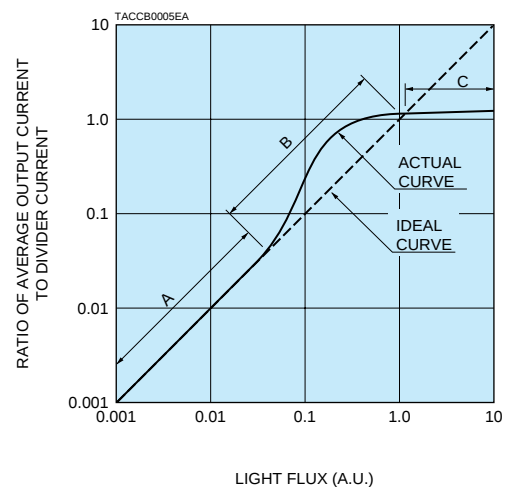


Figure 14 : Response of a PMT Using Voltage Divider (a)



11.2 Decoupling (Charge Storage) Capacitors

Generally high output current is required in applications where the input light is in the form of pulses. In order to maintain dynode potentials at a constant value during pulse durations and handle high peak currents, large capacitors are used as shown in Figure 13(b). The capacitor values depend on the output charge. If linearity of better than 1% is needed, the capacitor value between the last dynode and the anode should be at least 100 times the output charge per pulse, as shown in the following formula:

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

where I is the peak output current in amperes, t is the pulse width in seconds, and V is the voltage across the capacitor in volts. Hamamatsu provides socket assemblies incorporating voltage divider networks. They are compact, rugged, and carefully engineered to minimize electric leakage. (See page 52.)

12. CATHODE POTENTIAL

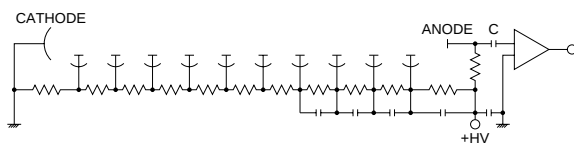
12.1 General

The general technique used for voltage divider circuits is to ground the anode with a high negative voltage applied to the cathode. This scheme eliminates the potential difference between the external circuit and the anode, facilitating the connection of such circuits such as ammeters or current to voltage conversion operational amplifiers to the PMT.

In scintillation counting, it's often impossible to use this technique, since the grounded scintillator is directly coupled to the PMT.

In such cases, it's recommended that the cathode is grounded, as shown in Figure 15, with a high positive voltage applied to the anode.

Figure 15 : Cathode Ground Scheme



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Using this scheme, a coupling capacitor C is used to isolate the high positive voltage applied to the anode from the signal, making it impossible to obtain a DC signal output. If the count rate of the PMT output pulses is high, this scheme may cause a base line shift.

12.2 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.

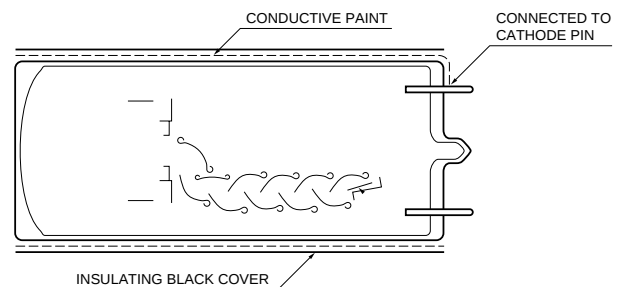
For these reasons, when designing a PMT housing with an electrostatic or magnetic shield case, extreme care should be required.

12.3 HA Coating

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 16. This method is called HA coating.

Figure 16 : HA Coating



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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 17.

Figure 17 : Incident Particles and PMT Output

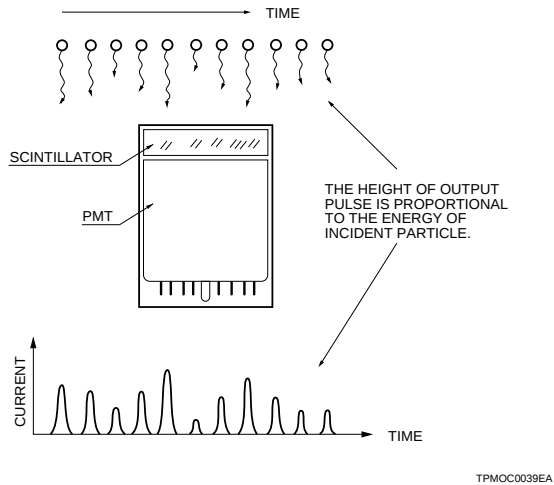
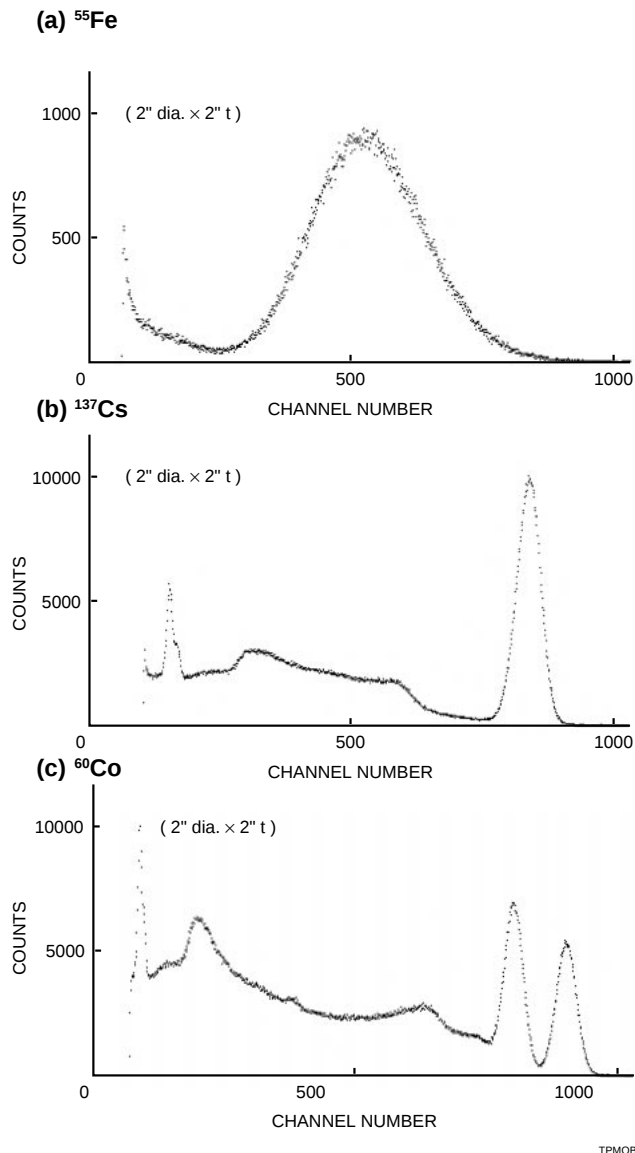


Figure 18: Typical Energy Spectra of NaI(Tl) Scintillator

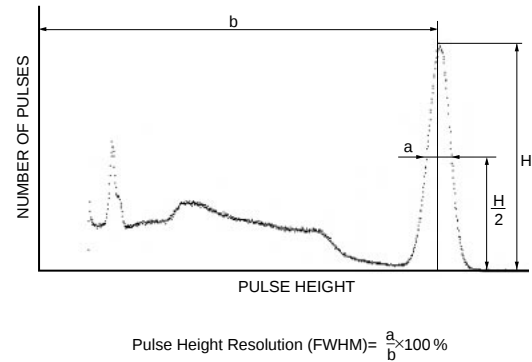


By analyzing these output pulses using a multichannel analyzer (MCA), pulse height distribution (PHD) or energy spectra, as shown in Figure 18, are obtained. From the PHD, the number of incident particles at various energy levels can be measured.

13.2 Energy Resolution

For the energy spectrum measurement, it's 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 19 shows the definition of the energy resolution using NaI(Tl) scintillator and ^{137}Cs γ -ray source. It's customarily stated as a percentage.

Figure 19 : Definition of Pulse Height Resolution



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

η : quantum efficiency

α : collection efficiency

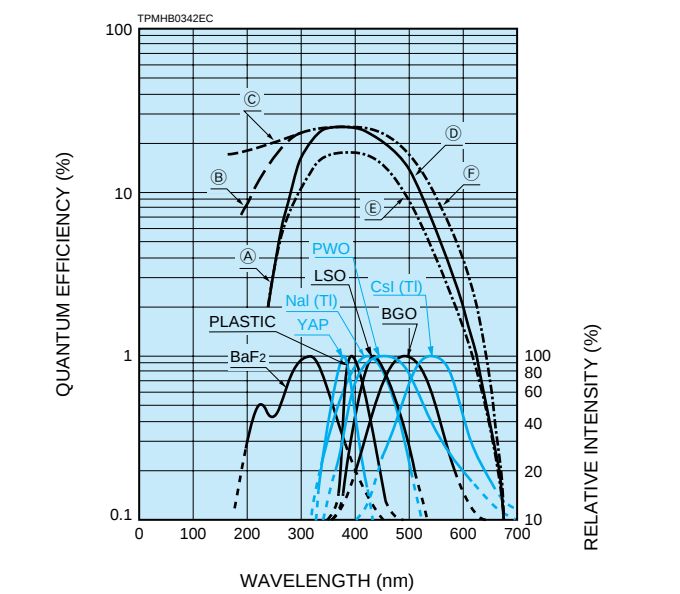
δ : mean secondary emission yield of each dynode

To obtain a good energy resolution, it's important to use a good scintillator having a high efficiency and a good intrinsic energy resolution. It's also important to reduce a light loss between a PMT and a scintillator. For this purpose, it's useful to couple them with silicon oil having a refractive index close to that of the face-plate window used in the PMT.

13.3 Emission Spectrum of Scintillator

The quantum efficiency of the PMT is one of the main factor of the energy resolution. It's necessary to choose the PMT whose spectral response matches the scintillator emission. Figure 20 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 20 : Typical Spectral Response and Emission Spectra of Scintillators



- Ⓐ : Borosilicate Glass
- Ⓑ : UV Glass
- Ⓒ : Synthetic Silica
- Ⓓ : Bialkali Photocathode
- Ⓔ : High Temp. Bialkali Photocathode
- Ⓕ : Extended Green Bialkali Photocathode

13.4 Features of Scintillators

Figure 21 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 manufactures.

Figure 21 : Typical Temperature Response of Various Scintillators

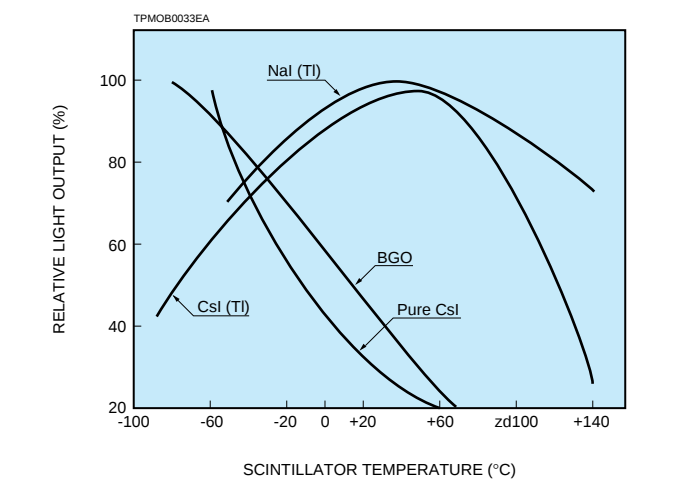


Table 1 : Summary of Scintillator Characteristics

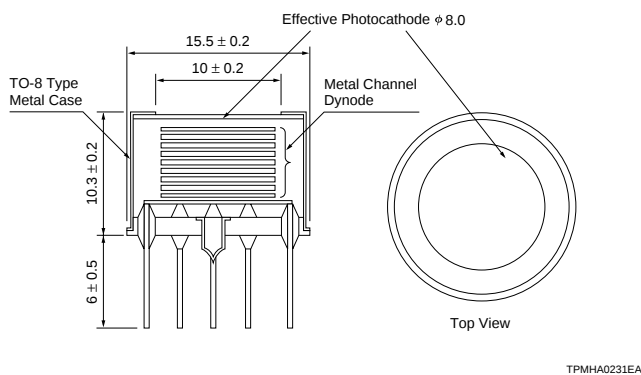
	NaI(Tl)	BGO	CsI(Tl)	Pure CsI	BaF ₂	GSO: Ce	Plastic	LSO	PWO	YAP
Density(g/cm ³)	3.67	7.13	4.51	4.51	4.88	6.71	1.03	7.35	8.28	5.55
Lrad (cm)	2.59	1.12	1.85	1.85	2.10	1.38	40	0.88	0.87	2.70
Refractive Index	1.85	2.15	1.80	1.80	1.58	1.85	1.58	1.82	2.16	1.97
Hygroscopic	Yes	No	Slightly	Slightly	Slightly	No	No	No	No	No
Luminescence (nm)	410	480	530	310	325	430	400	420	470	380
Decay Time (nsec)	230	300	1000	10	630	30	2.0	40	15	30
Relative Light Output	100	15	45 to 50	<10	20	20	25	70	0.7	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 (R7400 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 R7400 series are: smallest size, fast time response, ability of low light level detection and good immunity to magnetic fields.

Figure 22 : Cross Section and Top View of R7400

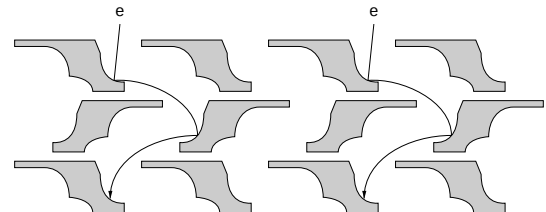


R7400 is a subminiature PMT that incorporates an eight stages electron multiplier constructed with stacked thin electrodes (metal channel dynode) into a TO-8 type metal can package of 15 mm in diameter and 10 mm in height. The development of this metal package and its unique thin electrodes have made 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. Fig. 22 shows a cross section of the R7400 and Fig. 23 shows that of a metal channel dynode with simulated electron trajectories.

The R5900 series is another version of metal package PMT. It incorporates 10 to 12 stages of metal channel dynodes into a metal package of 28 mm x 28 mm square and 20 mm in height. The prime features are similar to that of R7400 series, but its effective area is 18 mm x 18 mm instead of 8 mm diameter of R7400. The dimensional outline of R5900U is shown in Fig.24. 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.

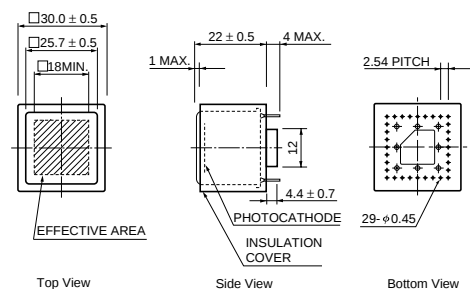
As the metal channel dynode is a sort of an array of small linear focused dynodes, secondary electrons hardly go to the adjacent dynode channel in a process of multiplication. It is possible to make multi-anode PMTs utilizing this feature. R5900 series is offering 6 various types of anode shapes as well as single channel type. These anode shapes are 4 (2 x 2), 16 (4 x 4) and 64 (8 x 8) matrix channels, 16 (1 x 16) linear channels as well as crossed-plate of 4X + 4Y and 6X + 6Y. Fig.25 shows the anode variation of the R5900 series. R5900 is for general scintillation counting. M4, M16 and M64 are suitable for scintillating fiber readout as well as RICH (Ring Image Cherenkov Counter), L16 is suitable for coupling with slit shape scintillators and ribbon-shaped scintillating fiber bundle. In the case of C8 and C12, it's possible to get position information by using a center of gravity method. Those are suitable for compact PET and radiation imaging.

Figure 23 : Cross Section of Metal Channel Dynode with Electron Trajectories



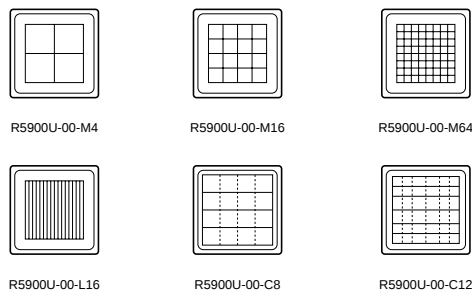
TPMHC0101EA

Figure 24 : Dimensional Outline of R5900U



TPMHA0278EF

Figure 25 : Anodo Variation of R5900 Series



TPMHC0204EA

15. FINE MESH PHOTOMULTIPLIER TUBE

In recent years, the demand for photodetectors to be operated in strong magnetic fields has increased, especially in the field of high energy physics. Conventional PMTs electron trajectories are affected by magnetic fields. The gain of these PMTs is decreased under such conditions. Therefore, it is necessary for these PMTs to either use a light guide to send signal light to a region outside the magnetic field or to use a magnetic shield. The light guide and its coupling to a PMT cause loss of light and deterioration of the timing characteristics of the signal light. The use of magnetic shield adds cost and energy loss for the next particle detector.

PMTs using fine mesh dynodes, it's called Fine Mesh PMTs, have been developed as photodetectors which can be operated in high magnetic field over 1.5 Tesla. Other features are fast time response and wide dynamic range. Fig.26 shows a cross section of a Fine Mesh PMT and Fig.27 shows details of a fine mesh dynode. Its mesh diameter is around $5\text{ }\mu\text{m}$ and its pitch is approximately $13\text{ }\mu\text{m}$.

When an electron hits on the upper part of the fine mesh dynode, secondary electrons are emitted upward from the fine mesh dynode. Those electrons return to the same dynode and pass through it to reach to next fine mesh dynode. This process is repeated through the last dynode stage and finally electrons are multiplied 10^6 or more. When magnetic field is set parallel to a tube axis, the electron trajectories are affected by Lorentz's force and electrons make spiral movement, since the electric field is parallel to the tube axis. Its spiral diameter is determined by the strength of magnetic field. When magnetic field is increased, the number of electrons, which are emitted upward from the fine mesh dynode and return to the same dynode, is increased, Due to this effect, a tube gain is decreased.

Fine Mesh PMT consists of 15 to 19 stages of fine mesh dynodes. Each dynode as well as the photocathode is set in close each other. Tube diameters from 1" to 3" are available. Examples of magnetic field characteristics are shown in Fig. 30 to Fig. 33 on page 37.

Figure 26 : Cross Section of a Fine Mesh PMT

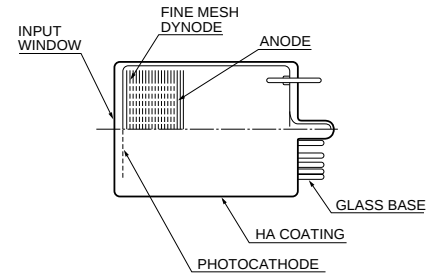
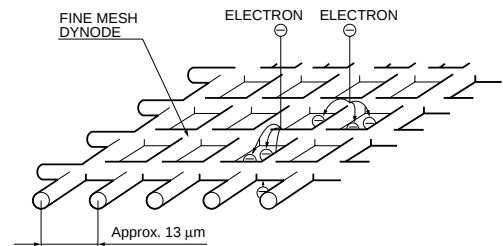


Figure 27 : Details of a Fine Mesh Dynode



TPMOC0012EB

Selection Guide by Applications

Applications	Examples of Applicable PMT
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HIGH ENERGY PHYSICS

COLLISION EXPERIMENT

CALORIMETER	R4125, R7899-01, R5505 (H6152-70), R6427 (H7415), R580 (H3178-51), R580-17 (H3178-61), R5946 (H6153-70), R329-02 (H6410), R1828-01 (H1949-51), R2154-02, R5924 (H6617-70), R6504 (H8318-70), R6091 (H6559), R1250 (H6527)
TOF COUNTER	R1635 (H3164-10), R4124, R1450 (H6524), R3478 (H6612), R4998 (H6533), R7899-01, R6427 (H7415), R1828-01 (H1949-51), R2083 (H2431), R5496, R4143 (H6525), R1250 (H6527)
TAGGING DETECTOR	R1635 (H3164-10), R4124, R1450 (H6524), R3478 (H6612), H6568
TRACKING DETECTOR	R5900U-00-M4, R5900U-00-L16, H6568, H7546, H7260
RICH (Ring Image Cherenkov Counter)	R5900U-00-M4, H6568, H7546
THRESHOLD CHERENKOV COUNTER	R2256 (H6521), R5113 (H6522), R2059 (H3177-51), R1584 (H6528)
ANY USE in High Magnetic Field	R5505 (H6152-70), R5946 (H6153-70), R5924 (H6614-70), R6504 (H8318-70)

SOLAR NEUTRINO AND LONG BASELINE EXPERIMENT

WATER CHERENKOV COUNTER	R6594, R5912, R5912-02, R7081, R7081-20, R3600-02 (R3600-06), R7250
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COSMIC RAY EXPERIMENT

GAMMA RAY TELESCOPE	R1635 (H3164-10), R2248, R4124, R2102, R6427 (H7415), R7056 (H7416), R7525
FLUORESCENCE DETECTOR	R580 (H6178-51), R6231, R6232-01
AIRSHOWER DETECTOR	R1166 (H6520), R580 (H3178-51), R329-02 (H6410), R1828-01 (H1949-51), R6091 (H6559), R1250 (H6527)

Models in blue are assembly type.

Applications	Examples of Applicable PMT
--------------	----------------------------

MEDICAL

GAMMA CAMERA	R1306, R6231, R6232-01, R1307, R1538-01, R6233, R6234-01, R6235-01, R6236-01, R6237-01
COMPACT GAMMA CAMERA	R5900U-00-C8, R5900U-00-C12, R2486-02 , R3292-02 , H6568 , H7546
ANIMAL PET	R5900U-00-C8, R5900U-00-C12, R2486-02 , R3292-02 , H6568 , H7546
WHOLE BODY PET	R1635, R1450, R7899-01, R1548
SURGICAL PROBE	R1635 (H3164-10), R1166, R5900U-00-C8, R2486-02
LIQUID SCINTILLATION COUNTER	R331, R331-05

RADIATION MONITOR

SURVEY METER	R1635 (H3164-10), R647-01 (H3165-10), R1924A, R7899-01
AREA MINITOR	R1306, R6231, R329-02 (H6410), R4607-06, R1307, R6233, R877, R877-01
COMPACT PROBE	R1635 (H3164-10), R647-01 (H3165-10), R5611-01, R7375-01, R1924A, R7373-01, R7354
2-D IMAGING MONITOR	R5900U-00-C8, R5900U-00-C12, R2486-02 , R3292-02
ANY USE in HIGH TEMPERATURE	R4177-06, R3991-04, R1288-06
ANY USE in SHOCK and VIBRATION	R4177-06, R5611-01, R3991-04, R1924A, R1288-06

Models in blue are assembly type.

List Guide for Photomultiplier Tubes

Tube Diameter	Type No.	①	②	Socket	④	Cathode Sensitivity			Anode Sensitivity				Maximum Rating ⑫		
		Spectral Response Range (nm) Curve Code	Outline No.		Dynode Structure No. of Stages	⑤	⑥	⑦	⑧	⑨	⑩	⑪		Anode to Cathode Voltage (Vdc)	Average Anode Current (mA)
						Luminous Typ. (μA/lm)	Blue Typ. (μA/lm-b)	Q.E. at Peak Typ. (%)	Anode to Cathode Voltage (Vdc)	Gain Typ.	Luminous Typ. (A/lm)	Dark Current			
												Typ. (nA)	Max. (nA)		

1 Spectral Response

The relationship between photocathode sensitivity and wavelength of input light.

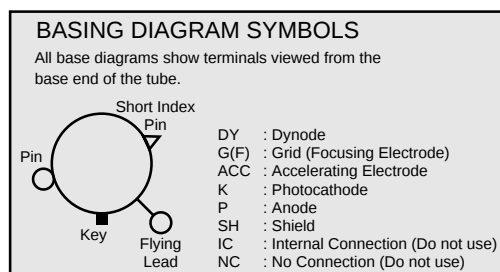
Curve code corresponds to that of spectral response curve on the inside back cover.

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

2 Outline No.

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

Basing diagram symbols are explained as follows:



TPMOC0068B

3 Socket

- ★ mark : A socket will be supplied with a PMT.
- no mark : A socket will be supplied as an option.

4 Dynode

<Dynode Structure>

Each mark means dynode structure as follows:

- LINE or L : linear focused
- BOX or B : box and grid
- B & L : box and linear focused
- CC : circular cage
- VB : venetian blind
- FM : fine mesh
- CM or M : coarse mesh
- MC : metal channel

<No. of Stages>

The number of dynodes used.

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

5 Cathode Sensitivity (Luminous)

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

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

6 Cathode Sensitivity (Blue)

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

7 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.)

8 Anode to Cathode 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 40 and 41.

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 Sensitivity (Luminous)

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

(Refer to section 4.1 on page 4 for further details.)

(at 25°C)

Typical Time Response ⑬				Typical Pulse Height Resolution (%) Scintillator	Stability ⑮		Pulse Linearity ⑯		Notes	Type No.
Rise Time Typ.	Transit Time Typ.	T.T.S. Typ. FWHM	Coincident Resolving Time (ns) Scintillator		Long Term	Short Term	±2% Deviation Typ.	±5% Deviation Typ.		
(ns)	(ns)	(ns)			(%)	(%)	(mA)	(mA)		

⑪ Anode Dark Current

The output current from the anode measured after 30 minutes storage in complete darkness.
(Refer to section 5 on page 5 for further details.)

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 7 for further details)

⑬ 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.

<C.R.T. (Coincident Resolving Time)>

This is defined as the FWHM of a coincident timing spectrum of a pair PMT's. The scintillator used are BGO, BaF₂ or CsF crystals.
(Refer to section 6 on page 5 and 6 for further details.)

⑭ Pulse Height Resolution (P.H.R.)

The P.H.R. is measured with the combination of an NaI(Tl) scintillator and a ¹³⁷Cs source as a standard measurement. If other scintillators or γ-ray sources are used, note is attached.
(Refer to section 13.2 on page 10 and 11 for further details.)

⑮ Stability

<Long Term Stability (Mean Gain Deviation)>

This is defined as follows under the operation for 16 hours at a constant count rate of 1k cps:

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

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.

<Short Term Stability>

This is the gain shift on count rate change. The tube is first operated at about 10k cps. The photo-peak count rate is then decreased to about 1k cps by increasing the distance between the ¹³⁷Cs source and the tube coupled to the NaI(Tl) scintillator.
(Refer to section 9 on page 7 for further details.)

⑯ 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 6 for further details.)

Photomultiplier Tubes

Tube Diameter	Type No.	Spectral Response Range (nm) Curve Code	① Outline No.	③ Socket	④ Dynode Structure No. of Stages	Cathode Sensitivity			Anode Sensitivity					
						⑤ Luminous Typ. (μA/lm)	⑥ Blue Sens. Index (CS 5-58) Typ.	⑦ Q.E. at Peak Typ. (%)	⑧ Anode to Cathode Supply Voltage (Vdc)	⑨ Gain Typ.	⑩ Luminous Typ. (A/lm)	⑪ Dark Current		
10mm (3/8 inch) to 38mm (1-1/2 inch) Dia. Types														
10mm (3/8")	R1635	300 to 650/A-D	①	E678-11N*	LINE/ 8	95	9.5	23	1250 ⑥	1.1×10 ⁶	100	1	50	
	R4868	300 to 650/A-D	②	E678-12A	LINE/ 10	95	9.5	23	1250 ②④	5.3×10 ⁶	500	5	50	
13mm (1/2")	R647-01	300 to 650/A-D	④	E678-13A*	LINE/ 10	105	10.0	25	1000 ⑭	1.4×10 ⁶	150	1	2	
	R4124	300 to 650/A-D	③	E678-13A*	LINE/ 10	95	9.5	23	1000 ②⑧	1.1×10 ⁶	100	2	15	
	R4177-06	300 to 650/A-E	④	E678-13E*	LINE/ 10	30	4.5	12	1500 ⑭	5.0×10 ⁵	15	0.5	10	
19mm (3/4")	R1166	300 to 650/A-D	⑤	E678-12L*	LINE/ 10	105	10.5	26	1000 ⑰	1.0×10 ⁶	100	1	5	
	R1281-06	300 to 650/A-E	⑥	E678-12L*	LINE/ 10	30	4.5	12	1500 ⑰	8.3×10 ⁵	25	0.5	10	
	R1450	300 to 650/A-D	⑦	E678-12L*	LINE/ 10	115	11.0	27	1500 ⑳	1.7×10 ⁶	200	3	50	
	R3478	300 to 650/A-D	⑧	E678-12L*	LINE/ 8	115	11.0	27	1700 ⑩	1.7×10 ⁶	200	10	300	
	R3991-04	300 to 650/A-E	⑨	E678-12A*	CC/ 10	30	4.5	12	1500 ㉓	3.3×10 ⁵	10	0.1	10	
	R4125	300 to 650/A-D	⑦	E678-12L*	LINE/ 10	115	11.0	27	1500 ⑱	8.7×10 ⁵	100	10	50	
	R5325	300 to 650/A-F	⑧	E678-12L*	LINE/ 6	125	11.0	27	1500 ①	8.0×10 ³	1	1	10	
	R5611-01	300 to 650/A-D	⑨	E678-12A*	CC/ 10	90	10.5	26	1000 ㉓	5.5×10 ⁵	50	3	20	
25mm (1")	R1288-06	300 to 650/A-E	⑩	E678-14C*	CC/ 10	30	4.5	12	1500 ㉓	3.3×10 ⁵	10	0.1	10	
	R1924A	300 to 650/A-D	⑩	E678-14C*	CC/ 10	90	10.5	26	1000 ㉓	2.0×10 ⁶	180	3	20	
	R4998	300 to 650/A-D	⑪	E678-12A*	LINE/ 10	70	9.0	22	2250 ⑰	5.7×10 ⁶	400	100	800	
	R5380	300 to 650/A-F	⑫	E678-14C*	LINE/ 6	125	11.0	27	1000 ③	6.0×10 ³	0.75	1	10	
	R5505	300 to 650/A-D	⑬	E678-17A*	FM/ 15	80	9.5	23	2000 ⑤③	5.0×10 ⁵	40	5	30	
	R7899-01	300 to 650/A-D	⑭	E678-12A*	LINE/ 10	95	11.0	27	1250 ㉓ <1500 ㉓>	2.0×10 ⁶ <1.7×10 ⁶ >	190 <160>	2 <2>	15 <20>	
28mm (1-1/8")	R3998-02	300 to 650/A-D	⑮	E678-14C*	B&L/ 9	90	10.5	26	1000 ⑫	1.3×10 ⁶	120	2	10	
	R6427	300 to 650/A-D	⑮	E678-14C*	LINE/ 10	95	11.0	27	1500 ③① <1500 ③①>	5.0×10 ⁶ <2.0×10 ⁶ >	475 <190>	10 <4>	200 <80>	
	R7057	160 to 650/C-D	⑮	E678-14C*	LINE/ 10	95	11.0	27	1500 ③② <1500 ③③>	2.0×10 ⁶ <8.0×10 ⁵ >	190 <76>	4 <1.5>	80 <30>	
	R7525	300 to 650/A-D	⑰	E678-14C*	LINE/ 8	95	11.0	27	1500 ⑧ <1500 ⑨>	5.0×10 ⁵ <2.0×10 ⁵ >	45 <19>	5 <2>	100 <40>	
38mm (1-1/2")	R580	300 to 650/A-D	⑱	E678-12A*	LINE/ 10	95	11.0	27	1250 ⑳ <1500 ㉒>	1.1×10 ⁶ <7.9×10 ⁵ >	100 <75>	3 <2>	20 <15>	
	R580-17	300 to 650/A-F	⑲	E678-12A*	LINE/ 10	125	11.0	27	1250 ㉓ <1500 ㉓>	1.2×10 ⁶ <1.1×10 ⁶ >	150 <140>	4 <4>	20 <20>	
	R980	300 to 650/A-D	㉒	E678-12A*	CC/ 10	100	11.5	28	1000 ㉒	3.5×10 ⁶	35	3	5	
	R3886	300 to 650/A-D	㉑	E678-12A*	CC/ 10	90	10.5	26	1000 ㉒	5.0×10 ⁵	45	3	5	
	R5330	185 to 650/B-D	⑱	E678-12A*	LINE/ 6	95	11.0	27	1250 ②	1.0×10 ⁴	0.95	2	15	
	R5946	300 to 650/A-D	㉒	E678-19D*	FM/ 16	80	9.5	23	2000 ⑤④	1.0×10 ⁶	80	5	30	

Note: The data in square bracket <> is measured with tapered voltage distribution ratio. The number in circle at "6 Anode to Cathode Supply Voltage" corresponds to the voltage distribution ratio on page 40 and 41.

(at 25°C)

Maximum Rating ¹²		Typical Time Response ¹³			¹⁴ Typical Pulse Height Resolution (%)	Stability ¹⁵		Pulse Linearity ¹⁶		Notes	Type No.
Anode to Cathode Voltage (Vdc)	Average Anode Current (mA)	Rise Time Typ. (ns)	Transit Time Typ. (ns)	T.T.S. Typ. (FWHM) (ns)		Long Term (%)	Short Term (%)	±2% Deviation (mA)	±5% Deviation (mA)		
1500	0.03	0.8	9	0.5	23/BGO *1	0.8	2.0	3	7	SILICA(R2496) and UV(R3878) types are available.	R1635
1500	0.03	1.0	11	0.7	23/BGO *1	0.8	2.0	2	5		R4868
1250	0.1	2.5	24	1.6	7.8	0.8	2.0	3	7	SILICA(R760) and UV(R960) types are available.	R647-01
1250	0.03	1.1	12	0.5	8.1	0.8	2.0	2	5		R4124
1800	0.02	2.0	20	—	12.0	2.0	2.0	8	13	Flying Lead type (R4177-04) is available.	R4177-06
1250	0.1	2.5	27	2.8	7.6	0.8	2.0	4	7	SILICA(R762) and UV(R750) types are available.	R1166
1800	0.02	2.9	26	—	10.0	1.0	2.0	25	40	Flying Lead type (R1281-04) is available.	R1281-06
1800	0.1	1.8	19	0.76	7.8	0.8	2.0	4	8		R1450
1800	0.1	1.3	14	0.36	7.8	0.8	2.0	4	8	SILICA(R2076) and UV(R3479) types are available.	R3478
1800	0.02	1.0	13	—	11.0	2.0	2.0	2	5		R3991-04
1800	0.1	2.5	16	0.85	7.8	1.0	2.0	100	170		R4125
1800	0.1	1.2	9.5	—	7.8	1.0	2.0	80	120	UV with 5-stage type (R5364) is available.	R5325
1250	0.1	1.5	17	0.8	8.0	1.0	2.0	1	2		R5611-01
1800	0.02	1.5	14	—	9.0	1.0	2.0	3	6		R1288-06
1250	0.1	1.5	17	0.9	7.8	0.5	2.0	30	50	Flying Lead type (R1924A-01) is available.	R1924A
2500	0.1	0.7	10	0.16	7.5	1.0	2.5	40	70	SILICA type (R5320) is available.	R4998
1800	0.1	1.6	12	—	7.5	1.0	2.0	80	120		R5380
2300	0.01	1.5	5.6	0.35	9.5	2.0	2.0	180	250	SILICA (R7494) and UV type (R5506) is available.	R5505
1800	0.1	1.6 <1.6>	17 <16>	0.6 <0.7>	7.8	0.5	2.0	30 <100>	50 <150>	Glass Base type (R7899) is available.	R7899-01
1500	0.1	3.4	23	3.0	7.5	1.0	1.0	8	10	Flying Lead type (R3998-01) is available.	R3998-02
2000	0.2	1.7 <1.7>	16 <16>	0.5 <0.5>	7.8	0.5	2.0	10 <100>	30 <150>	UV type (R7056) is available.	R6427
2000	0.2	1.7 <1.7>	16 <16>	0.5 <0.5>	7.8	0.5	2.0	10 <100>	30 <150>		R7057
1750	0.2	1.3 <1.3>	14 <14>	—	7.8	0.5	2.0	10 <100>	30 <150>		R7525
1750	0.1	2.7 <2.7>	37 <40>	4.5 <4.5>	7.7	0.5	0.5	40 <150>	60 <200>		R580
1750	0.1	2.7 <2.7>	27 <40>	2.0 <2.0>	7.7	0.5	0.5	40 <150>	60 <200>		R580-17
1250	0.1	2.8	40	4.8	7.6	0.7	2.0	1	3		R980
1250	0.1	2.5	32	2.2	7.6	0.7	2.0	1	3		R3886
1600	0.1	2.5	25	—	7.7	1.0	2.0	80	120		R5330
2300	0.01	1.9	7.2	0.35	9.5	2.0	2.0	350	500	SILICA (R6149) and UV (R6148) types are available. 19-stage with Flying Lead type (R7761) is available.	R5946

Note 1 : This data is measured with ²²Na source and BGO scintillator.

Tube Diameter	Type No.	① Spectral Response Range (nm)	② Outline No.	③ Socket	④ Dynode Structure No. of Stages	Cathode Sensitivity			Anode Sensitivity				
		Curve Code	Luminous Typ. (μA/lm)	Blue Sens. Index (CS 5-58) Typ.	Q.E. at Peak Typ. (%)	Anode to Cathode Supply Voltage	Gain Typ.	Luminous Typ. (A/lm)	Dark Current				
									Typ. (nA)	Max. (nA)			
51mm (2 inch) to 508mm (20 inch) Dia. Types													
51mm (2")	R329-02	300 to 650/A-D	23	E678-21A*	LINE/ 12	90	10.5	26	1500 ⁴⁶ <2000 ⁴⁷ >	1.1×10 ⁶ <3.0×10 ⁶ >	100 <270>	6 <10>	40 <100>
	R331-05	300 to 650/A-D	24	E678-21A*	LINE/ 12	90	10.5	26	1500 ⁴⁶	1.3×10 ⁶	120	18cpm ⁺²	25cpm ⁺²
	R1306	300 to 650/A-D	25	E678-14V	BOX/ 8	110	12.0	30	1000 ^⑤	2.7×10 ⁵	30	2	20
	R1828-01	300 to 650/A-D	26	E678-21A*	LINE/ 12	90	10.5	26	2500 ⁴¹ <2500 ⁴² >	2.0×10 ⁷ <1.0×10 ⁷ >	1800 <900>	50 <25>	400 <200>
	R1840	300 to 650/A-D	27	E678-14V	CM/ 10	60	8.0	20	1250 ²⁰ <1250 ²¹ >	1.7×10 ⁵ <1.3×10 ⁵ >	10 <8>	5 <5>	50 <50>
	R2083	300 to 650/A-D	28	E678-19F*	LINE/ 8	80	10.0	25	3000 ^⑪	2.5×10 ⁶	200	100	800
	R2154-02	300 to 650/A-D	29	E678-14V	LINE/ 10	90	10.5	26	1250 ²⁰ <1500 ²² >	1.0×10 ⁶ <6.0×10 ⁵ >	90 <54>	5 <3>	20 <15>
	R4607-06	300 to 650/A-E	30	E678-15B*	CC/ 10	30	4.5	12	1500 ²⁰	3.3×10 ⁵	10	3	50
	R5496	300 to 650/A-D	31	E678-19E*	LINE/ 10	80	10.0	25	2500 ¹⁶	1.3×10 ⁷	1000	100	800
	R5924	300 to 650/A-D	32	—	FM/ 19	70	9.0	22	2000 ⁵⁵	1.0×10 ⁷	700	30	200
	R6231	300 to 650/A-D	33	E678-14V	B&L/ 8	110	12.0	30	1000 ^⑦	2.7×10 ⁵	30	2	20
60mm	R6232-01	300 to 650/A-D	34	—	B&L/ 8	110	12.0	30	1000 ^⑦	2.7×10 ⁵	30	2	20
64mm (2.5")	R6504	300 to 650/A-D	35	—	FM/ 19	70	9.0	22	2000 ⁵⁵	1.0×10 ⁷	700	50	300
76mm (3")	R1307	300 to 650/A-D	36	E678-14V	BOX/ 8	110	12.0	30	1000 ^⑦	2.7×10 ⁵	30	2	20
	R2238	300 to 650/A-D	37	E678-14V	CM/ 12	60	8.0	20	1250 ⁴³ <1250 ⁴⁴ >	5.0×10 ⁵ <4.0×10 ⁵ >	30 <23>	5 <5>	50 <50>
	R4143	300 to 650/A-D	38	E678-20A*	LINE/ 12	80	9.5	23	2500 ³⁹ <2500 ⁴⁰ >	5.0×10 ⁶ <5.6×10 ⁵ >	400 <45>	50 <10>	500 <50>
	R6091	300 to 650/A-D	39	E678-21A*	LINE/ 12	90	10.5	26	1500 ⁴⁶ <2000 ⁴⁷ >	5.0×10 ⁶ <1.0×10 ⁷ >	450 <900>	10 <30>	60 <120>
	R6233	300 to 650/A-D	40	E678-14V	B&L/ 8	110	12.0	30	1000 ^⑦	2.7×10 ⁵	30	2	20
127mm (5")	R877	300 to 650/A-D	41	E678-14V	BOX/ 10	80	10.0	25	1250 ¹⁵	5.0×10 ⁵	40	10	50
	R1250	300 to 650/A-D	42	E678-20A*	LINE/ 14	70	9.0	22	2000 ⁴⁸ <2500 ⁴⁹ >	1.4×10 ⁷ <4.0×10 ⁷ >	1000 <2800>	50 <300>	300 <1800>
	R1512	300 to 650/A-D	41	E678-14V	VB/ 10	95	11.0	27	1500 ¹⁵	1.1×10 ⁶	100	20	100
	R1584	185 to 650/B-D	43	E678-20A*	LINE/ 14	70	9.0	22	2000 ⁴⁸	1.4×10 ⁷	1000	50	300
	R6594	300 to 650/A-D	44	E678-20A*	B&L/ 10	80	10.0	25	1500 ³⁴ <1500 ³⁵ >	3.0×10 ⁶ <2.0×10 ⁶ >	240 <160>	30 <20>	300 <200>
204mm (8")	R5912	300 to 650/A-D	45	E678-20A*	B&L/ 10	70	9.0	22	1500 ⁵⁰	1.0×10 ⁷	700	50	700
	R5912-02	300 to 650/A-D	45	E678-20A*	B&L/ 14	70	9.0	22	1500 ⁵²	1.0×10 ⁹	70000	1000	5000
254mm (10")	R7081	300 to 650/A-D	46	E678-20A*	B&L/ 10	80	10.0	25	1500 ⁵⁰	1.0×10 ⁷	800	50	700
	R7081-20	300 to 650/A-D	46	E678-20A*	B&L/ 14	80	10.0	25	1500 ⁵²	1.0×10 ⁹	80000	1000	5000
508mm (20")	R3600-02	300 to 650/A-D	47	E678-20A*	VB/ 11	60	8.0	20	2000 ³⁷	1.0×10 ⁷	600	200	1000
	R7250	300 to 650/A-D	48	E678-20A*	B&L/ 10	60	8.0	20	2000 ⁵¹	1.0×10 ⁷	600	200	1000

NOTE : The data in square bracket <> is measured with tapered voltage distribution ratio. The number in circle at "Anode to Cathode Supply Voltage" corresponds to the voltage distribution ratio on page 40 and 41.

(at 25°C)

Maximum Rating ¹²		Typical Time Response ¹³			¹⁴ Typical Pulse Height Resolution (%)	Stability ¹⁵		Pulse Linearity ¹⁶		Notes	Type No.
Anode to Cathode Voltage (Vdc)	Average Anode Current (mA)	Rise Time Typ. (ns)	Transit Time Typ. (ns)	T.T.S. Typ. (FWHM) (ns)		Long Term (%)	Short Term (%)	±2% Deviation (mA)	±5% Deviation (mA)		
2700	0.2	2.6 <2.7>	48 <40>	1.1 <1.1>	7.3	1.0	1.0	15 <100>	30 <200>	SILICA (R2256) and UV (R5113) types are available.	R329-02
2500	0.2	2.6	48	1.1	—	—	—	15	30	SILICA type (R331) is available.	R331-05
1500	0.1	7.0	60	—	6.3(8.5) *3	0.5	0.5	1	5	K-FREE type (R1306-15) is available.	R1306
3000	0.2	1.3 <1.7>	28 <32>	0.55 <0.55>	7.8	1.0	1.0	100 <250>	200 <500>	SILICA (R2059) and UV (R4004) types are available.	R1828-01
1500	0.1	5.0 <5.0>	15 <17>	0.7 <1.3>	8.5	0.5	1.0	80 <200>	200 <400>		R1840
3500	0.2	0.7	16	0.37	7.8	1.0	2.0	100	150	SILICA type (R3377) is available.	R2083
1750	0.1	3.4 <3.4>	31 <33>	3.6 <3.6>	7.6	0.5	0.5	50 <150>	70 <200>	Glass Base type (R3149) is available.	R2154-02
1800	0.02	2.5	29	—	10.0	2.0	2.0	1	5		R4607-06
3000	0.2	1.5	24	0.27	7.8	1.0	2.0	100	150		R5496
2300	0.1	2.5	9.5	0.44	9.5	2.0	2.0	500	700	SILICA (R6609) and UV (R6608) types are available.	R5924
1500	0.1	5.0	48	11.7	6.3(8.5) *3	0.5	0.5	1	5		R6231
1500	0.1	6.0	52	12.2	6.3(8.5) *3	0.5	0.5	1	5		R6232-01
2300	0.1	2.7	11	0.47	9.5	2.0	2.0	700	1000	UV type (R6505) is available.	R6504
1500	0.1	8.0	64	—	6.3(8.5) *3	0.5	0.5	1	5	K-FREE type (R1307-07) is available.	R1307
1500	0.1	5.5 <5.5>	17 <21>	0.8 <2.0>	8.5	0.5	1.0	200 <500>	500 <650>		R2238
3000	0.2	1.8 <1.8>	32 <36>	0.6 <0.6>	7.8	1.0	1.0	100 <150>	180 <250>	UV type (R4885) is available.	R4143
2500	0.2	2.6 <2.3>	48 <40>	2 <1.5>	7.8	1.0	1.0	40 <80>	60 <110>		R6091
1500	0.1	6.0	52	12.2	6.3(8.5) *3	0.5	0.5	1	5		R6233
1500	0.1	10.0	90	—	8.0	0.5	0.5	10	20	K-FREE type (R877-01) is available.	R877
3000	0.2	2.5 <2.2>	54 <53>	1.2 <1.2>	8.3	1.0	1.0	100 <160>	150 <250>		R1250
2000	0.1	9.0	82	—	7.5	0.5	1.0	5	20		R1512
3000	0.2	2.5	54	1.2	—	—	—	100	150		R1584
2000	0.1	3.5 <3.5>	45 <45>	1.5 <1.5>	—	—	—	30 <100>	50 <150>		R6594
1800	0.1	3.8	55	2.4	—	—	—	20	40		R5912
2000	0.1	4.0	68	2.8	—	—	—	40	70		R5912-02
1800	0.1	4.3	63	2.9	—	—	—	20	40		R7081
2000	0.1	4.5	78	3.3	—	—	—	40	70		R7081-20
2500	0.1	10.0	95	5.5	—	—	—	20	40		R3600-02
2500	0.1	7.0	110	3.5	—	—	—	60	80		R7250

NOTE 2 : This data is a value of coincidence background noise.

NOTE 3 : This data in parentheses is measured with ⁵⁷Co source.

Tube Diameter	Type No.	Spectral Response Range (nm) Curve Code	Outline No.	Socket	Dynode Structure No. of Stages	Cathode Sensitivity			Anode Sensitivity				
						Luminous Typ. ($\mu\text{A/Lm}$)	Blue Sens. Index (CS 5-58) Typ.	Q.E. at Peak Typ. (%)	Anode to Cathode Voltage	Gain Typ.	Luminous Typ. (A/Lm)	Dark Current	
												Typ. (nA)	Max. (nA)

Metal Package Photomultipliers and Assemblies

16mm TO-8 type	R7400U	300 to 650/A-D	49	E678-12M	MC/ 8	70	8.0	21	800 ④	7.0×10^5	50	0.2	2
	R7400U-06	160 to 650/C-D	50	E678-12M	MC/ 8	70	8.0	21	800 ④	7.0×10^5	50	0.2	2
30mm Square Type	R5900U	300 to 650/A-D	51	E678-32B	MC/ 10	70	8.0	20	800 ①9	2.0×10^6	140	2	20
	R5900U-00-M4	300 to 650/A-D	52	E678-32B	MC/ 10	70	8.0	20	800 ①9	2.0×10^6	140	0.5	—
	R5900U-00-L16	300 to 650/A-D	53	E678-32B	MC/ 10	70	8.0	20	800 ①7	4.0×10^6	280	0.2	2
Assemblies	H6568	300 to 650/A-D	P50	—	MC/ 12	70	8.0	20	800 ③8	3.3×10^6	140	1	—
	H7546	300 to 650/A-D	P51	—	MC/ 12	70	8.0	20	800 ④5	3.0×10^5	21	0.2	—
	H7260	300 to 650/A-D	P51	—	MC/ 10	70	8.0	20	800 ①7	2.0×10^6	140	0.2	2

Fine Mesh Photomultipliers

25mm (1")	R5505	300 to 650/A-D	13	E678-17A*	FM/ 15	80	9.5	23	2000 ⑤3	5.0×10^5	40	5	30
38mm (1.5")	R5946	300 to 650/A-D	22	E678-19D*	FM/ 16	80	9.5	23	2000 ⑤4	1.0×10^6	80	5	30
51mm (2")	R5924	300 to 650/A-D	32	—	FM/ 19	70	9.0	22	2000 ⑤5	1.0×10^7	700	30	200
64mm (2.5")	R6504	300 to 650/A-D	35	—	FM/ 19	70	9.0	22	2000 ⑤5	1.0×10^7	700	50	300

Square, Rectangular Shape Photomultipliers

10mm (3/8")	R2248	300 to 650/A-D	54	E678-11N*	LINE/ 8	95	9.5	23	1250 ⑥	1.1×10^6	100	1	50
13mm (1/2")	R2102	300 to 650/A-D	55	E678-13A*	LINE/ 10	100	9.5	23	1000 ①4	1.0×10^6	100	1	15
25mm (1")	R2497	300 to 650/A-D	56	E678-12A	LINE/ 10	115	11.0	27	1500 ②8	2.6×10^6	300	10	100
38mm (1.5")	R2604-01	300 to 650/A-D	57	E678-12A	B&L/ 9	90	10.5	26	1000 ①2	2.2×10^5	20	2	10
60mm	R6236-01	300 to 650/A-D	58	—	B&L/ 8	110	12.0	30	1000 ⑦	2.7×10^5	30	2	20
76mm (3")	R6237-01	300 to 650/A-D	59	—	B&L/ 8	110	12.0	30	1000 ⑦	2.7×10^5	30	2	20
25mm (1" Dual)	R1548	300 to 650/A-D	60	E678-17A*	LINE/ 10	80	9.5	23	1250 ③0	2.5×10^6	200	20	250

Hexagonal Shape Photomultipliers

60mm	R1538-01	300 to 650/A-D	61	E678-14V	BOX/ 8	110	12.0	30	1000 ⑤	2.7×10^5	30	2	20
60mm	R6234-01	300 to 650/A-D	62	—	B&L/ 8	110	12.0	30	1000 ⑦	2.7×10^5	30	2	20
76mm (3")	R6235-01	185 to 650/B-D	63	—	B&L/ 8	110	12.0	30	1000 ⑦	2.7×10^5	30	2	20

2 π Shape Photomultipliers

19mm (3/4")	R7375-01	300 to 650/A-D	64	E678-12A	CC/ 10	90	10.5	26	1000 ②7	1.1×10^6	100	3	20
25mm (1")	R7373-01	300 to 650/A-D	65	E678-12A	CC/ 10	90	10.5	26	1000 ②7	1.1×10^6	100	3	20
28mm (1-1/8")	R7354	300 to 650/A-D	66	E678-14C*	B&L/ 9	80	9.5	23	1000 ①3	1.5×10^6	120	2	10

(at 25°C)

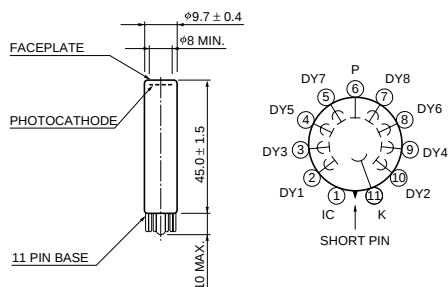
Maximum Rating ¹²		Typical Time Response ¹³			¹⁴ Typical Pulse Height Resolution (%)	Stability ¹⁵		Pulse Linearity ¹⁶		Notes	Type No.
Anode to Cathode Voltage (Vdc)	Average Anode Current (mA)	Rise Time Typ. (ns)	Transit Time Typ. (ns)	T.T.S. Typ. (FWHM) (ns)		Long Term (%)	Short Term (%)	±2% Deviation Typ. (mA)	±5% Deviation Typ. (mA)		
1000	0.1	0.78	5.4	0.23	—	—	—	15	30	UV type (R7400U-03) is available.	R7400U
1000	0.1	0.78	5.4	0.23	—	—	—	15	30		R7400U-06
900	0.1	1.40	8.8	0.26	—	—	—	30	60	UV type (R5900U-03) is available.	R5900U
900	0.1	1.20	8.8	0.32	—	—	—	2	4	Each data is measured with 1 channel.	R5900U-00-M4
900	0.1	0.60	8.8	0.18	—	—	—	0.8	1.2		R5900U-00-L16
900	0.014	0.83	8.8	0.30	—	—	—	0.5	1	Assembly with Divider Network	H6568
900	0.018	1.50	8.8	0.30	—	—	—	0.3	0.6	Assembly with Divider Network	H7546
900	0.1	0.60	8.8	0.18	—	—	—	0.6	0.8	Assembly with Divider Network	H7260
2300	0.01	1.5	5.6	0.35	9.5	2.0	2.0	180	250	SILICA (R7494) and UV type (R5506) is available.	R5505
2300	0.01	1.9	7.2	0.35	9.5	2.0	2.0	350	500	SILICA (R6149) and UV (R6148) types are available. 19-stage with Flying Lead type (R7761) is available.	R5946
2300	0.1	2.5	9.5	0.44	9.5	2.0	2.0	500	700	SILICA (R6609) and UV (R6608) types are available.	R5924
2300	0.1	2.7	11	0.47	9.5	2.0	2.0	700	1000	UV type (R6505) is available.	R6504
1500	0.03	0.9	9.0	0.6	23/BGO*1	0.8	2.0	3	7		R2248
1250	0.1	2.5	24	2.2	8.1	0.8	2.0	3	7		R2102
1800	0.1	2.4	22	0.7	19/BGO*1	0.5	2.0	15	20		R2497
1500	0.1	5.0	40	—	8.0	0.8	2.0	8	10		R2604-01
1500	0.1	6.0	52	12.2	6.3 (8.5)*3	0.5	0.5	1	5		R6236-01
1500	0.1	6.0	52	12.2	6.3 (8.5)*3	0.5	0.5	1	5		R6237-01
1750	0.1	1.8	20	1.0	20/BGO*1	0.7	2.0	10	15	Flying Lead type (R1548-02) is available.	R1548
1500	0.1	8.0	60	—	6.3 (8.5)*3	0.5	0.5	1	5		R1538-01
1500	0.1	6.0	52	12.2	6.3 (8.5)*3	0.5	0.5	1	5		R6234-01
1500	0.1	6.0	52	12.2	6.3 (8.5)*3	0.5	0.5	1	5		R6235-01
1250	0.1	1.5	17	0.8	8	1.0	2.0	1	2		R7375-01
1250	0.1	2	19	1.1	7.8	0.5	2.0	1	3		R7373-01
1500	0.1	11	33	4.5	8	1.0	2.0	8	10		R7354

NOTE 1 : This data is measured with ²²Na source and BGO scintillator.NOTE 3 : This data in parentheses is measured with ⁵⁷Co source.

Dimensional Outlines and Basing Diagrams

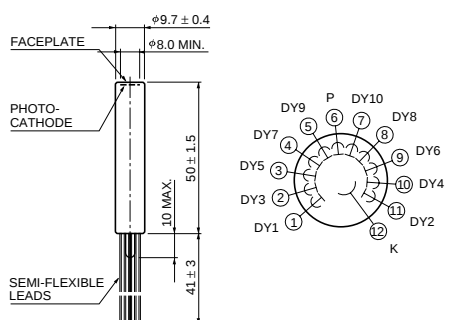
For Photomultiplier Tubes

1 R1635



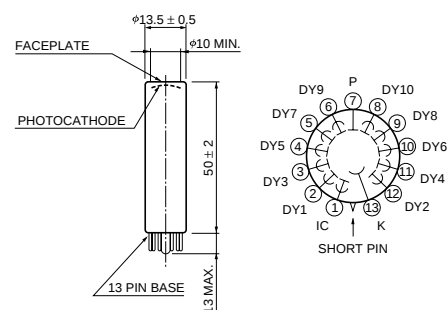
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2 R4868



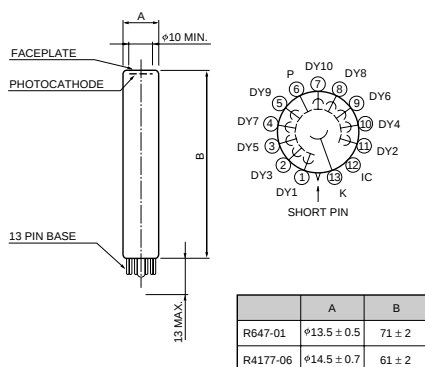
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3 R4124



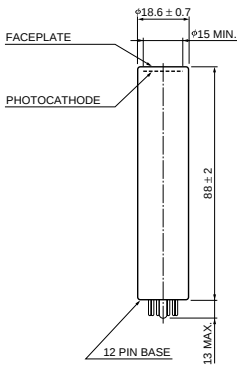
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4 R647-01, R4177-06



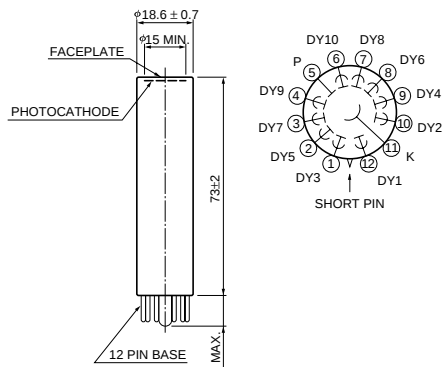
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5 R1166



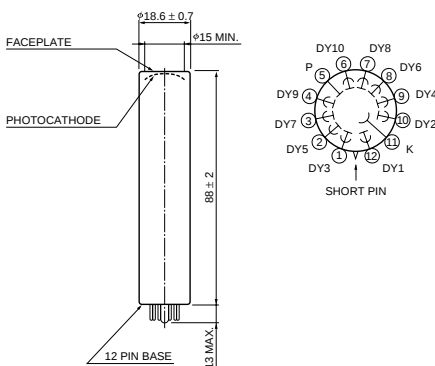
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6 R1281-06



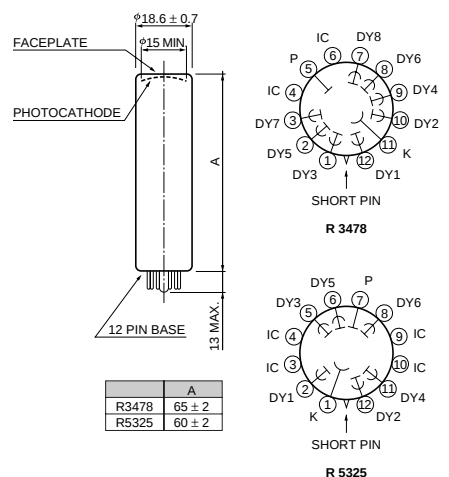
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7 R1450, R4125



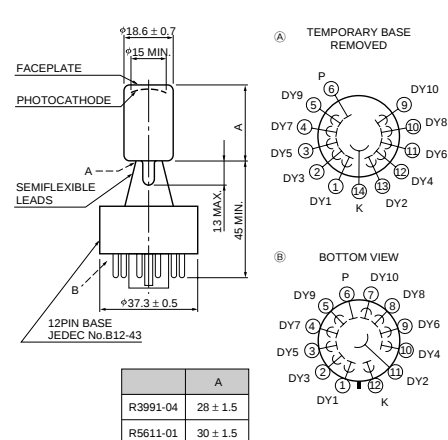
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8 R3478, R5325



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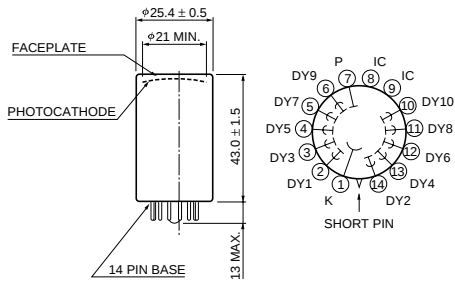
9 R3991-04, R5611-01



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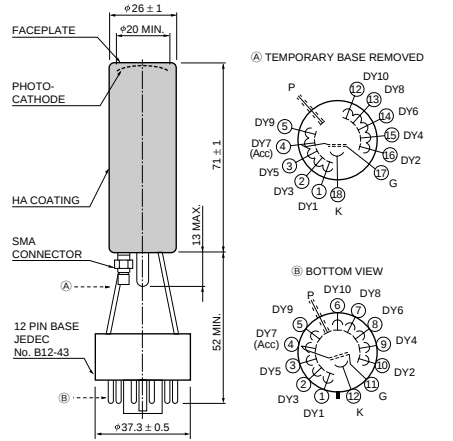
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10 R1288-06, R1924A



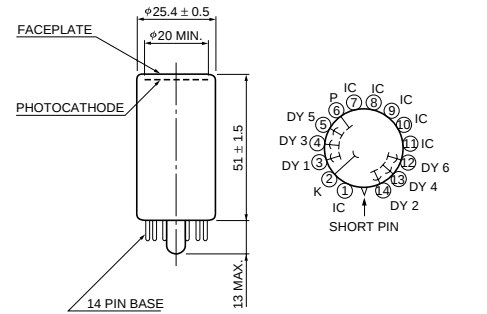
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11 R4998



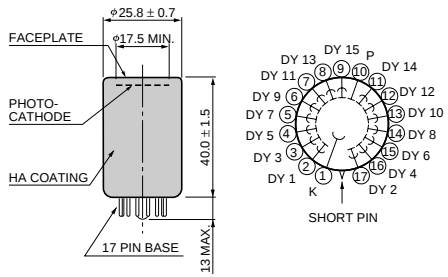
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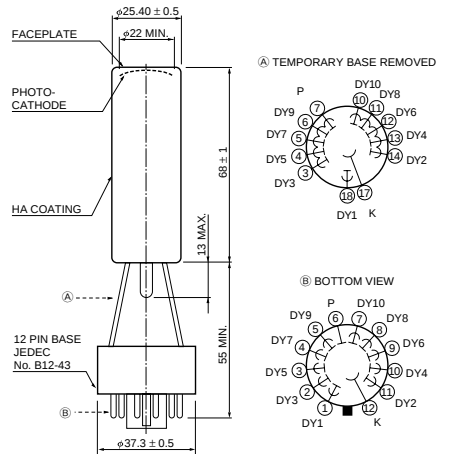
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13 R5505



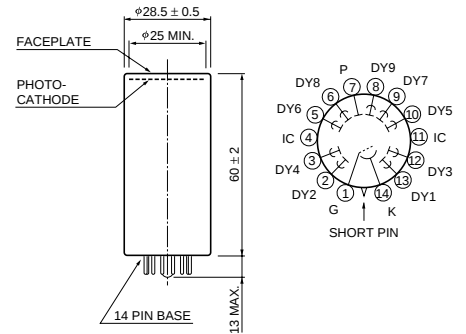
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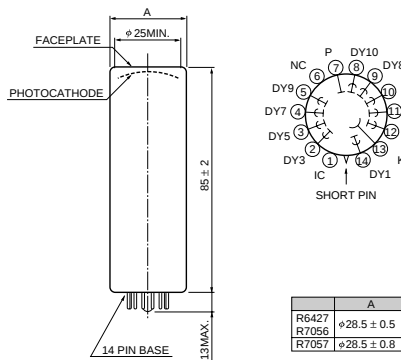
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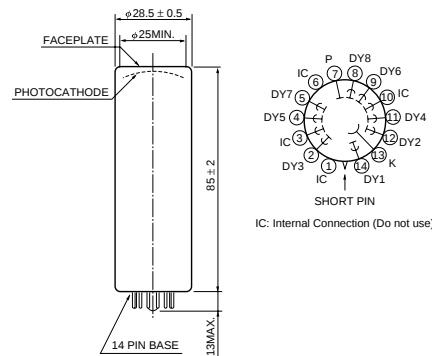
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16 R6427, R7057



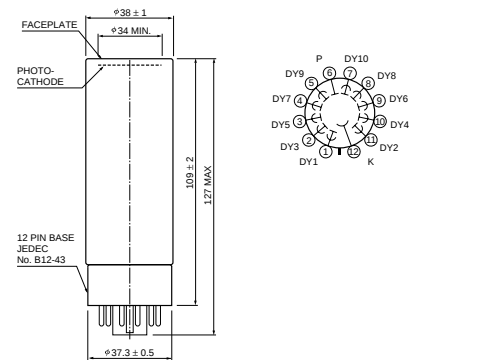
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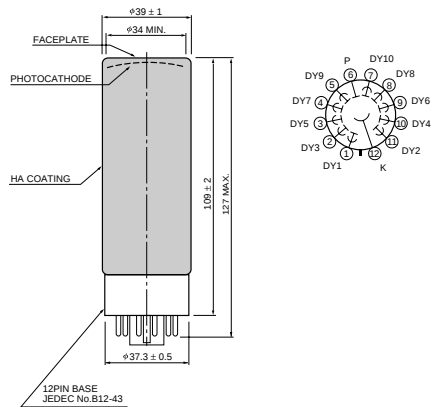
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18 R580, R5330



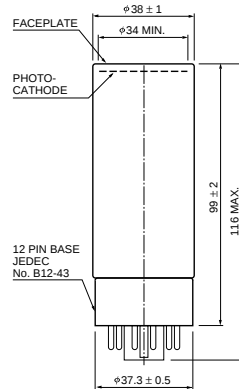
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19 R580-17



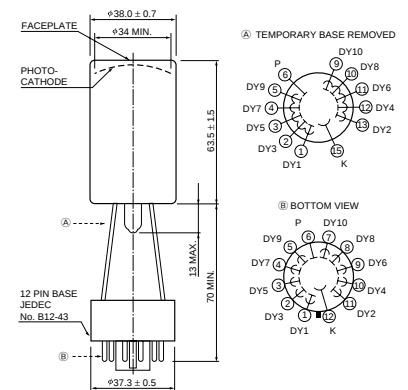
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20 R980



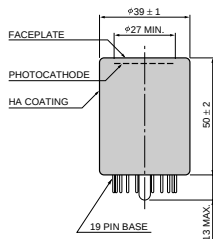
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21 R3886



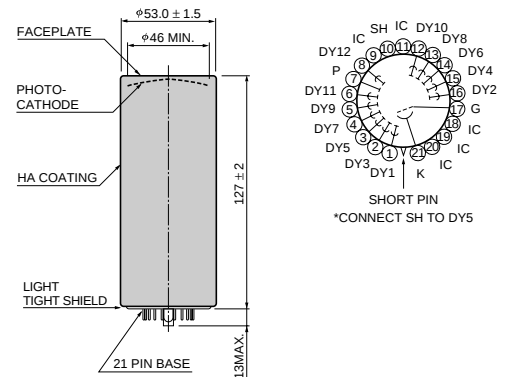
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22 R5946



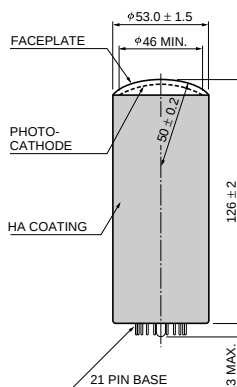
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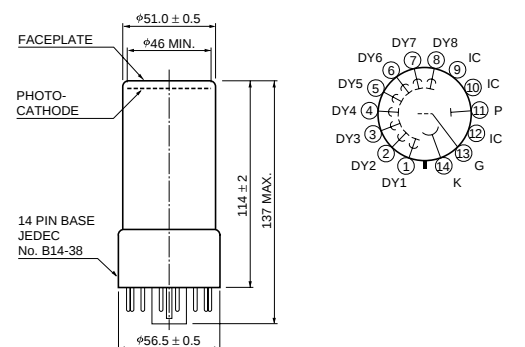
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24 R331-05



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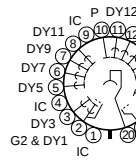
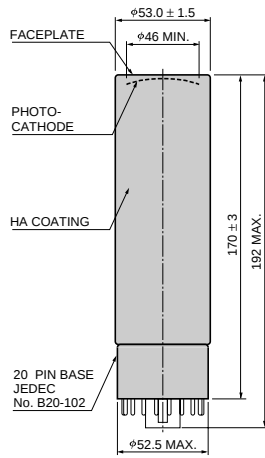
25 R1306



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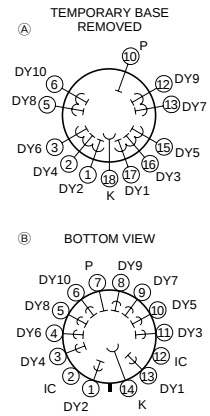
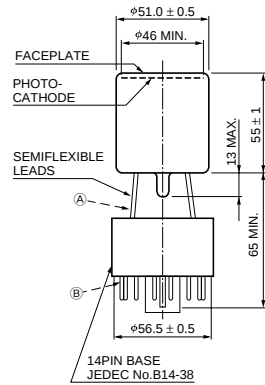
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26 R1828-01



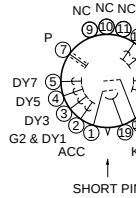
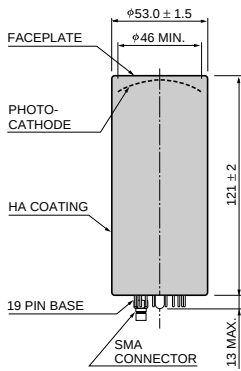
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27 R1840



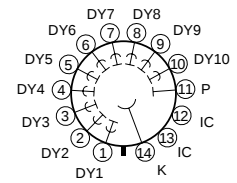
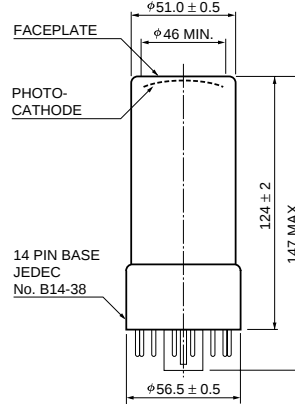
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28 R2083



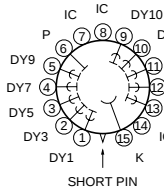
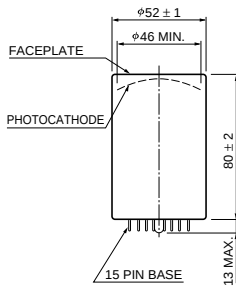
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29 R2154-02



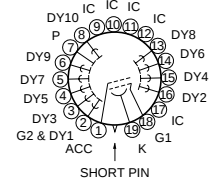
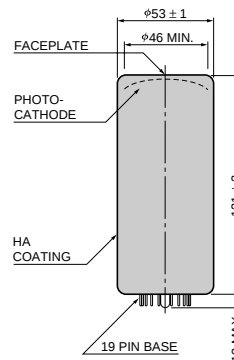
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30 R4607-06



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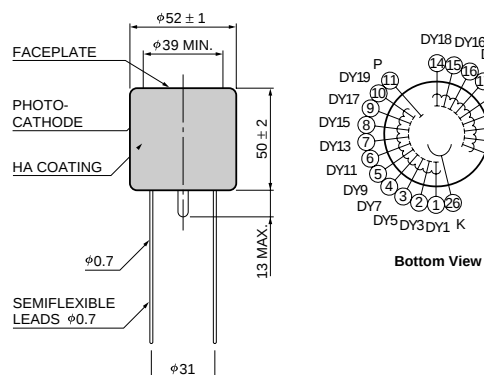
31 R5496



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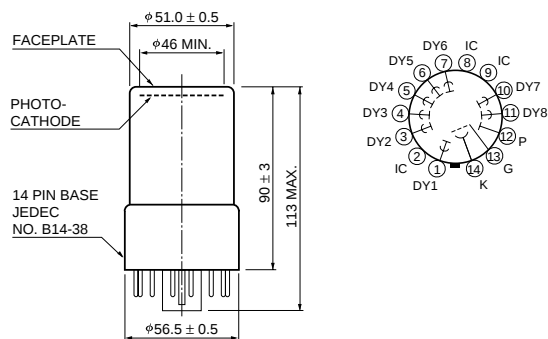
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32 R5924



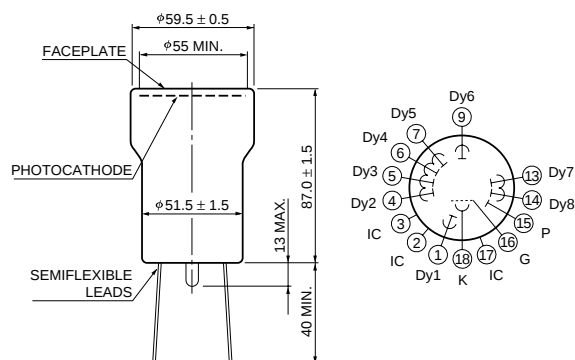
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33 R6231



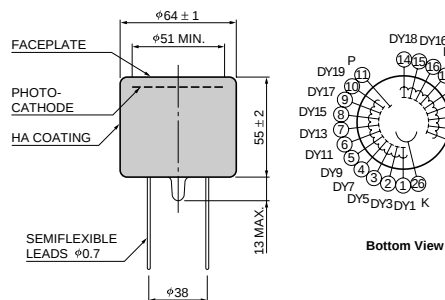
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34 R6232-01



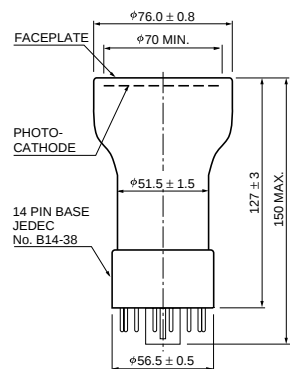
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35 R6504



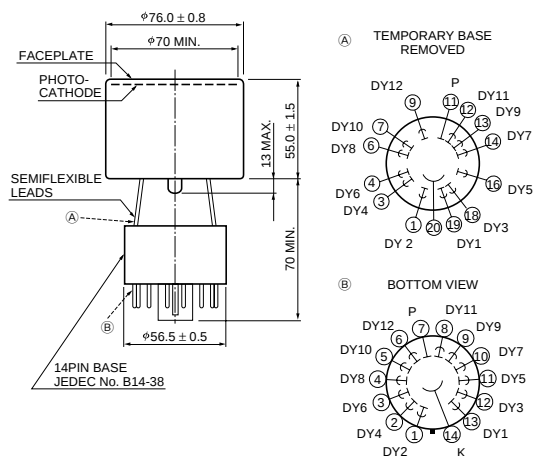
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36 R1307



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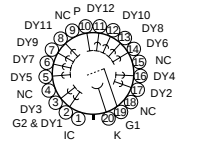
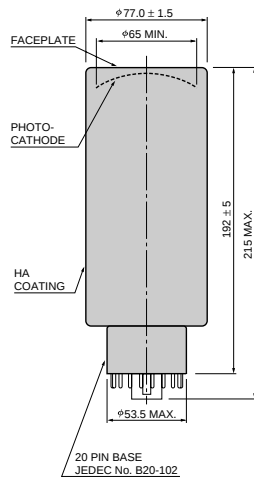
37 R2238



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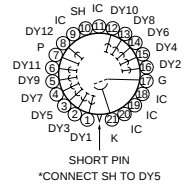
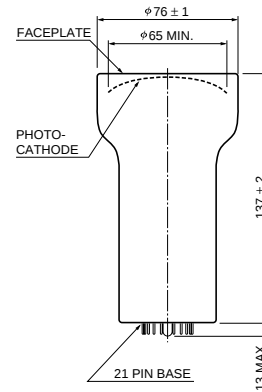
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38 R4143



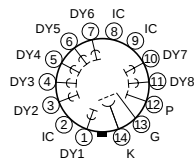
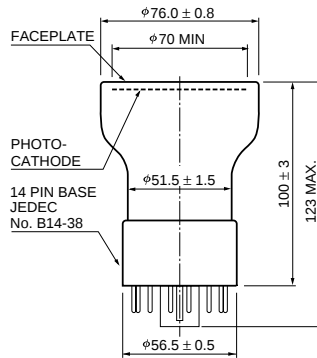
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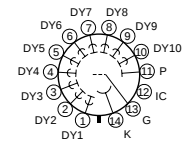
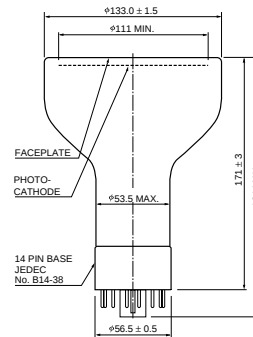
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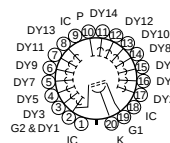
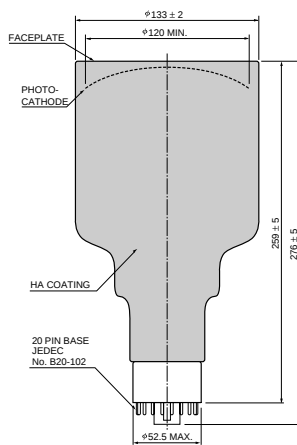
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41 R877,R1512



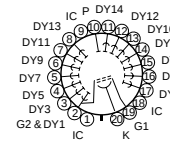
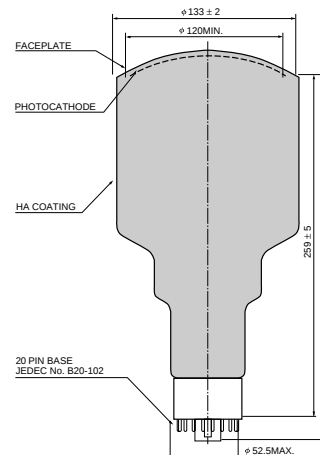
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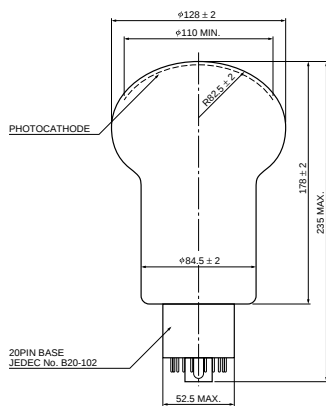
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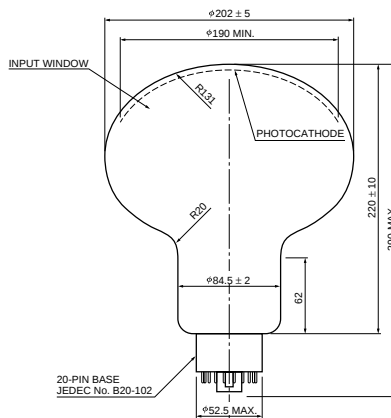
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44 R6594



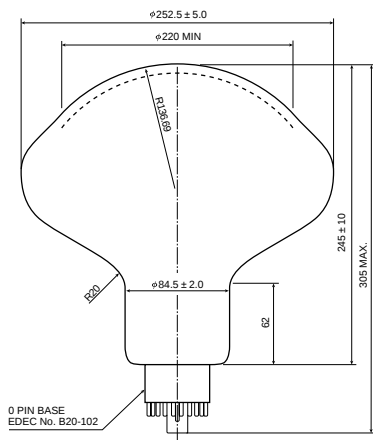
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45 R5912,R5912-02



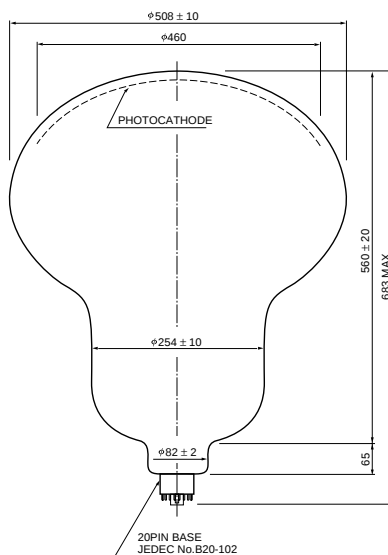
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46 R7081,R7081-20



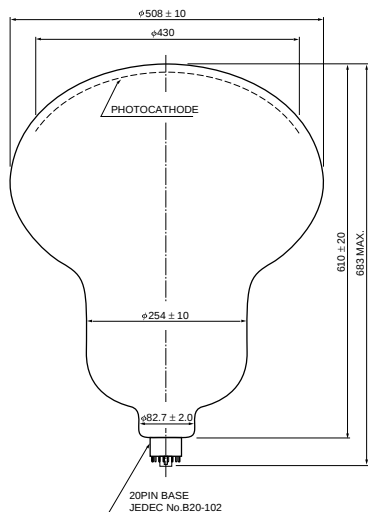
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47 R3600-02



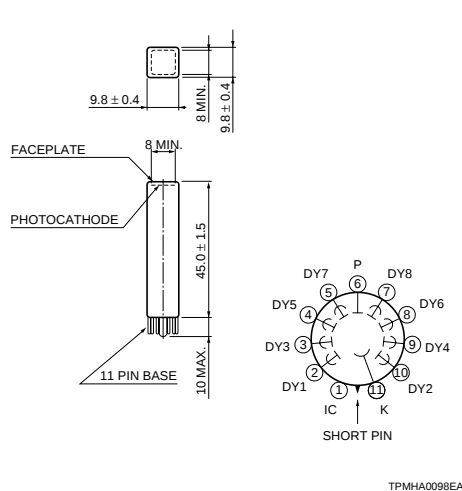
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48 R7250



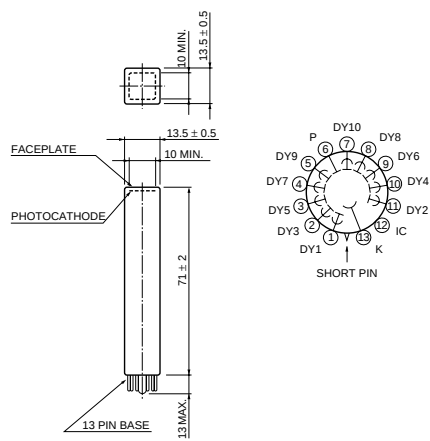
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54 R2248



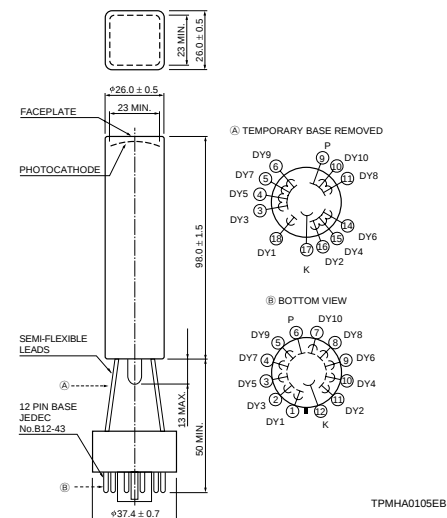
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55 R2102



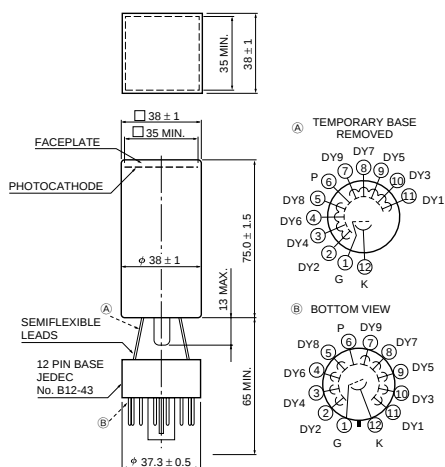
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56 R2497



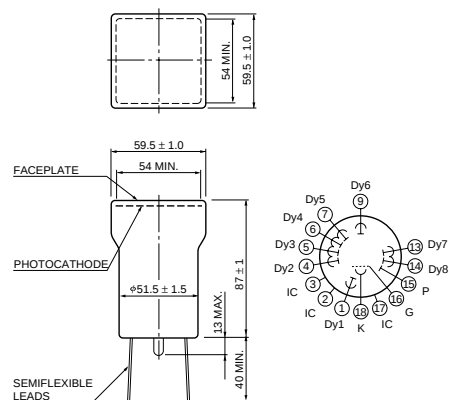
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57 R2604-01



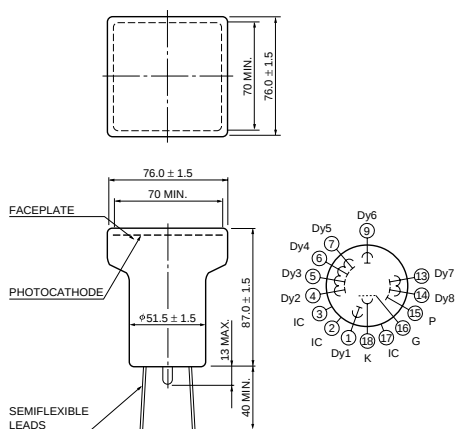
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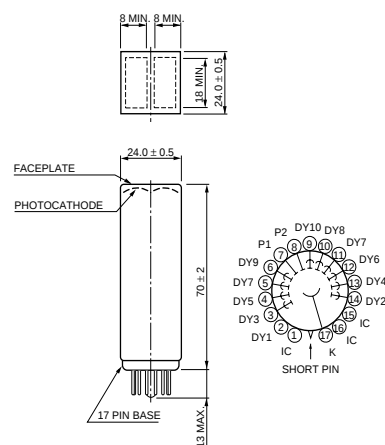
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59 R6237-01



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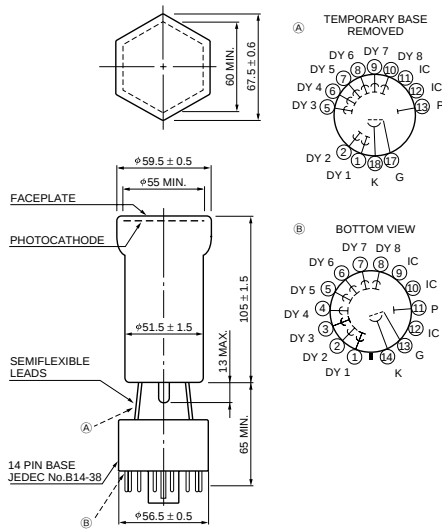
60 R1548



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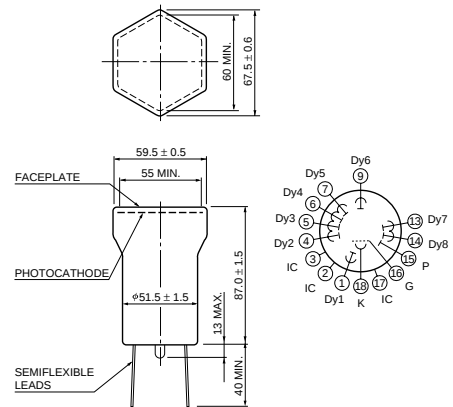
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61 R1538-01



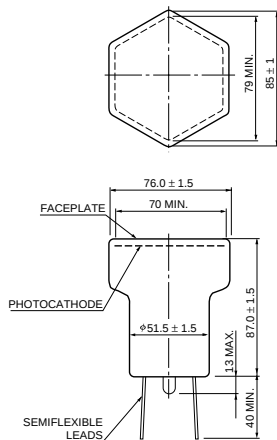
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62 R6234-01



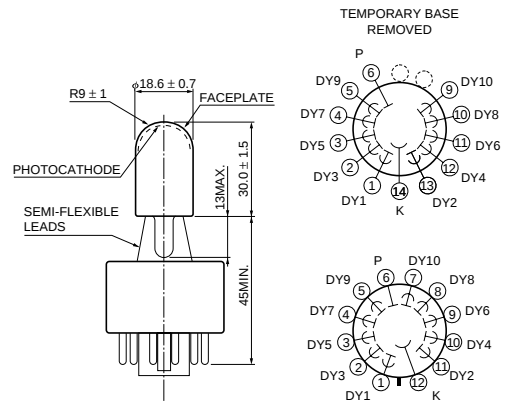
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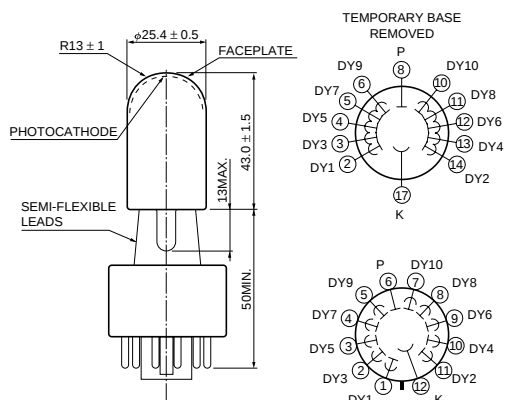
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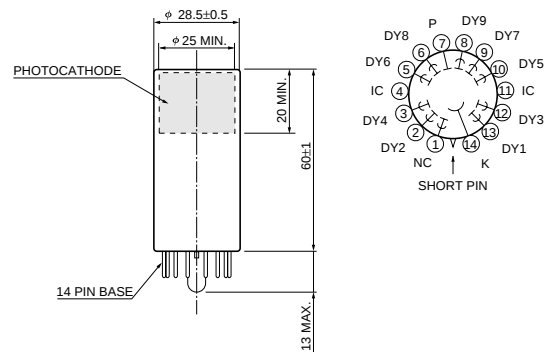
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65 R7373-01



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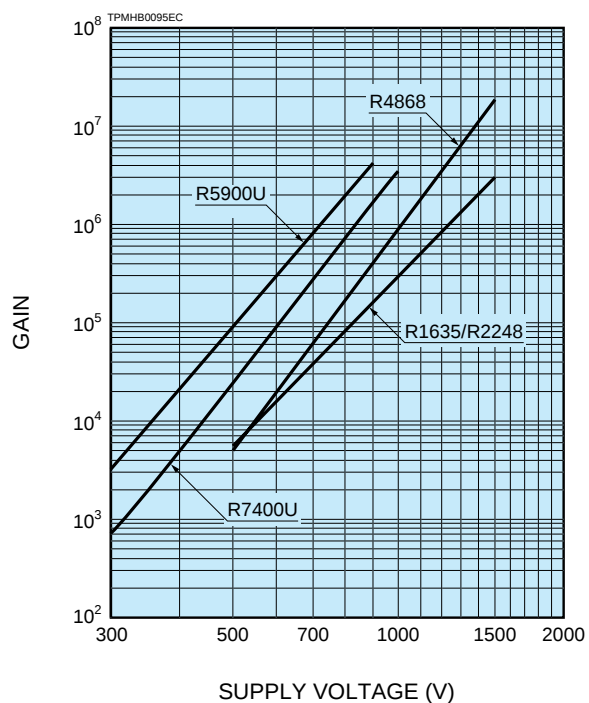
66 R7354



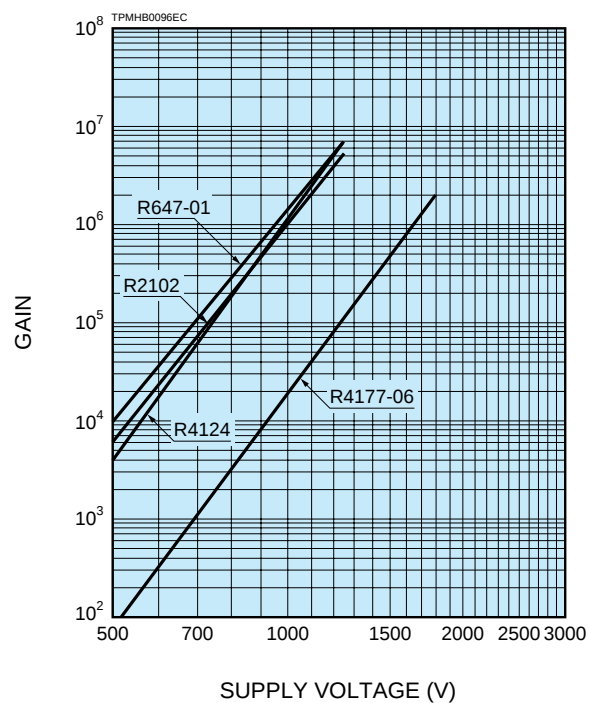
TPMHA0416EA

Typical Gain Characteristics

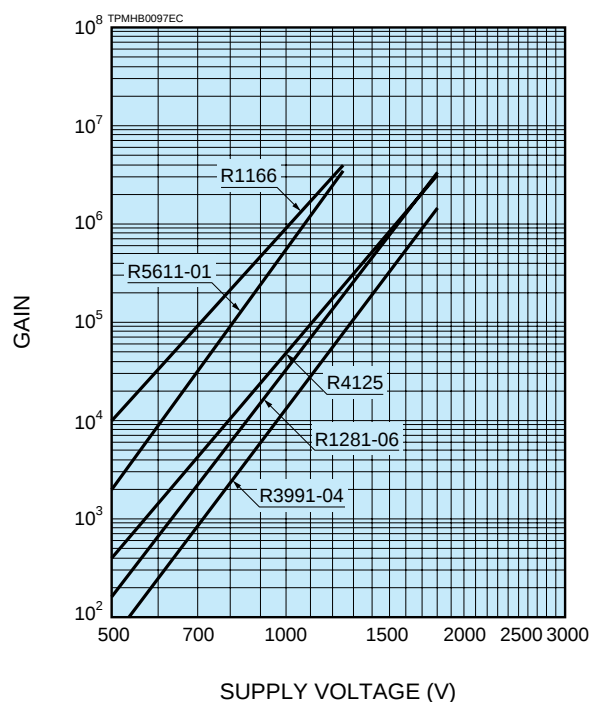
● 10mm (3/8") Dia. and Metal Package Types



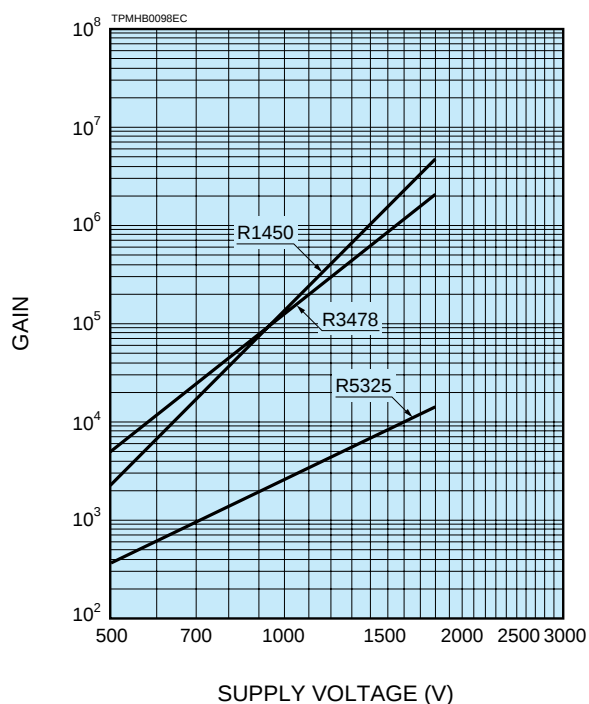
● 13mm (1/2") Dia. Types



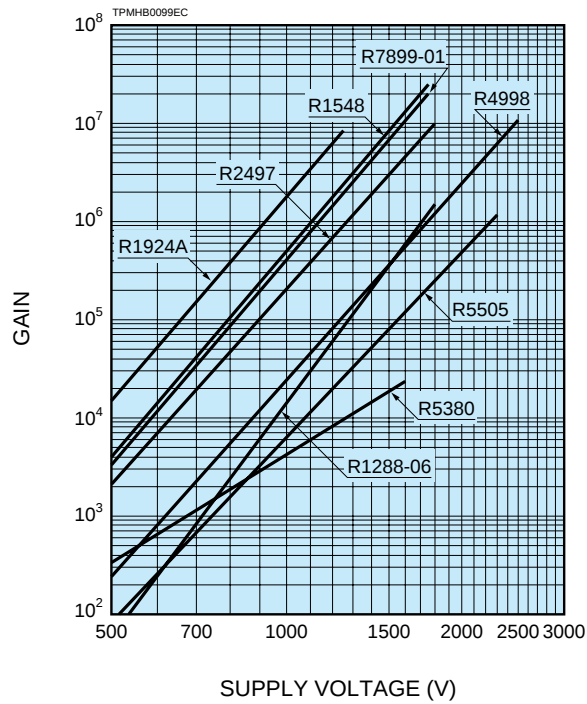
● 19mm (3/4") Dia. Types



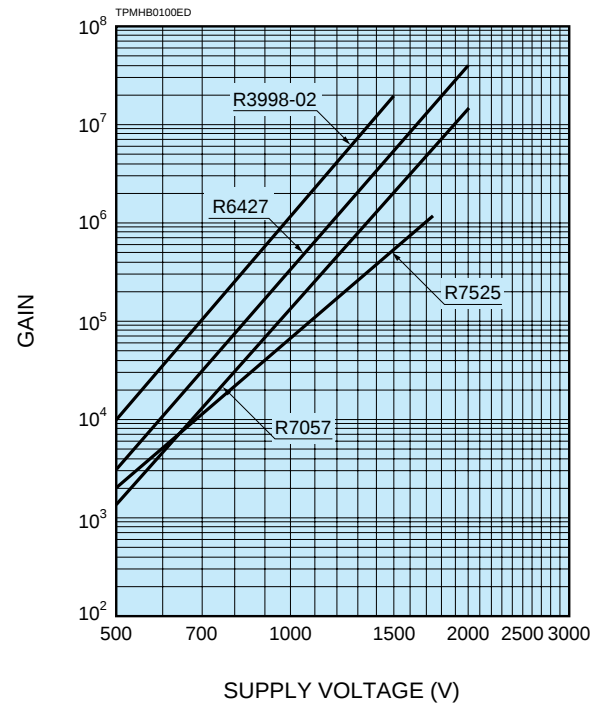
● 19mm (3/4") Dia. Types



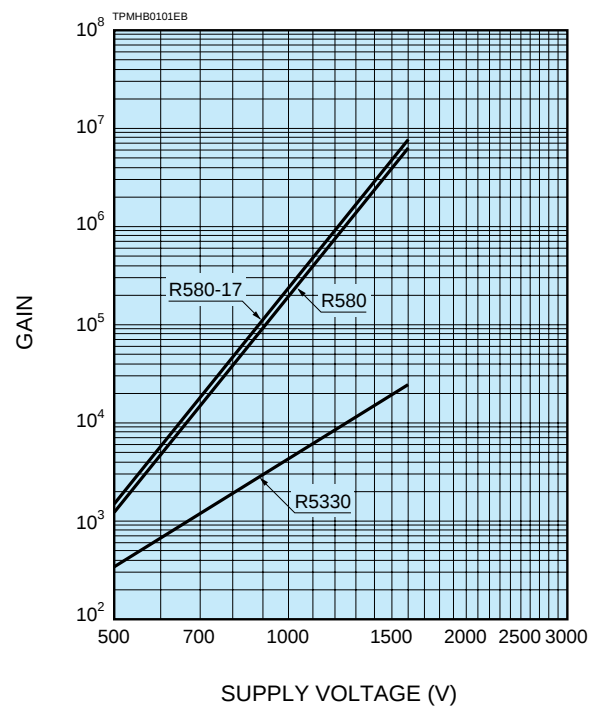
● 25mm (1") Dia. Types



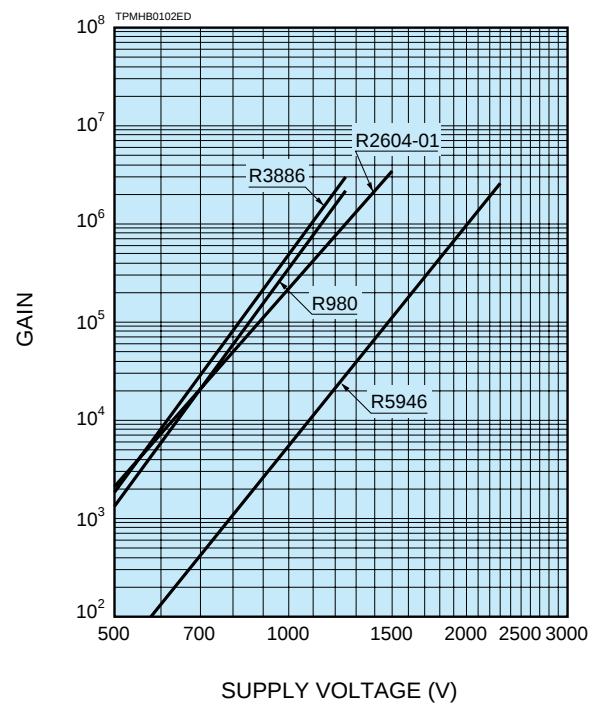
● 28mm (1-1/8") Dia. Types



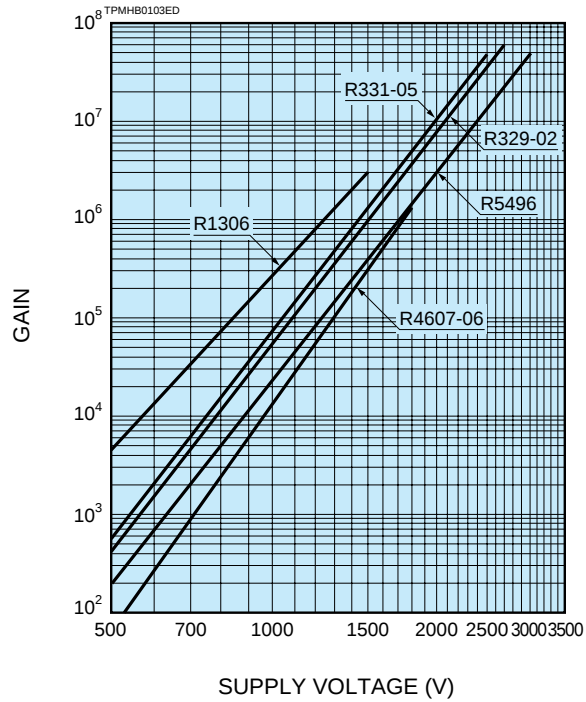
● 38mm (1-1/2") Dia. Types



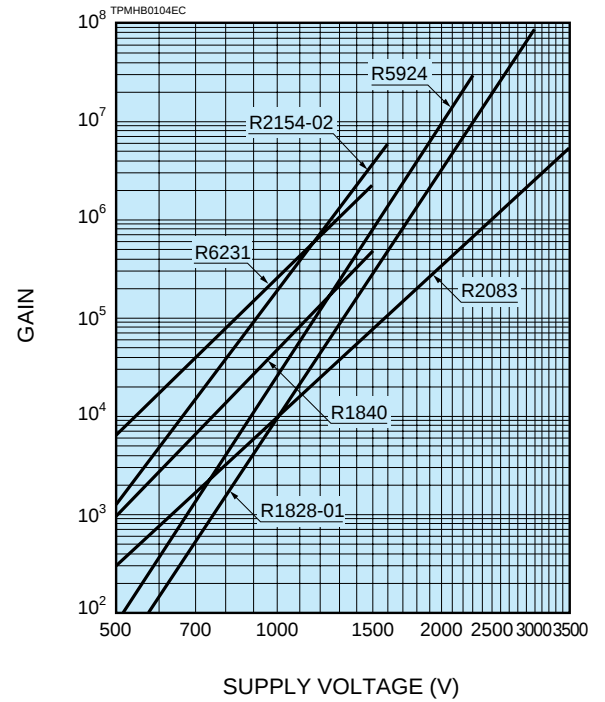
● 38mm (1-1/2") Dia. Types



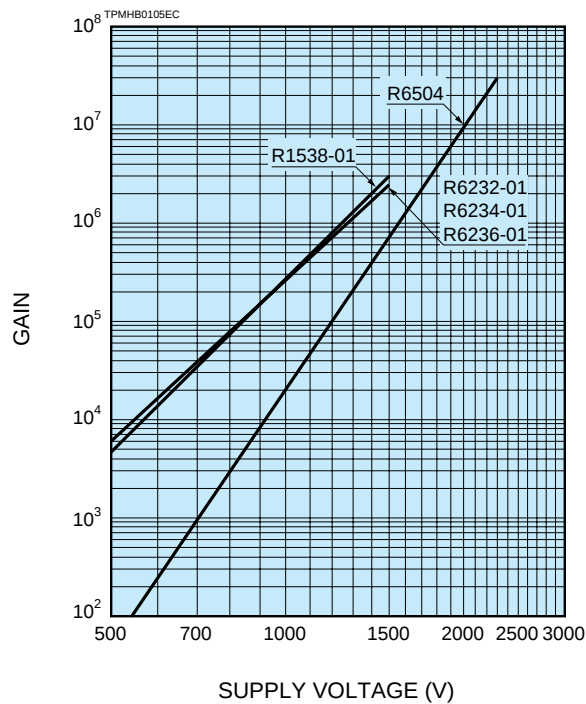
● 51mm (2") Dia. Types



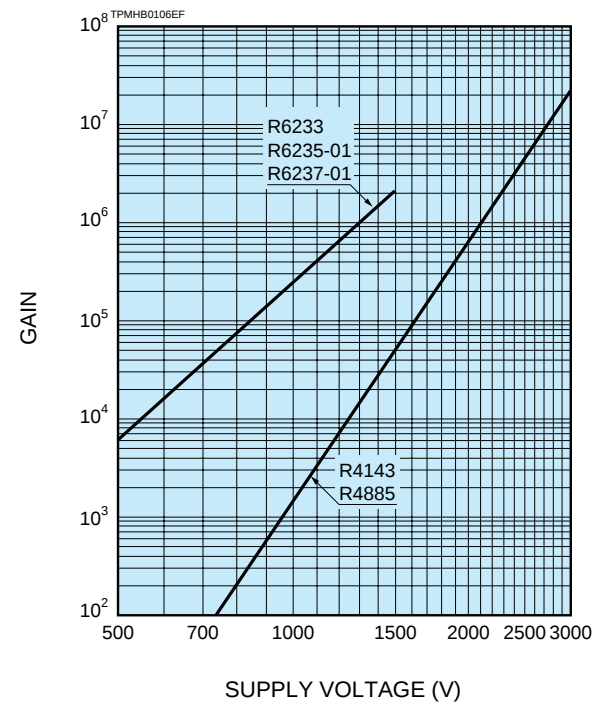
● 51mm (2") Dia. Types



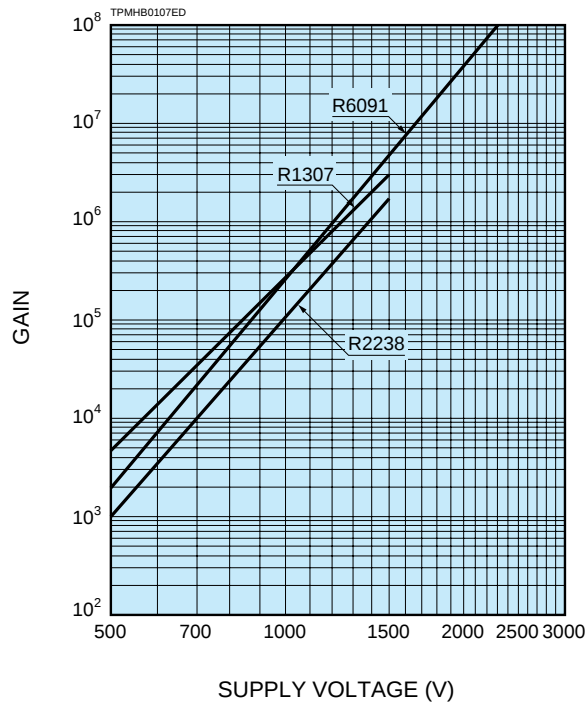
● 60mm and 64mm (2.5") Dia. Types



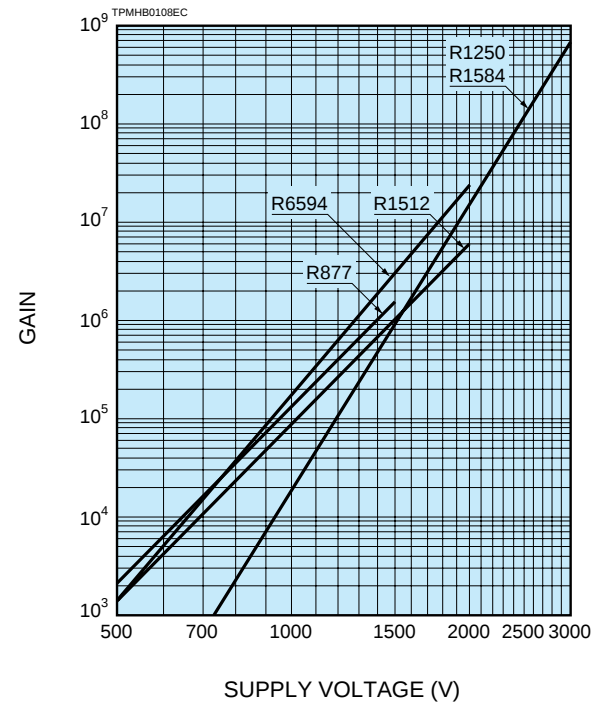
● 76mm (3") Dia. Types



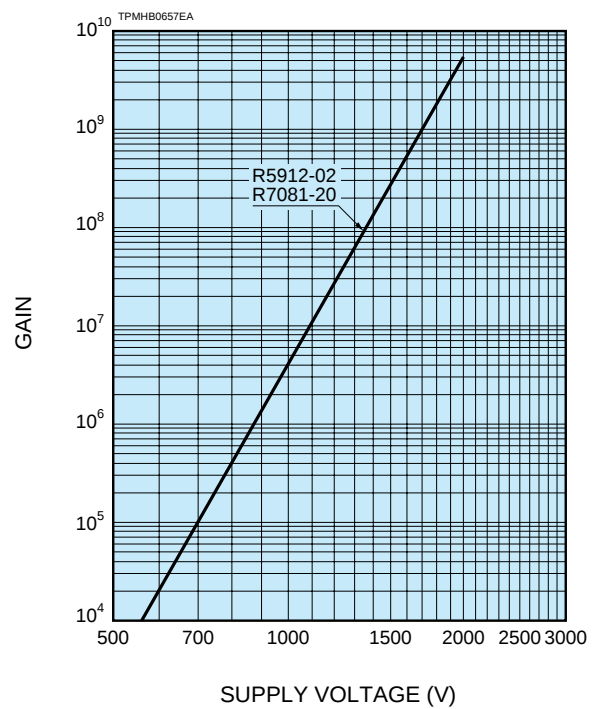
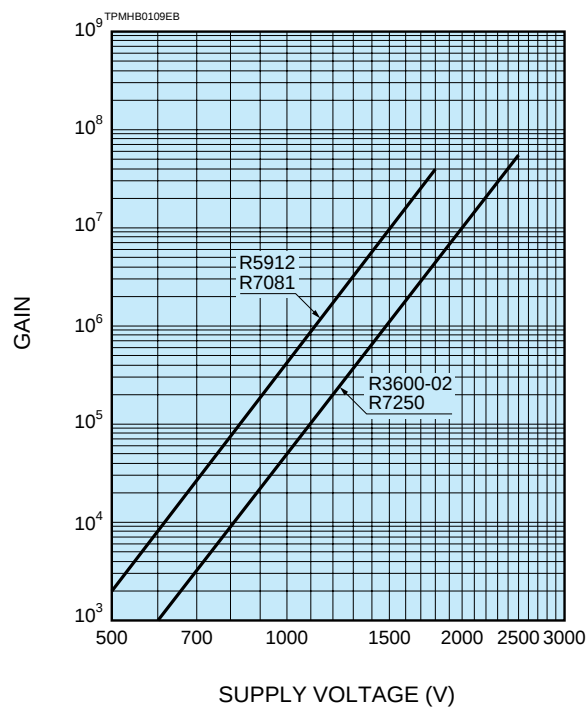
● 76mm (3") Dia. Types



● 127mm (5") Dia. Types



● 204mm (8"), 254mm (10") and 508mm (20") Dia. Types



Position Sensitive Photomultiplier Tubes

Tube Diameter	Type No.	Spectral Response Range(nm) /Curve Code	Outline No.	Anode Configuration			Socket	Dynode Structure No. of Stages	Cathode Sensitivity		
				Effective Area (mm)	Number of Plates or Wires	Anode Pitch (mm)			Luminous Typ. (μA/Lm)	BlueSens. Index (CS 5-58) Typ.	QE at Peak Typ. (%)

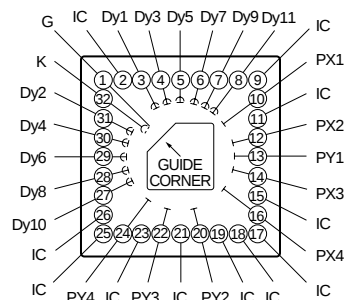
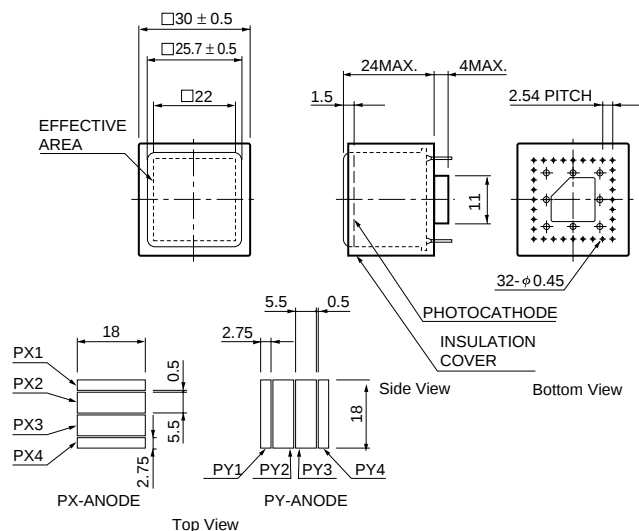
Position Sensitive Photomultiplier Tubes with Metal Channel Dynodes

30mm Square Type	R5900U-00-C8	300 to 650/A-D	①	22×22	4(X)+4(Y) Plates	6.0	E678-32B	MC/11	70	8.0	20
	R5900U-00-C12	300 to 650/A-D	②	22×22	6(X)+6(Y)Plates	4.0	E678-32B	MC/11	70	8.0	20

Position Sensitive Photomultiplier Tubes

3"	R2486-02	300 to 650/A-D	3	φ50	16(X)+16(Y) Wires	3.75	—	CM/12	80	9.0	23
5"	R3292-02	300 to 650/A-D	4	φ100	28(X)+28(Y)Wires	4.0	—	CM/12	80	9.0	23

1 R5900U-C8

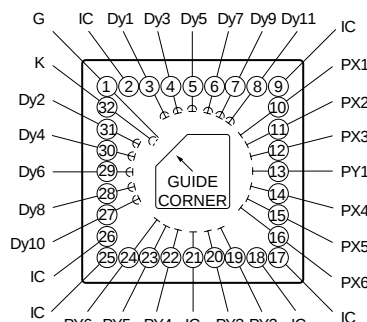
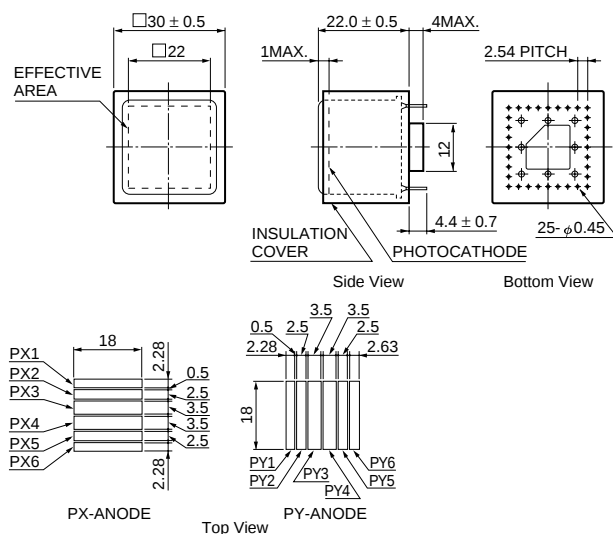


Basing Diagram

K : Photocathode
Dy : Dynode (Dy1-Dy11)
P : Anode (PX1-PX4)
(PY1-PY4)
IC : Internal Connection
(Do not use)

TPMHA0356FA

② R5900U-C12



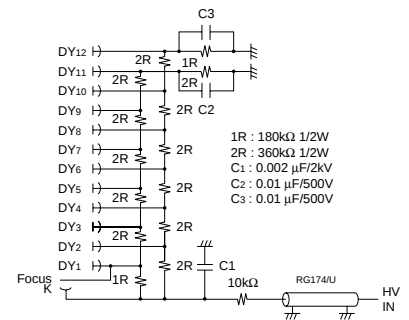
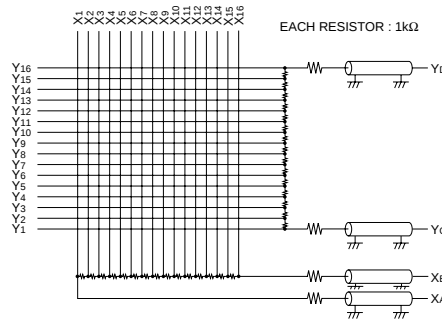
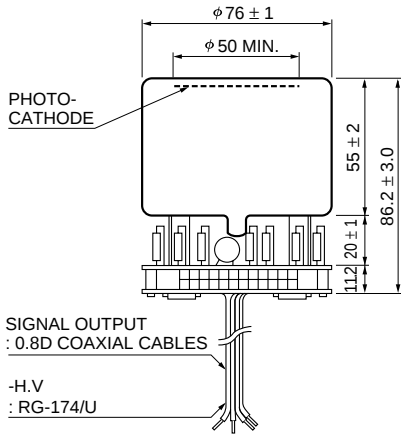
Bottom View
Basing Diagram

K : Photocathode
Dy: Dynode (Dy1-Dy11)
P : Anode (PX1-PX6)
(PY1-PY6)
IC : Internal Connection
(Do not use)
G : Grid

TPMHA0447EA

Anode Sensitivity		Anode Sensitivity			12 Maximum Rating		13 Time Response			Note
8 Anode to Cathode Supply Voltage (vdc)	9 Gain Typ.	10 Luminous Typ. (A/Lm)	11 Dark Current		Anode to Cathode Voltage (Vdc)	Average Anode Current (mA)	Rise Time Typ. (ns)	Transit Time Typ. (ns)	T.T.S. Typ. (FWHM) (ns)	
			Typ. (nA)	Max. (nA)						
800(36)	7.0×10^5	50	2	—	900	0.1	1.40	9.5	0.70	Flangeless type(R7600-00-C8)is available.
800(36)	7.0×10^5	50	2	—	900	0.1	1.40	9.5	0.70	Flangeless type(R7600-00-C12)is available.
1250(38)	1.0×10^5	8	20	—	1300	0.1	5.5	17	—	No suffix number PMT alone -01 : PMT+Voltage Divider -02 : -01+Resistor Chain -05 : -02+HA+4 Preamplifier
1250(38)	1.0×10^5	8	40	—	1300	0.1	6.0	20	—	

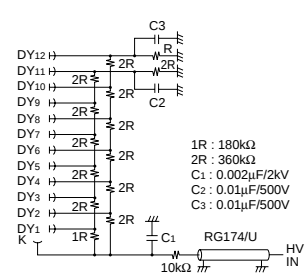
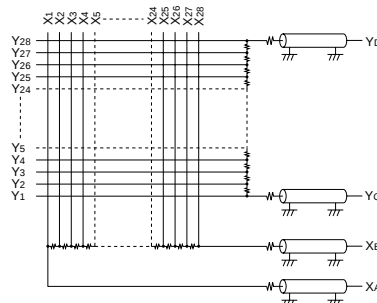
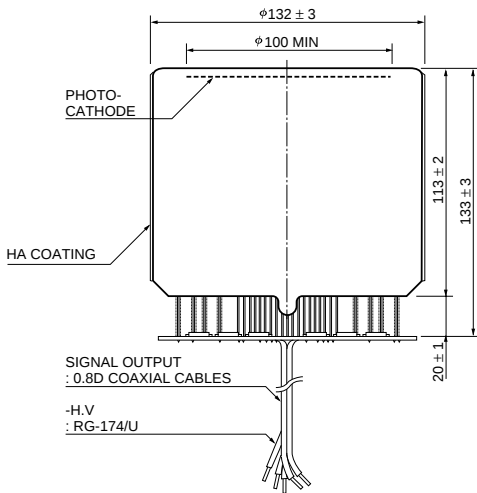
3 R2486-02



TPMHA0160ED

TPMHA0086EC

4 R3292-02



TPMHA0162EE

TPMHA0088EC

Voltage Distribution Ratios

Interstage voltages 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 and 9 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							
		K	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	P
①	6	2	1	1	1	1.5	2	3	
②		2	1	1	1	2	4	2	
③		3	1	1	1	2	3	2	

No.	Stages	K	G1	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	P
④	8	1	—	1	1	1	1	1	1	1	1	0.5
⑤		1	1	1	1	1	1	1	1	1	1	1
⑥		2	—	2	1	1	1	1	1	1	1	1
⑦		2	2	1	1	1	1	1	1	1	1	1
⑧		4	—	1	1.5	1	1	1	1	1	1	1
⑨		4	—	1	1.5	1	1.2	1.2	2	3.3	3	3
⑩		7	—	1	1.5	1	1	1	1	1	1	1

No.	Stages	K	G1	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Acc	Dy7	Dy8	P
⑪	8	1.3	4.8	1.2	1.8	1	1	1	1	0.5	3	2.5	

Acc : Grid (Accelerating Electrode)

No.	Stages	K	G1	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	P
⑫	9	3	1	1	1	1	1	1.5	1	1	1	1	1
⑬		4	1	1	1	1	1	1.5	1	1	1	1	1

No.	Stages	K	G1	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	P
⑭	10	1	—	1	1	1	1	1	1	1	1	1	1	1
⑮		1	1	1	1	1	1	1	1	1	1	1	1	1
⑯		1.3	4.8	1.2	1.8	1	1	1	1	1	1.5	3	2.5	
⑰		1.5	—	1	1	1	1	1	1	1	1	1	1	1
⑱		1.5	—	1	1	1	1	1	1	1.2	1.8	3.6	3.3	
⑲		1.5	—	1.5	1.5	1	1	1	1	1	1	1	1	1
⑳		2	—	1	1	1	1	1	1	1	1	1	1	1
㉑		2	—	1	1	1	1	1	1	1.2	1.5	1.8	2	
㉒		2	—	1	1	1	1	1	1.2	1.5	2.2	3.6	3	
㉓		2	—	1	1.5	1	1	1	1	1	1	1	0.75	
㉔		2	—	2	1	1	1	1	1	1	1	1	1	1
㉕		2.6	—	1.2	1.2	1	1	1	1	1	1	1	1	1
㉖		2.6	—	1.2	1.2	1	1	1	1	1.5	2.3	3	3.5	
㉗		3	—	1	1	1	1	1	1	1	1	1	1	1
㉘		3	—	1	1.5	1	1	1	1	1	1	1	1	1
㉙		3	—	1	1.5	1	1	1	1	1	2	3	2	
㉚		4	—	1	1.5	1	1	1	1	1	1	1	1	1
㉛		4	—	1	1.5	1	1	1	1.2	1.5	2	3.3	3	
㉜		6	—	1	1.5	1	1	1	1	1	1	1	1	1
㉝		6	—	1	1.5	1	1	1	1.2	1.5	2	3.3	3	

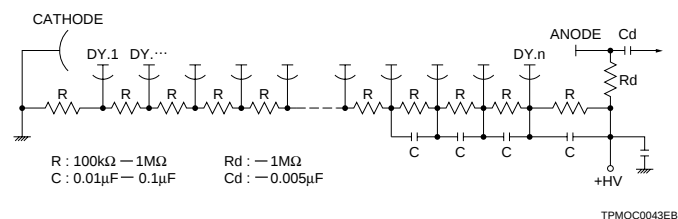
No.	Stages	K	Dy1	F1	F3	F2	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	P
⑳	10	8	0.18	0	0.17	0.85	1.5	1	1	1	1	1	1	1	1	1
㉞		8	0.18	0	0.17	0.85	1.5	1	1	1	1.2	1.5	1.8	3	2.4	

< note >

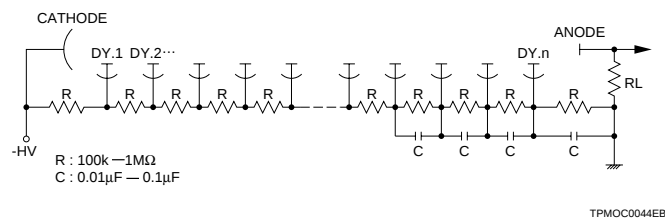
K : Cathode G : Grid F : Focusing Electrode Dy : Dynode P : Anode ㉞ : Acc should be connected to Dy7

Schematic Diagrams of Voltage Divider Networks

(1) Cathode Ground Scheme



(2) Anode Ground Scheme



Voltage Distribution Ratio

Voltage Distribution No.	Number of Stages	Voltage Distribution Ratios													
		K	G1	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	Dy11	P
36	11	0.5	1.5	2	1	1	1	1	1	1	1	1	1	0.5	

No.	Stages	K	F2	F1	F3	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	Dy11	P
37	11	5	1	2	0.02	3	1	1	1	1	1	1	1	1	1	1	1

No.	Stages	K	G1	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	Dy11	Dy12	P
38	12	1	—	1	1	1	1	1	1	1	1	1	1	1	1	1
39		1	3	1.2	1.8	1	1	1	1	1	1	1.5	1.5	3	2.5	
40		1	3	1.2	1.8	1	1	1	1	1.5	2.5	3.6	4.5	8.6	4	
41		1.2	2.8	1.2	1.8	1	1	1	1	1	1.5	1.5	3	2.5		
42		1.2	2.8	1.2	1.8	1	1	1.2	1.5	2	2.8	4	5.7	8	5	
43		2	—	1	1	1	1	1	1	1	1	1	1	1	1	1
44		2	—	1	1	1	1	1	1	1	1	1.2	1.5	1.8	2	
45		3	—	2	2	1	1	1	1	1	1	1	1	2	5	
46		4	0	1	1.5	1	1	1	1	1	1	1	1	1	1	
47		4	0	1	1.5	1	1	1	1.2	1.5	2	2.4	3	3.9	3	

No.	Stages	K	G1	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	Dy11	Dy12	Dy13	Dy14	P
48	14	2.5	7.5	1.2	1.8	1	1	1	1	1	1	1	1	1.5	1.5	3	2.5	
49		2.5	7.5	1.2	1.8	1	1	1	1	1.2	1.5	2	2.8	4	5.7	8	5	

No.	Stages	K	Dy1	F2	F1	F3	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	Dy11	Dy12	Dy13	Dy14	P
50	10	11.3	0	0.6	0	3.4	5	3.33	1.67	1	1	1	1	1	—	—	—	—	—	1
51		18.5	0	0.6	0	3.4	5	3.33	1.7	1	1	1	1	1	—	—	—	—	—	1
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	

No.	Stages	K	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	Dy11	Dy12	Dy13	Dy14	Dy15	Dy16	Dy17	Dy18	Dy19	P
53	15	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	—	—	—	—	—	1
54	16	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	—	—	—	—	1
55	19	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

< note >

K : Cathode G : Grid F : Focusing Electrode Dy : Dynode P : Anode

46, 47 : Shield should be connected to Dy5

Quick Reference for PMT Hybrid Assemblies

Assembly Type No.	PMT Characteristics				Assembly Characteristics							Notes
	Tube Diameter	Tube Type No.		Refer- ence Page for PMT Feature	Outline No.	H.V Input Terminal	Signal Output Terminal	Case Material	Maximum Rating			
		Voltage Distribution Ratio							Overall Voltage (V)	Divider Current (mA)	Average Anode Current (μA)	
H3164-10	10mm (3/8")	R1635	⑥	16	①	Coaxial Cable*	RG-174/U	Magnetic Shield Wrapping	-1500	0.41	17 at 1250V	H3164-11 (with 50Ω**)
H3695-10		R2496	⑥	17	②	Coaxial Cable*	RG-174/U	Magnetic Shield Wrapping	-1500	0.37	15 at 1250V	H3695-11 (with 50Ω**)
H3165-10	13mm (1/2")	R647-01	⑭	16	③	RG-174/U or equiv.	RG-174/U	Magnetic Shield Wrapping	-1250	0.34	14 at 1000V	H3165-11 (with 50Ω**)
H6520	19mm (3/4")	R1166	⑰	16	④	Coaxial Cable*	RG-174/U	Magnetic Shield Case	-1250	0.33	13 at 1000V	H6520-01 (with 50Ω**)
H6524		R1450	⑰	16	⑤	Coaxial Cable*	RG-174/U	Magnetic Shield Case	-1800	0.43	18 at 1500V	H6524-01 (with 50Ω**)
H6613		R2076	⑩	17	⑥	Coaxial Cable*	RG-174/U	Magnetic Shield Case	-1800	0.35	17 at 1700V	H6613-01 (with 50Ω**)
H6612		R3478	⑩	16	⑦	Coaxial Cable*	RG-174/U	Magnetic Shield Case	-1800	0.35	17 at 1700V	H6612-01 (with 50Ω**)
H6533	25mm (1")	R4998	⑰	16	⑧	Coaxial Cable*	RG-174/U	Magnetic Shield Case	-2500	0.36	16 at 2250V	H6610(R5320)
H6152-70		R5505	⑤③	16	⑨	Coaxial Cable*	RG-174/U	P.O.M Case	+2300	0.41	18 at 2000V	+HV
H7415	28mm (1-1/8")	R6427	③①	16	⑩	Coaxial Cable*	RG-174/U	Magnetic Shield Case	-2000	0.41	16 at 1500V	H7415-01 (with 50Ω**)
H7416		R7056	③①	17	⑩	Coaxial Cable*	RG-174/U	Magnetic Shield Case	-2000	0.41	16 at 1500V	H7416-01 (with 50Ω**)
H7417		R7057	③②	16	⑪	Coaxial Cable*	RG-174/U	Magnetic Shield Case	-2000	0.37	14 at 1500V	H7417-01 (with 50Ω**)
H3178-51	38mm (1-1/2")	R580	②②	26	⑫	SHV	BNC	Magnetic Shield Case	-1750	0.63	27 at 1500V	
H3178-61		R580-17	②⑥	16	⑫	SHV	BNC	Magnetic Shield Case	-1750	0.61	26 at 1500V	
H6153-70		R5946	⑤④	16	⑬	Coaxial Cable*	RG-174/U	P.O.M Case	+2300	0.39	17 at 2000V	+HV

NOTE

* marks = It's possible to attach an SHV connector fitting RG-174/U to the coaxial cable.

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

*** marks = 2 anode outputs and a dynode output.

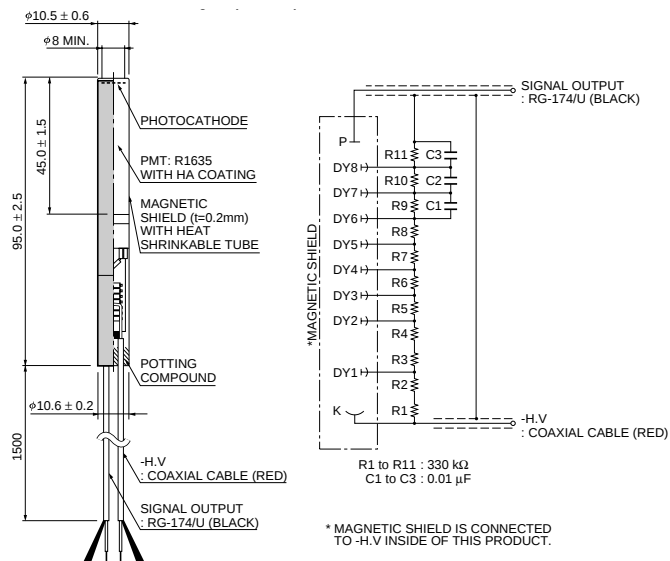
Assembly Type No.	PMT Characteristics				Assembly Characteristics							
	Tube Diameter	Tube Type No.		Reference Page for PMT Feature	Outline No.	H.V Input Terminal	Signal Output Terminal	Case Material	Maximum Rating			Notes
		Voltage Distribution Ratio							Overall Voltage (V)	Divider Current (mA)	Average Anode Current (μA)	
H6410	51mm (2")	R329-02	④7	18	⑭	SHV	BNC	Magnetic Shield Case	-2700	0.67	25 at 2000v	H6521(R2256), H6522(R5113)
H7195		R329-02	④7	18	⑮	SHV	BNC×3***	Magnetic Shield Case	-2700	1.23	46 at 2000V	with dynode output
H1949-50		R1828-01	④1	18	⑯	SHV	BNC×3***	Magnetic Shield Case	-3000	1.39	58 at 2500V	H3177-50(R2059), H4022-50(R4004) with dynode output
H1949-51		R1828-01	④1	18	⑰	SHV	BNC	Magnetic Shield Case	-3000	0.70	29 at 2500V	H3177-51(R2059), H4022-51(R4004)
H2431-50		R2083	⑪	18	⑱	SHV	BNC	Magnetic Shield Case	-3500	0.61	26 at 3000V	H3378-50 (R3377)
H6614-70		R5924	⑤⑤	18	⑲	Coaxial Cable*	RG-174/U	P.O.M case	+2300	0.33	15 at 2000V	+HV
H8318-70	64mm (2.5")	R6504	⑤⑤	18	⑳	Coaxial Cable*	RG-174/U	P.O.M case	+2300	0.33	15 at 2000V	+HV
R2238-01	76mm (3")	R2238	④③	18	㉑	RG-174/U	RG-174/U	—	-1500	0.45	19 at 1250V	
H6525		R4143	③⑨	18	㉒	SHV	BNC	Magnetic Shield Case	-3000	0.70	29 at 2500V	H6526(R4885)
H6559		R6091	④7	18	㉓	SHV	BNC	Magnetic Shield Case	-2500	0.62	25 at 2000V	
H6527	127mm (5")	R1250	④⑧	18	㉔	SHV	BNC	Magnetic Shield Case	-3000	1.02	34 at 2000V	
H6528		R1584	④⑧	18	㉔	SHV	BNC	Magnetic Shield Case	-3000	1.02	34 at 2000V	
R3600-06	508mm (20")	R3600-02	③7	18	㉕	RG-174/U or equiv.	RG-58C/U	—	+2500	0.44	18 at 2000V	

H6568	Metal Package PMT	16ch(4×4)	③⑧	20	㉖	Coaxial Cable*	Coaxial Cable*	P.O.M case	-1000	0.35	14 at 800V	(14 μA is total anode current)
H7546		64ch(8×8)	④⑤	20	㉗	Terminal PIN	Terminal PIN	P.O.M case	-1000	0.45	18 at 800V	(18 μA is total anode current)
H7260		32ch(1×32)	①7	20	㉘	Terminal PIN	Terminal PIN	P.O.M case	-900	0.37	100 at 800V	(100 μA is total anode current)

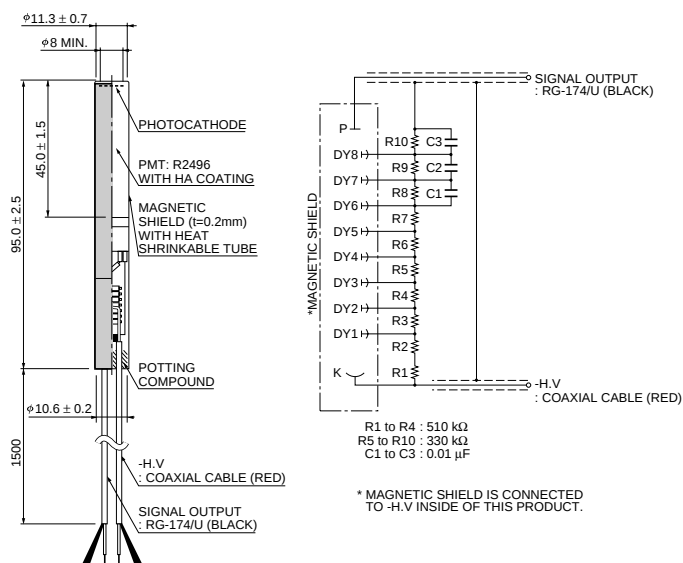
Dimensional Outlines and Circuit Diagrams

For PMT Hybrid Assemblies

① H3164-10



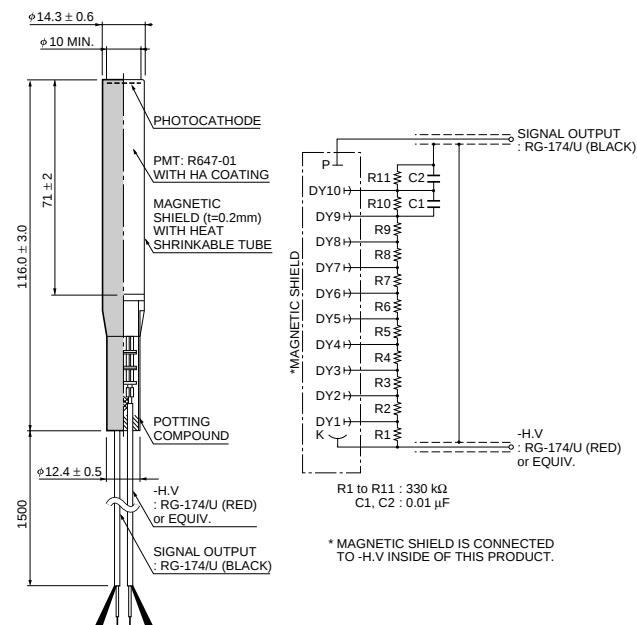
② H3695-10



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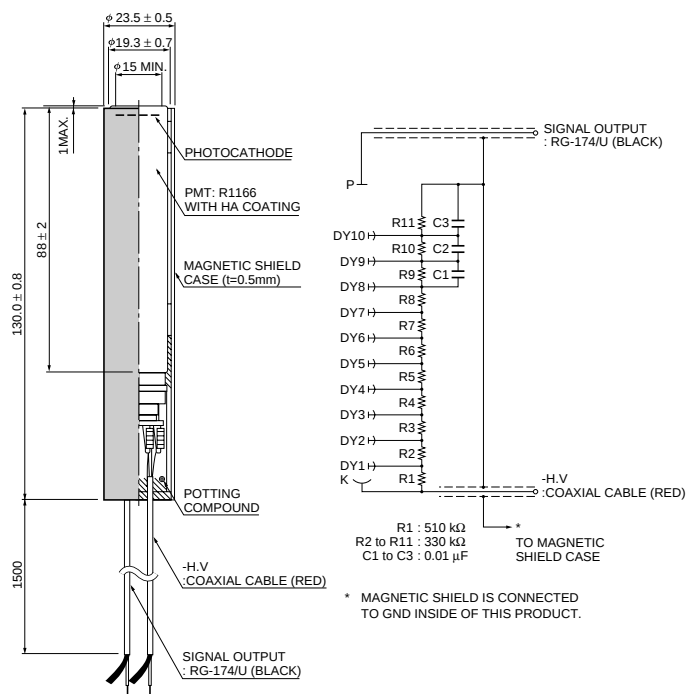
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③ H3165-10

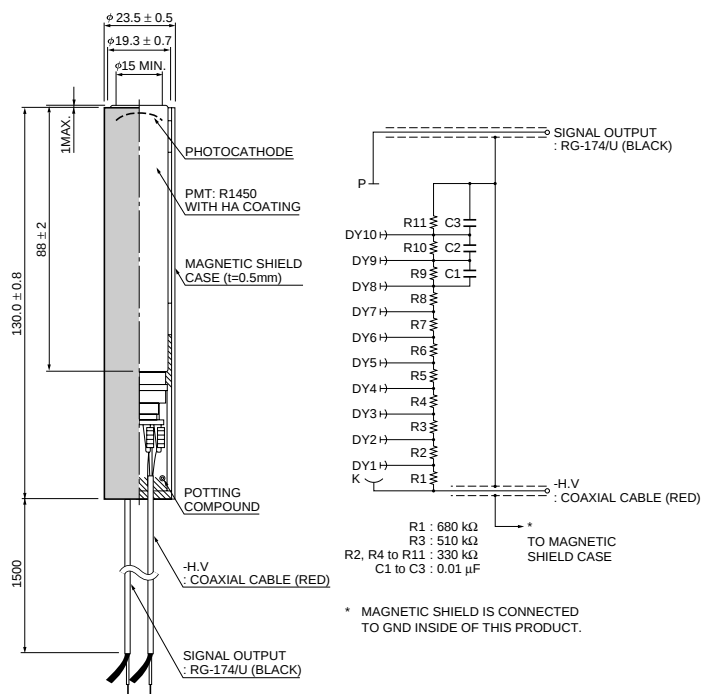


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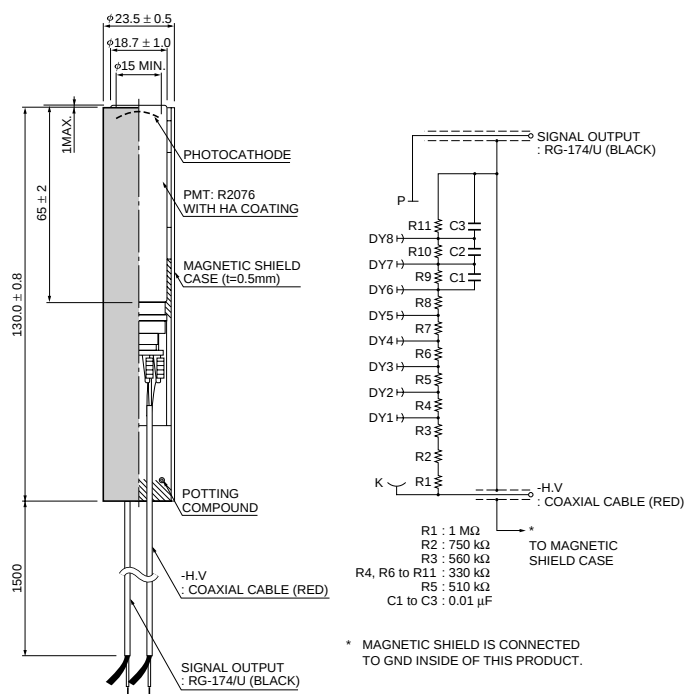
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4 H6520

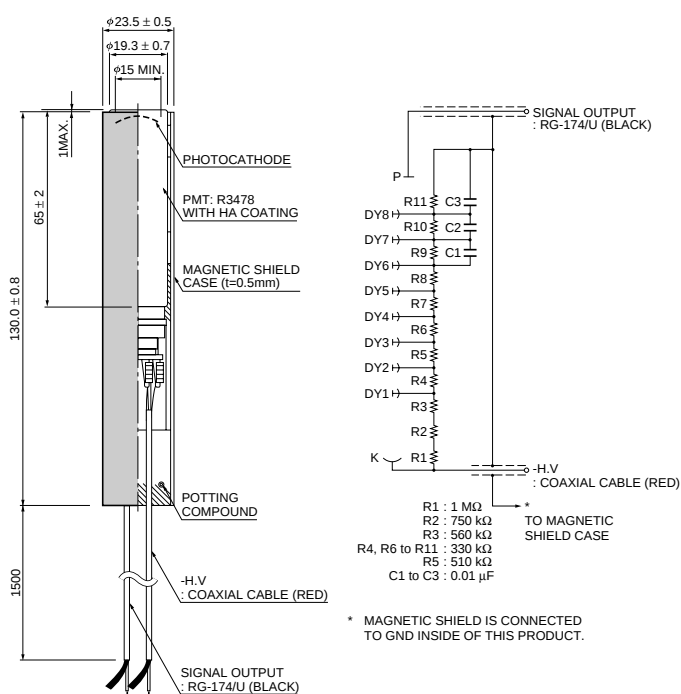
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5 H6524

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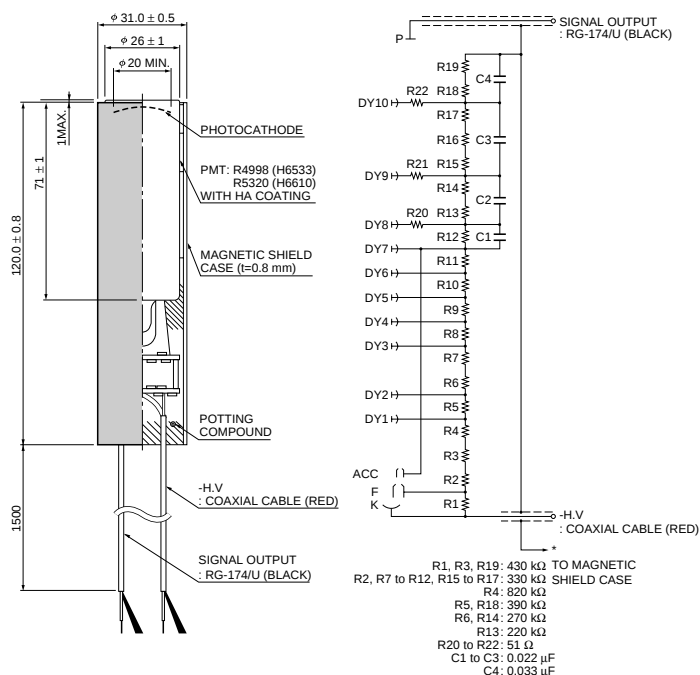
6 H6613

TPMHA0314EA

7 H6612

TPMHA0315EA

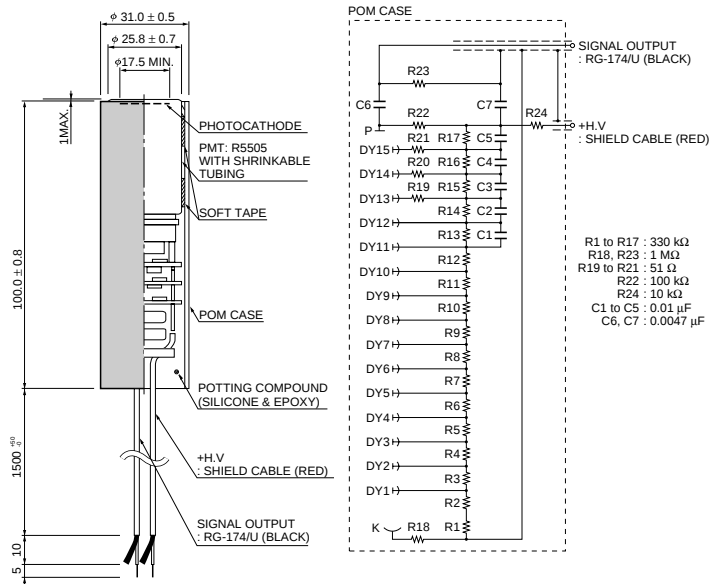
8 H6533, H6610



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

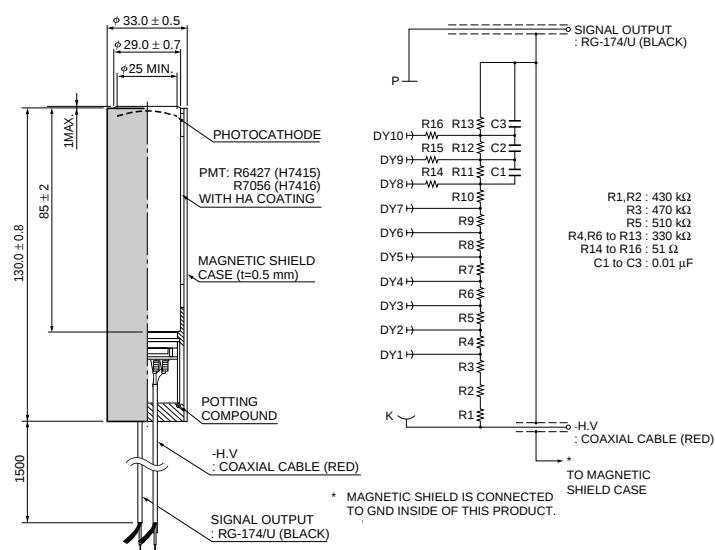
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9 H6152-70



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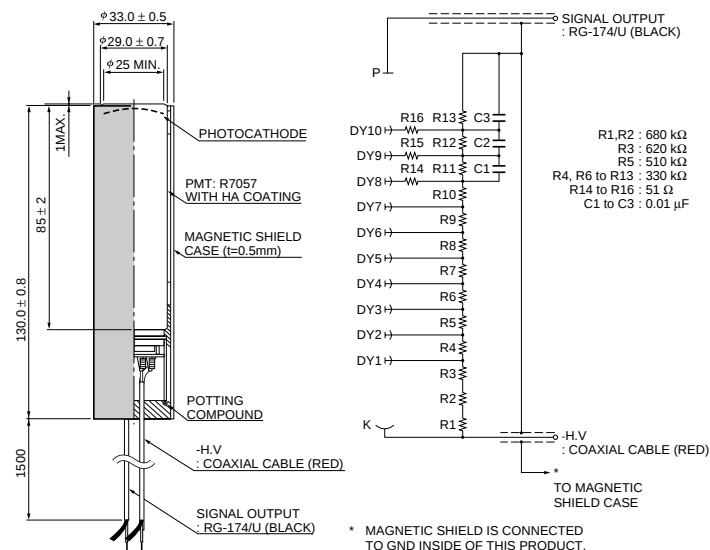
10 H7415, H7416



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11 H7417

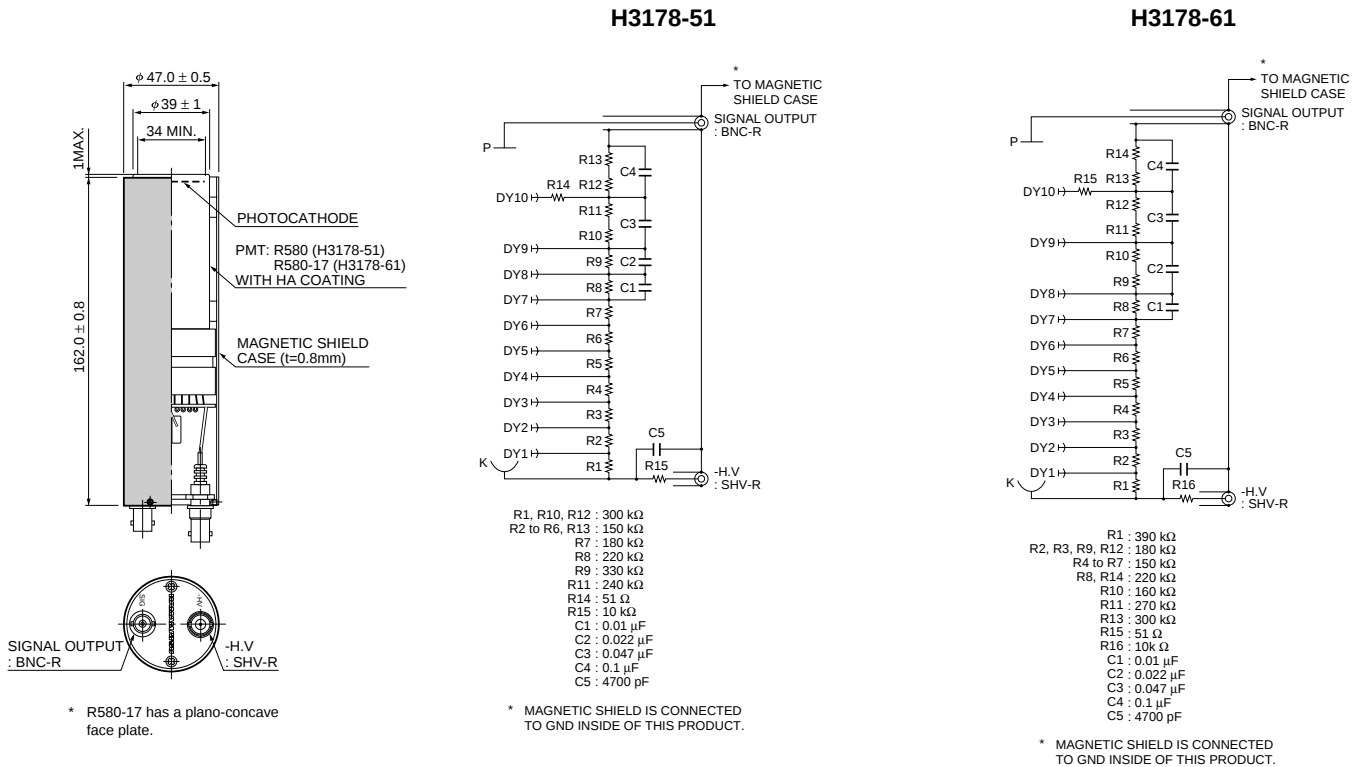


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TPMHA0319EB

(Unit : mm)

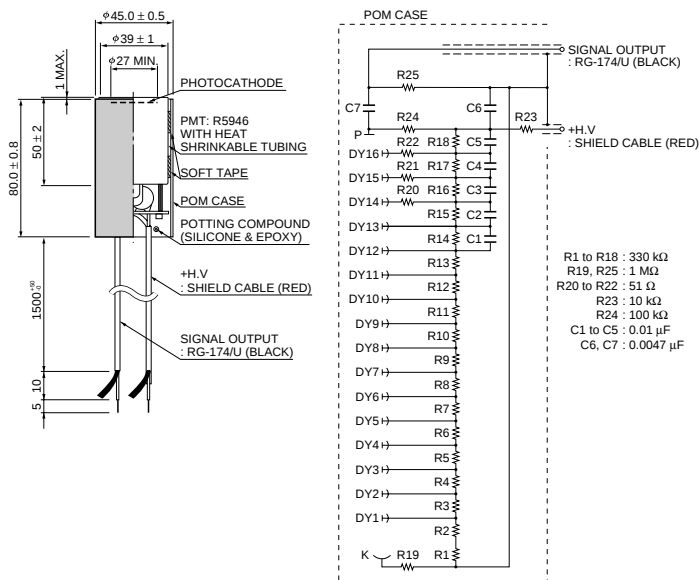
12 H3178-51, H3178-61



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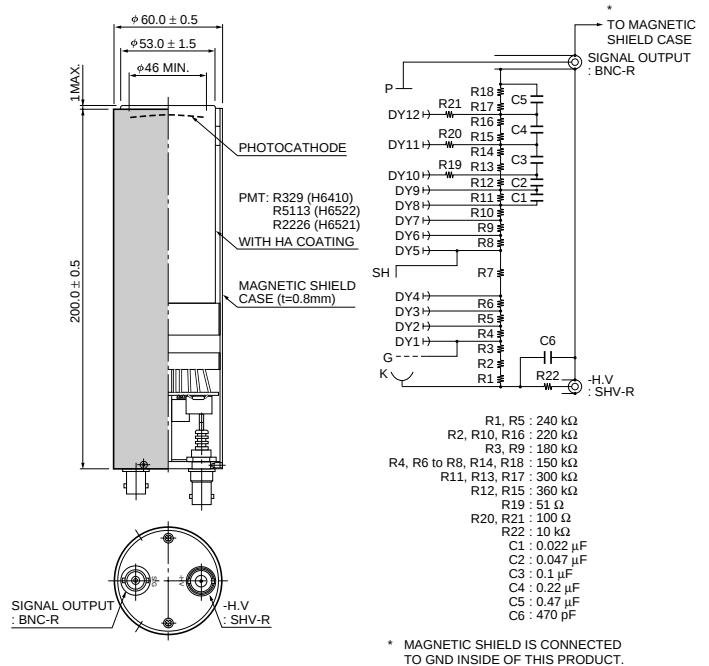
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13 H6153-70



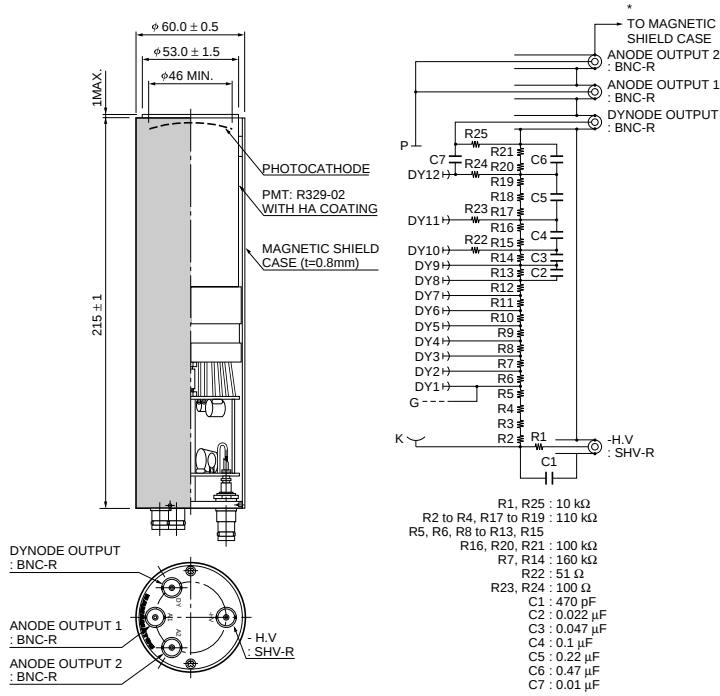
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14 H6410, H6521, H6522



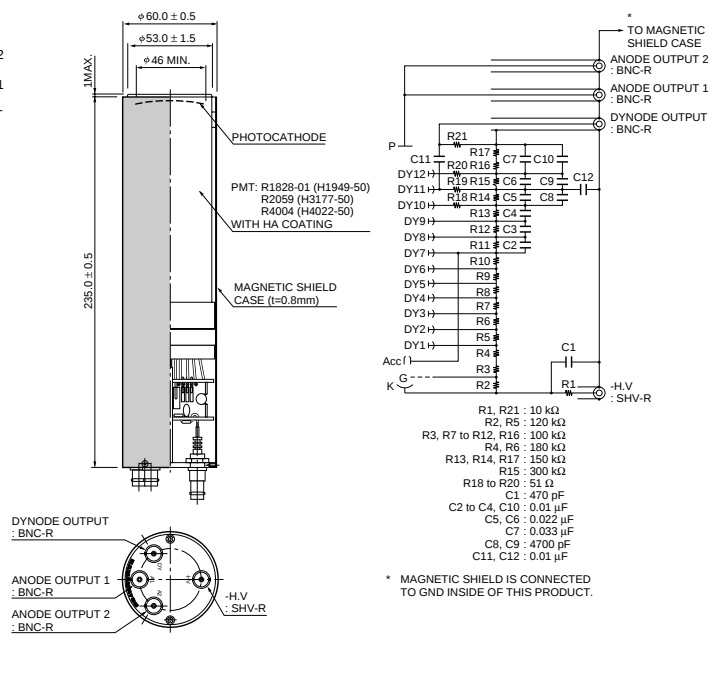
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15 H7195



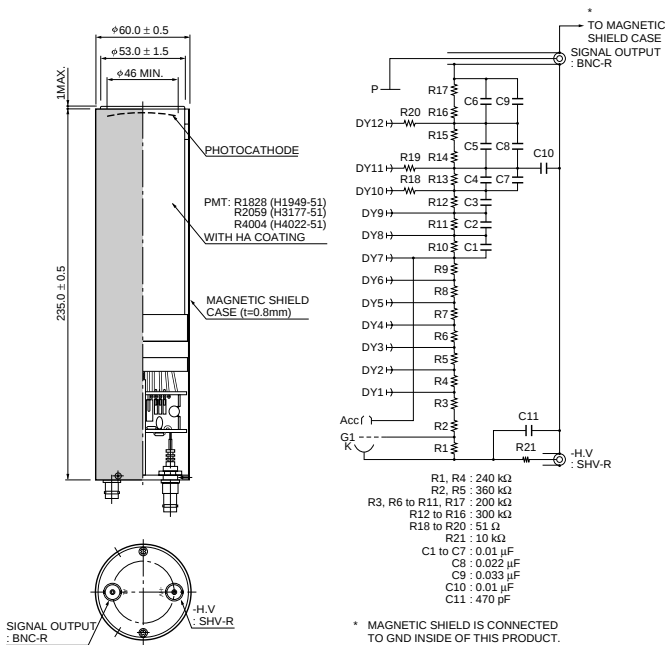
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16 H1949-50, H3177-50, H4022-50



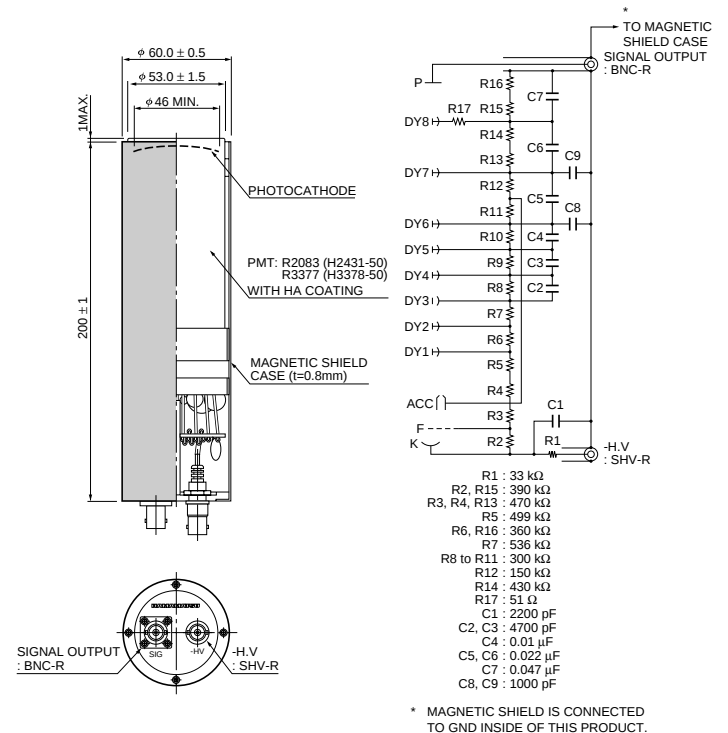
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17 H1949-51, H3177-51, H4022-51



TPMHA0326EC

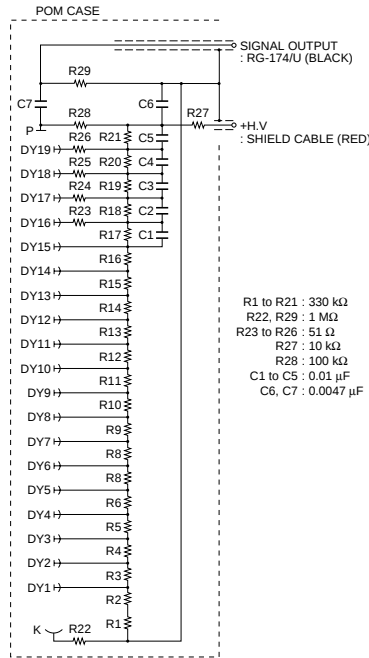
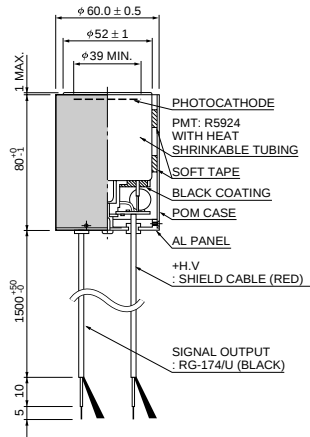
18 H2431-50, H3378-50



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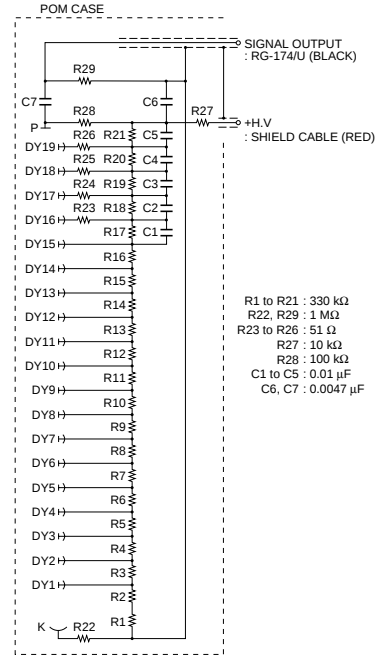
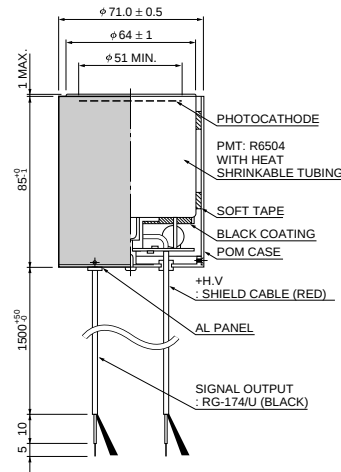
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19 H6614-70



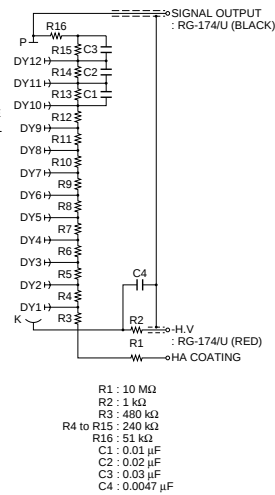
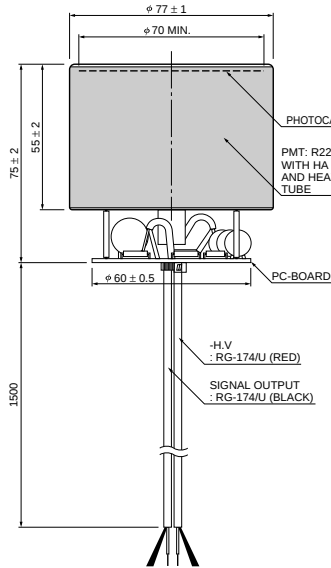
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20 H8318-70



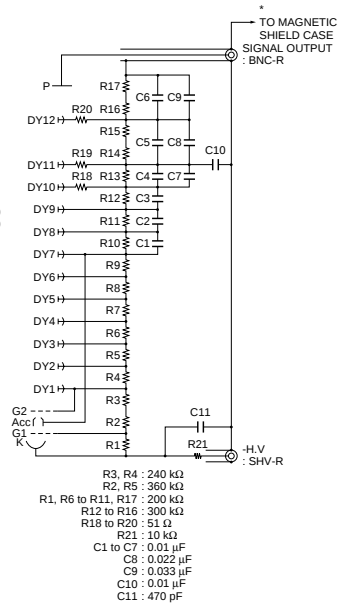
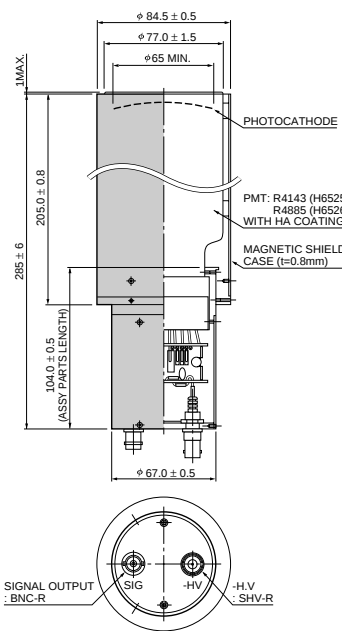
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21 R2238-01



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22 H6525, H6526

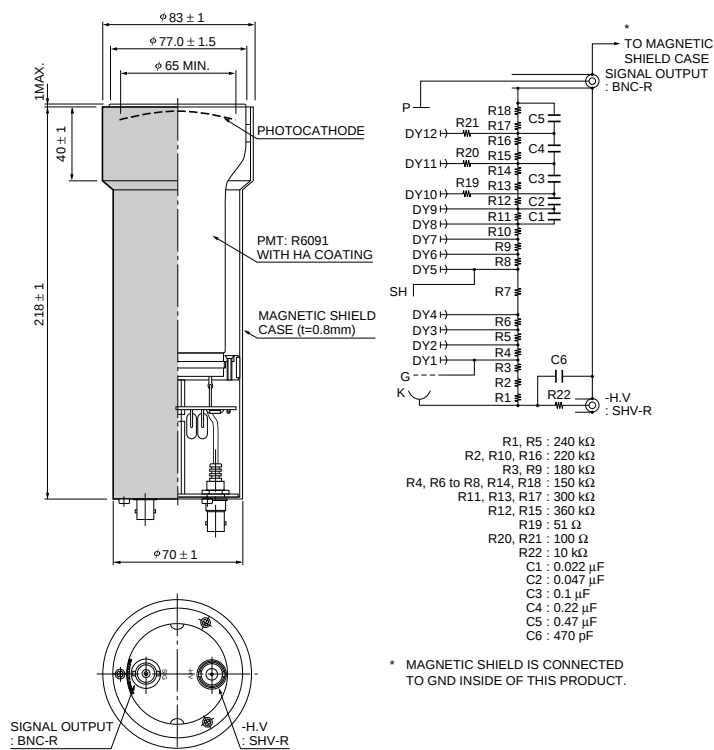


* MAGNETIC SHIELD IS CONNECTED TO GND INSIDE OF THIS PRODUCT.

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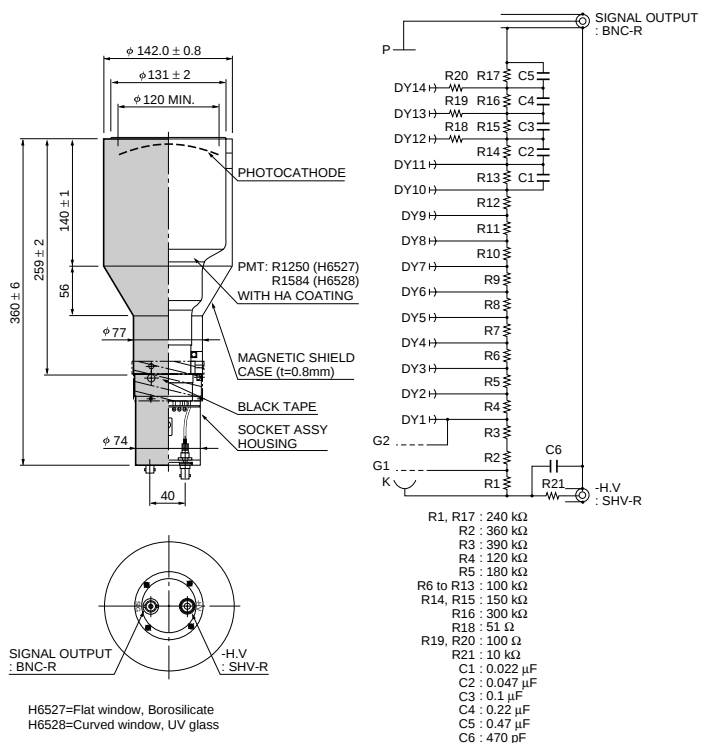
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23 H6559



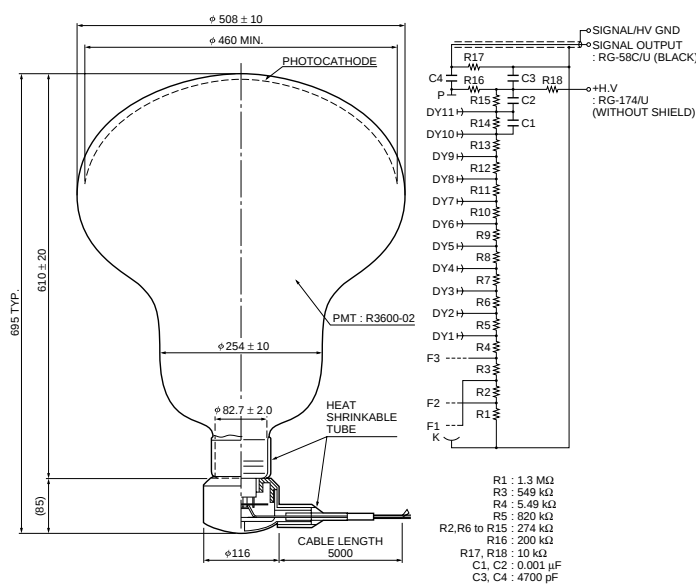
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24 H6527, H6528



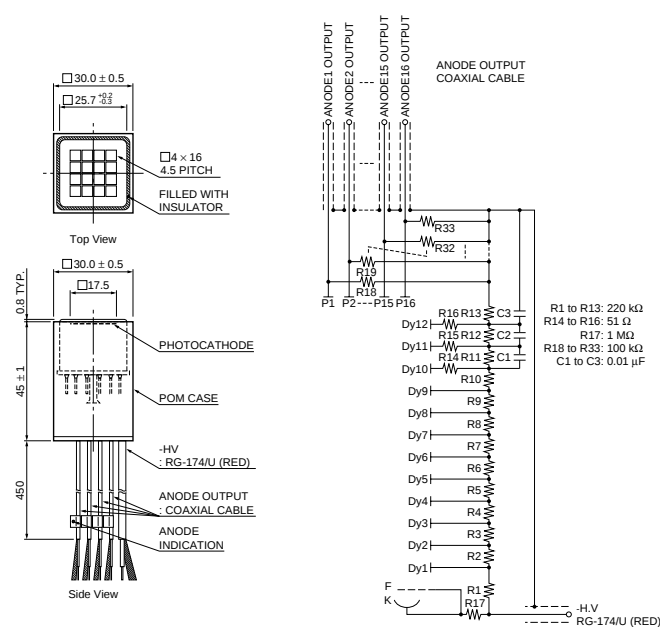
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25 R3600-06



TPMHA0156EC

26 H6568

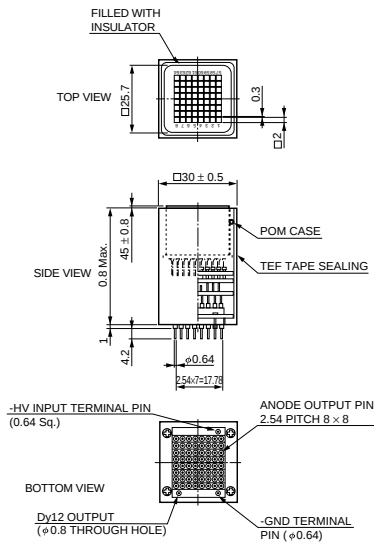


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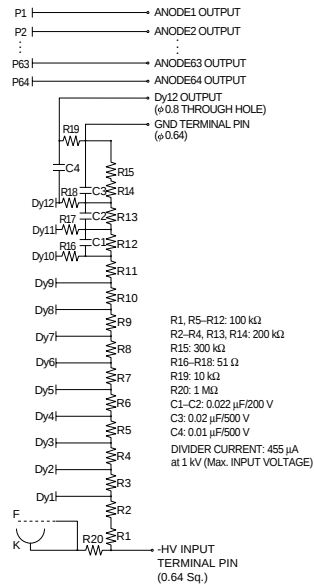
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27 H7546

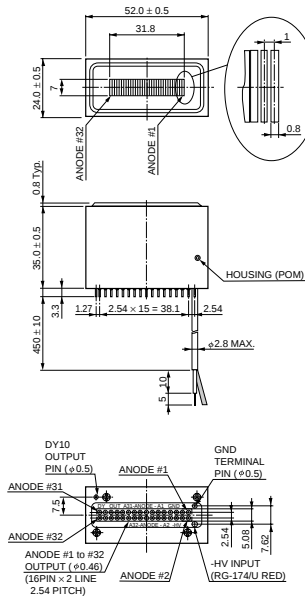


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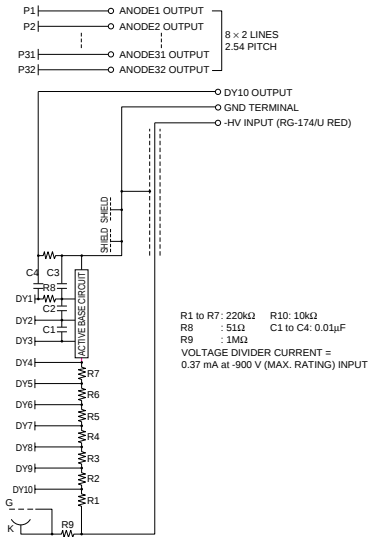
28 H7260



TPMHC0179EA



TPMHA0456ED



TPMHC0193EB

Quick Reference for PMT Socket Assemblies

Assembly Type No.	PMT Characteristics				Assembly Characteristics							Notes
	Tube Diameter	Tube Type No.		Reference Page for PMT Feature	Out-line No.	H.V Input Terminal	Signal Output Terminal	Output Signal	Maximum Rating			
		Voltage Distribution Ratio							Overall Voltage (V)	Divider Current (mA)	Average Anode Current (μA)	
E1761-21	10mm (3/8")	R1635		16								
		R2248	⑥	20	①	SHV	BNC	DC/PULSE	-1500	0.41	17 at 1250V	
E1761-22		R3878		17								
		R2496	⑥	17	①	SHV	BNC	DC/PULSE	-1500	0.37	15 at 1250V	
E849-90	13mm (1/2")	R647-01		16								
		R760	⑭	17	②	SHV	BNC	DC/PULSE	-1250	0.34	17 at 1250V	
		R960		17								
		R2102		20								
E974-22	19mm (3/4")	R1450	②③	16	③	SHV	BNC	DC/PULSE	-1800	0.43	18 at 1500V	
		R2076		17								
E2253-05		R3478	⑩	16	④	SHV	BNC	DC/PULSE	-1800	0.35	17 at 1700V	
		R3479		17								
E974-19		R4125	⑱	16	⑤	AWG22	RG-174/U	DC/PULSE	-1800	0.32	13 at 1500V	
E2037-02	25mm (1")	R1548	③①	20	⑥	AWG24	AWG24	DC/PULSE	-1750	0.18	6 at 1250V	6 μA is for total of 2 anodes.
E2924-500		R1924A	②⑦	16	⑦	SHV	BNC	DC/PULSE	-1250	0.29	12 at 1000V	
		R5505	⑤③	16	⑧	SHV	BNC	DC/PULSE	+2300	0.41	18 at 2000V	E6133-03(-HV) is available.
E6133-04		R5506		17								
E2924-10		R7899	②⑧	17	⑨	AWG22	RG-174/U	DC/PULSE	-1800	0.67	27 at 1500V	
E2624-14	28mm (1-1/8")	R6427	③①	16	⑩	SHV	BNC	DC/PULSE	-2000	0.41	16 at 1500V	
		R7056		17								
E2624-04		R6427	③①	16	⑪	SHV	BNC	DC/PULSE	-2000	0.49	18 at 1500V	
		R7056		17								
E2624-17		R7057	③②	16	⑩	SHV	BNC	DC/PULSE	-2000	0.37	14 at 1500V	
E2624-10		R7057	③③	16	⑪	SHV	BNC	DC/PULSE	-2000	0.45	17 at 1500V	
E2183-500	38mm (1-1/2")	R580							-1750	0.44	16 at 1250V	
		R980	②①	16	⑫	SHV	BNC	DC/PULSE	-1250	0.31	12 at 1000V	
		R3886							-1250	0.31	12 at 1000V	
E2183-501		R580							-1750	0.63	27 at 1500V	
		R980	②②	16	⑫	SHV	BNC	DC/PULSE	-1250	0.45	18 at 1000V	
		R3886							-1250	0.45	18 at 1000V	
E6113-03		R5946		16								
		R6148	⑤④	17	⑬	SHV	BNC	DC/PULSE	+2300	0.39	17 at 2000V	E6113-02(-HV) is available.
		R6149		17								
E5859	51mm (2")	R329-02		18								
		R2256	④⑦	19	⑭	SHV	BNC	DC/PULSE	-2700	0.67	18 at 1500V	Shield case is available. +HV type(E5859-02) is available.
		R5113		19								
E5859-01		R329-02		18								
		R2256	④⑥	19	⑭	SHV	BNC	DC/PULSE	-2700	0.75	21 at 1500V	Shield case is available. +HV type(E5859-03) is available.
		R5113		19								
		R331-05		18								
E2979-500		R1828-01		18								
		R2059	④①	19	⑮	SHV	BNC	DC/PULSE	-3000	0.70	29 at 2500V	with shield case
		R4004		19								
E6316-01	127mm (5")	R877	⑮	18	⑯	SHV	BNC	DC/PULSE	-1500	0.38	16 at 1250V	Shield case is available.
		R1512							-2000	0.50	19 at 1500V	
E7693		R1250	④⑧	18	⑰	SHV	BNC	DC/PULSE	-3000	1.02	34 at 2000V	Shield case is available.
		R1584										
E7694	204mm (8") 254mm (10")	R5912	⑤①	18	⑰	SHV	BNC	DC/PULSE	-1800	0.39	15 at 1500V	+HV type (E7694-01)is available.
		R7081										

Quick Reference for PMT Socket Assemblies

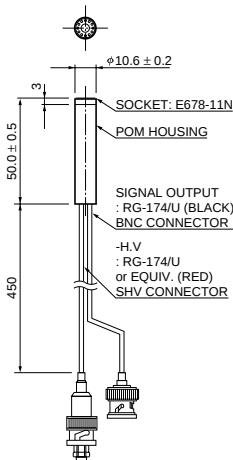
Assembly Type No.	PMT Characteristics				Assembly Characteristics							
	Type	Tube Type No. Voltage Distribution Ratio		Reference Page for PMT Feature	Out- line No.	H.V Input Terminal	Signal Output Terminal	Output Signal	Maximum Rating			Notes
		Overall Voltage (V)	Divider Current (mA)						Average Anode Current (μA)			
E5770	16mm To-8 Type	R7400U	④	20	⑰	PIN	PIN	DC/PULSE	-1000	0.37	15 at 800V	on-board type
E5780		R7400U-03 R7400U-06	④	20	⑳	AWG22	RG-174/U	DC/PLUSE	-1000	0.37	15 at 800V	cable type
E5996	30mm Square Type	R5900U R5900U-03	⑱	20	㉑	RG-174/U	RG-174/U	DC/PLUSE	-900	0.33	15 at 800V	
E7083		R5900U-00-M4	⑱	20	㉒	RG-174/U	Coaxial cable	DC/PLUSE	-900	0.33	15 at 800V	
E6736		R5900U-00-L16	⑰	20	㉓	RG-174/U	Coaxial cable	DC/PLUSE	-900	0.37	17 at 800V	Active base type(E6572) is available.
E6669-01		R5900U-00-C8	③⑥	38	㉔	RG-174/U	coaxial cable	DC/PLUSE	-900	0.30	13 at 800V	
E7514		R5900U-00-C12	③⑥	38	㉕	RG-174/U	coaxial cable	DC/PLUSE	-900	0.30	13 at 800V	

Dimensional Outlines and Circuit Diagrams

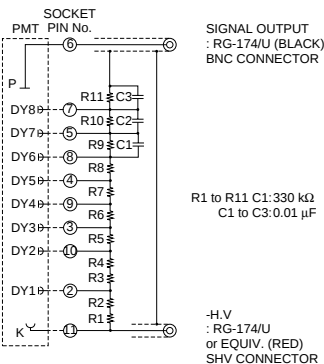
For PMT Socket Assemblies

(Unit : mm)

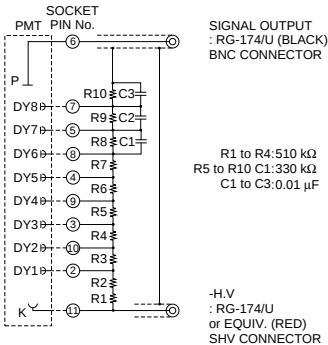
① E1761-21, E1761-22



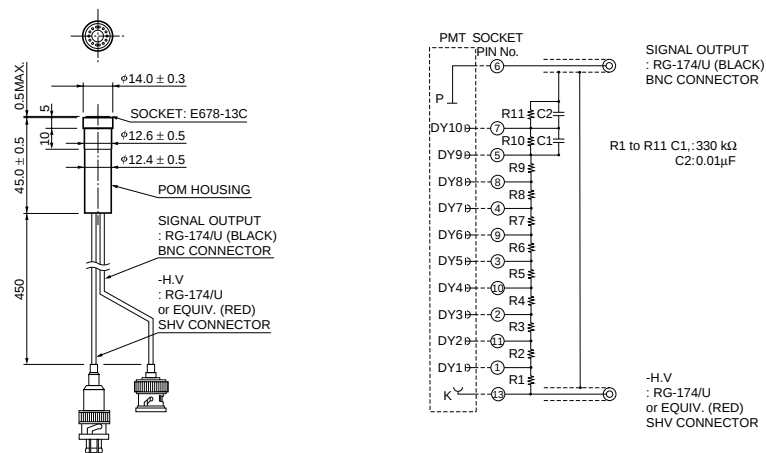
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E1761-22

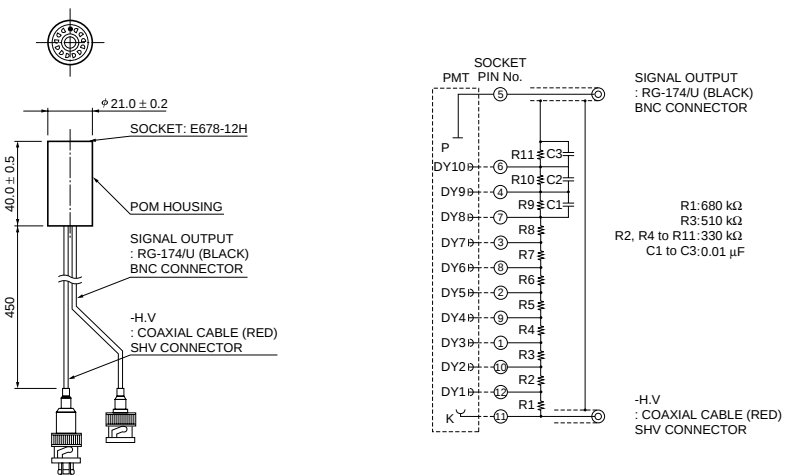


2 E849-90



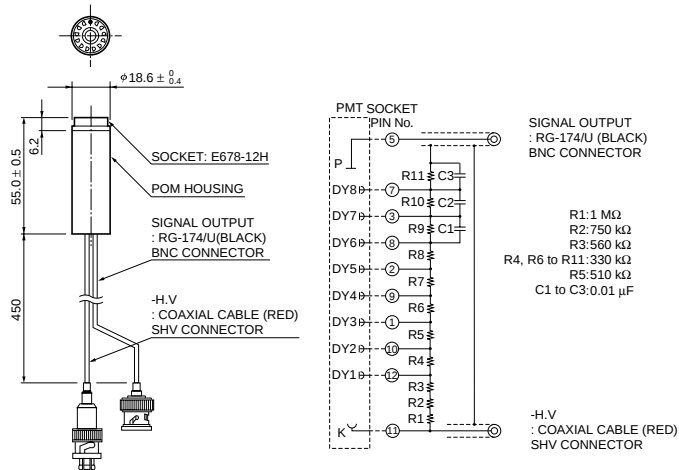
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3 E974-22



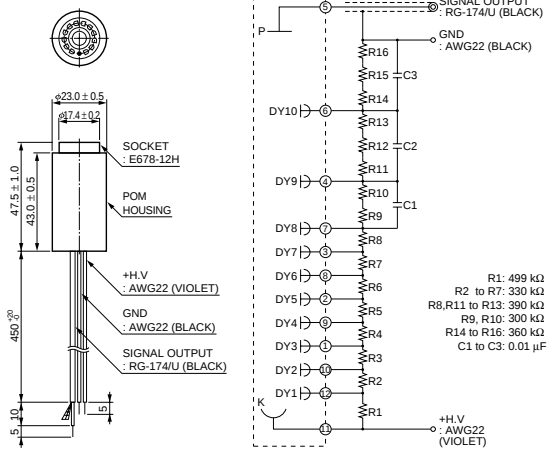
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4 E2253-05



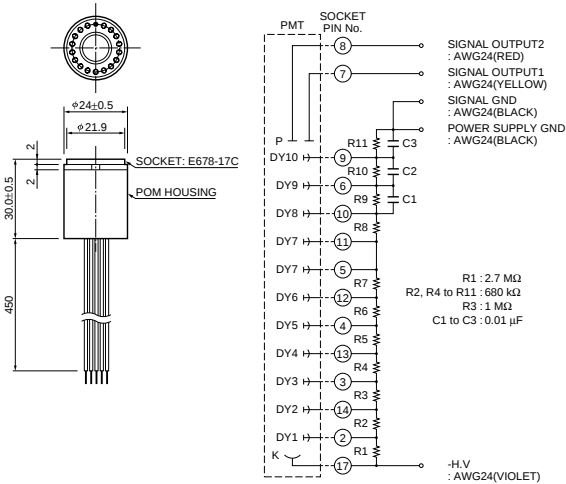
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5 E974-19



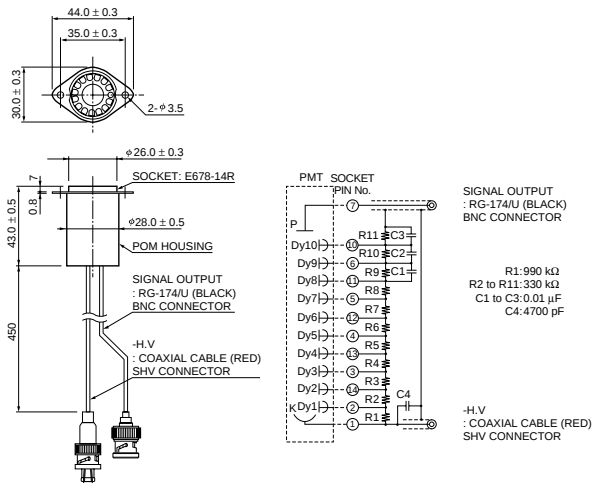
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6 E2037-02



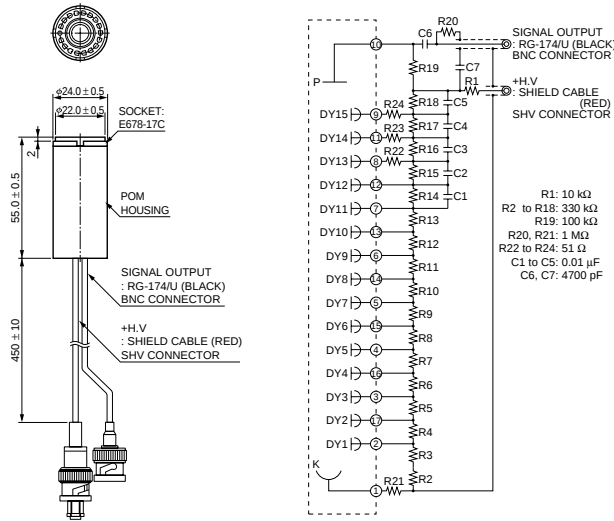
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7 E2924-500



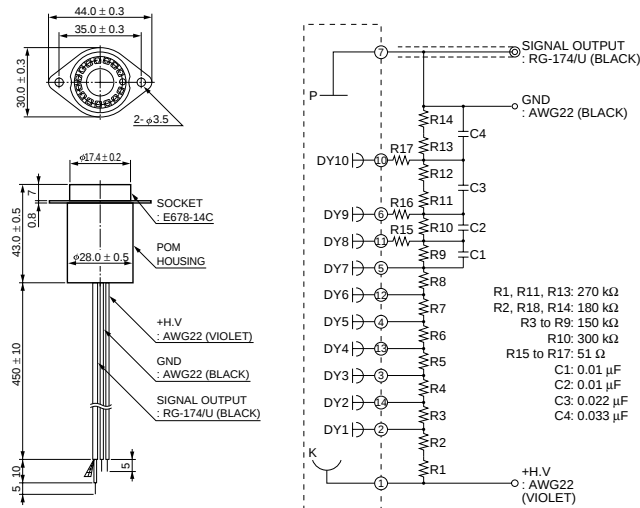
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8 E6133-04



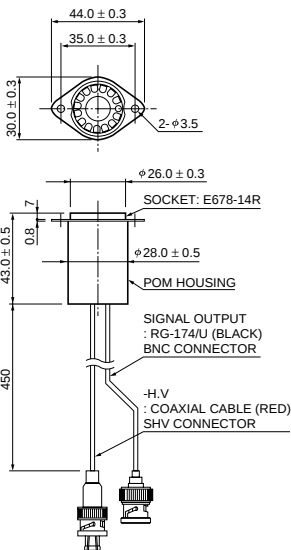
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9 E2924-10

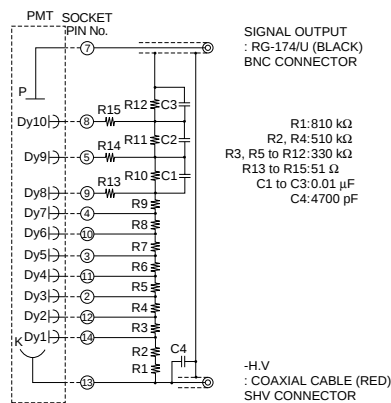


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10 E2624-14, E2624-17

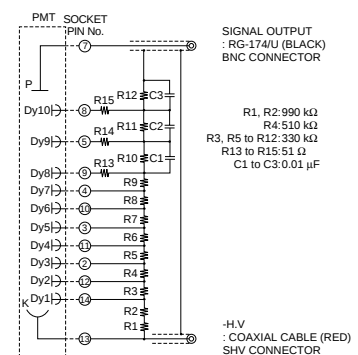


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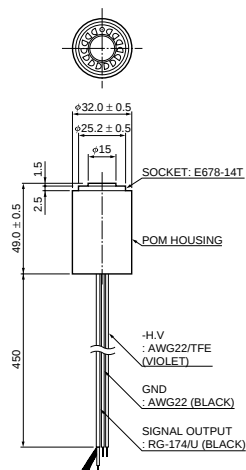
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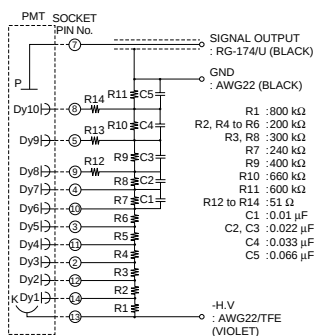


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11 E2624-04, E2624-10

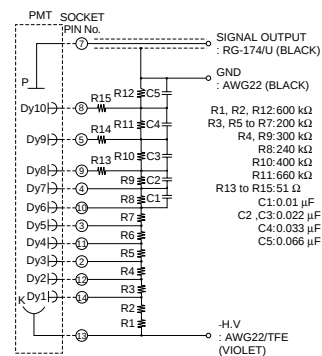


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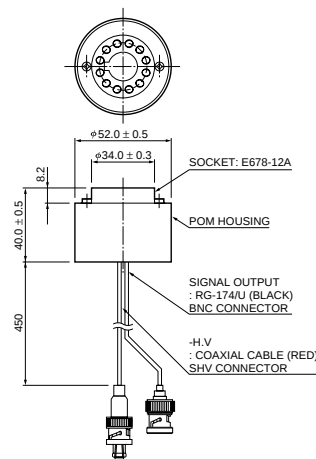
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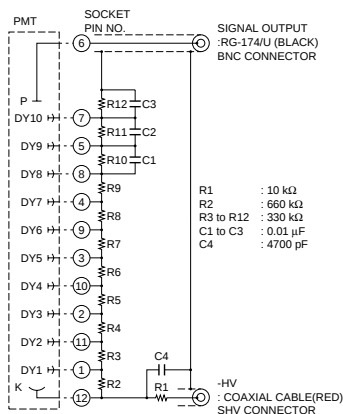


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12 E2183-500, E2183-501

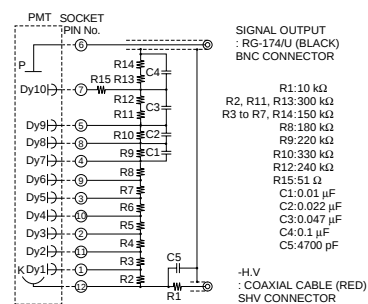


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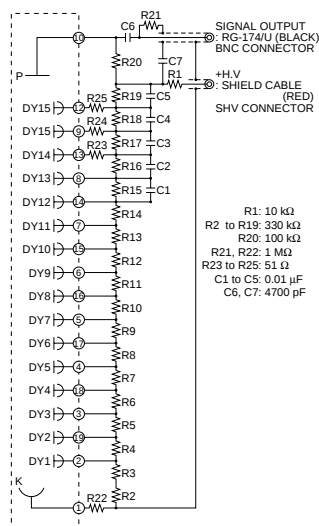
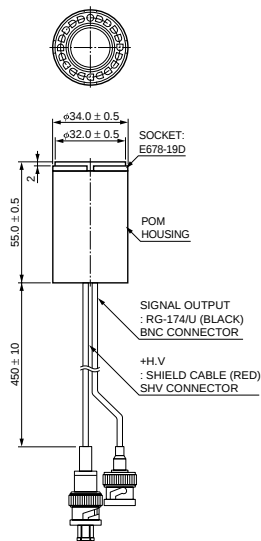
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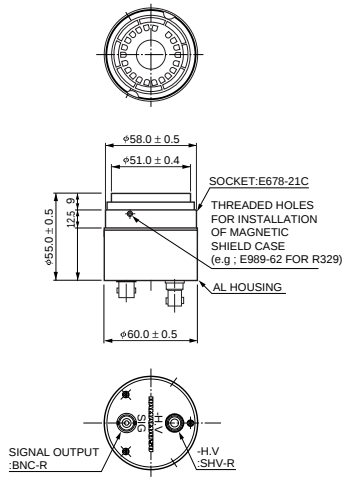
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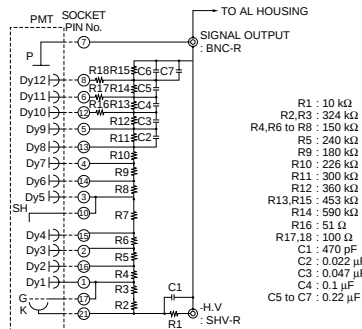


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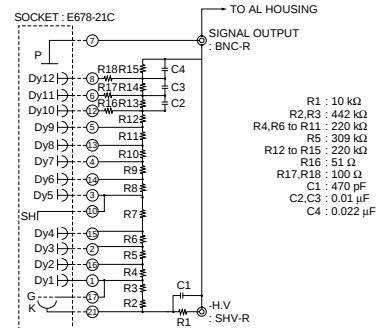


E5859



* AL HOUSING IS CONNECTED TO GND INSIDE OF THIS PRODUCT.
Note : Magnetic shield case is available to order separately.

E5859-01

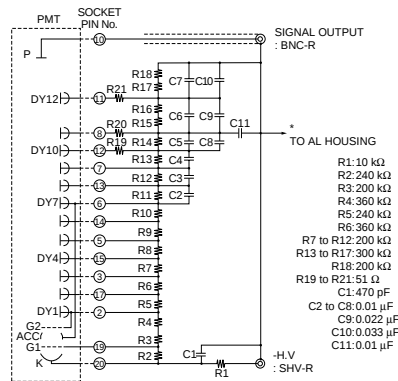
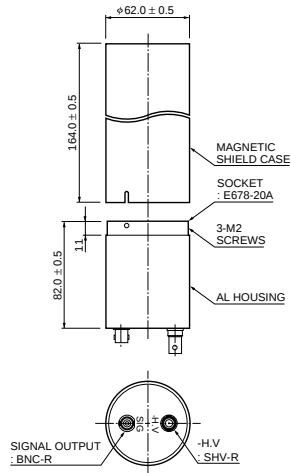


* AL HOUSING IS CONNECTED TO GND INSIDE OF THIS PRODUCT.
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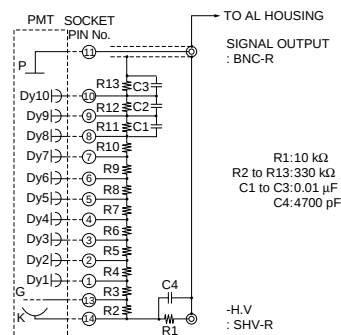
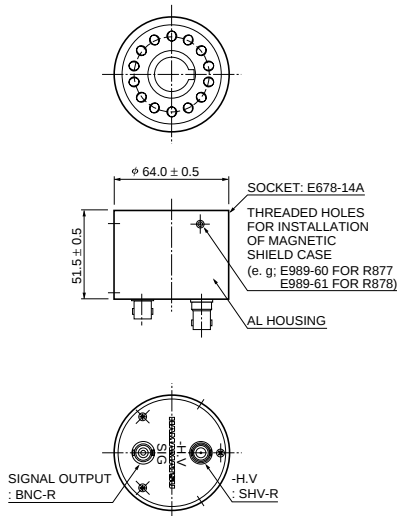
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* AL HOUSING IS CONNECTED TO GND INSIDE OF THIS PRODUCT.

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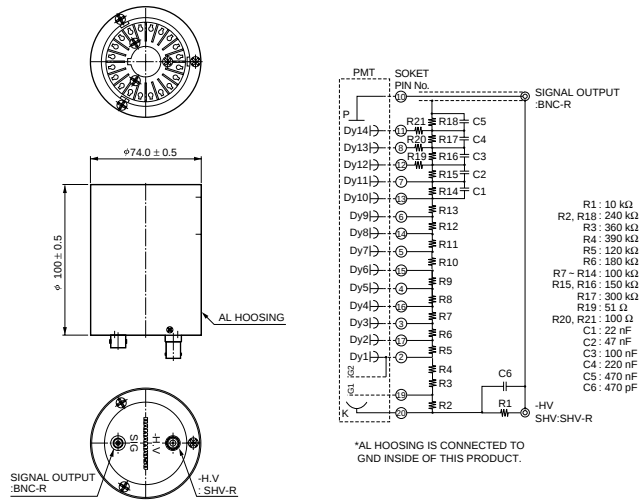
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* AL HOUSING IS CONNECTED TO GND INSIDE OF THIS PRODUCT.
Note : Magnetic shield case is available to order separately.

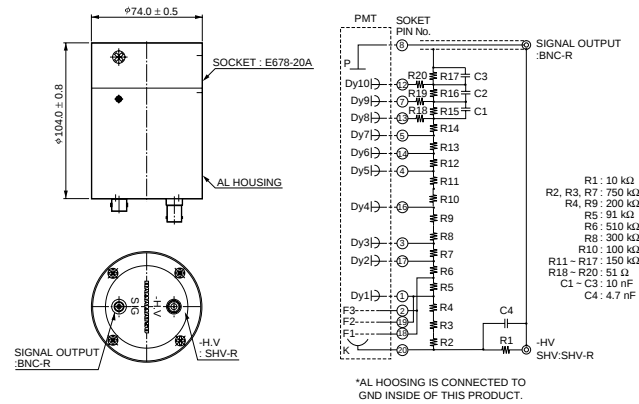
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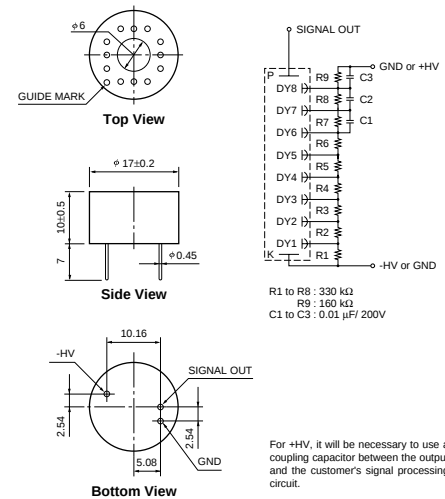
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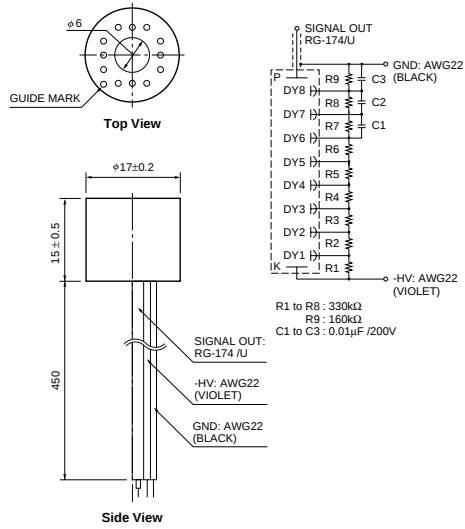
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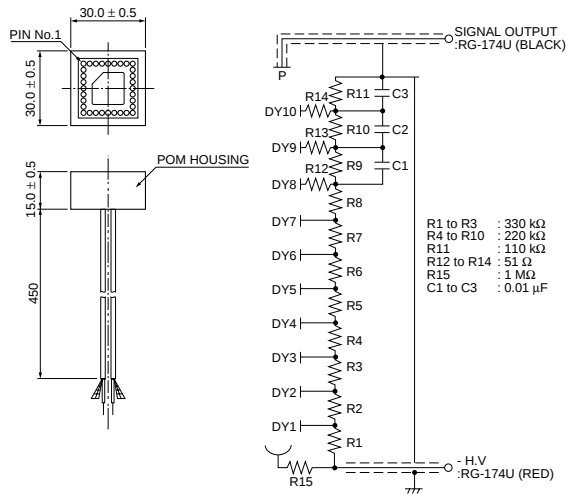
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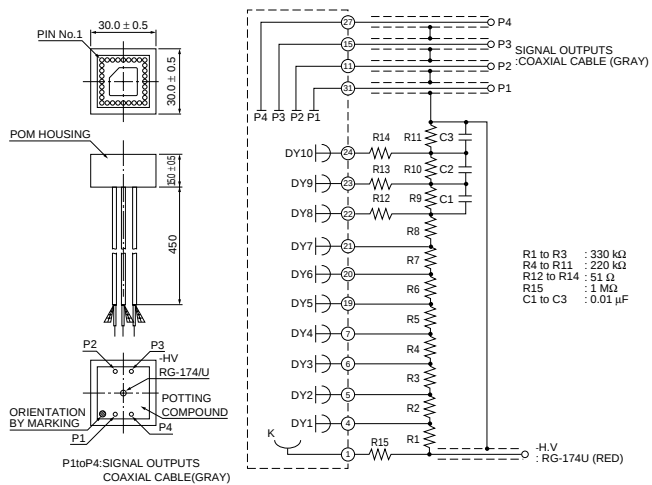
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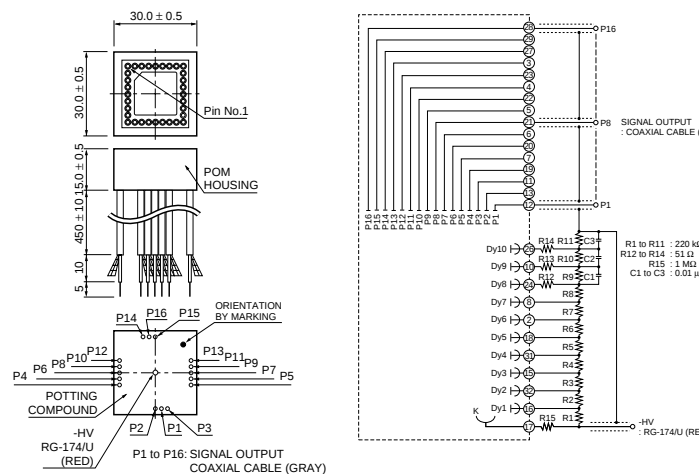
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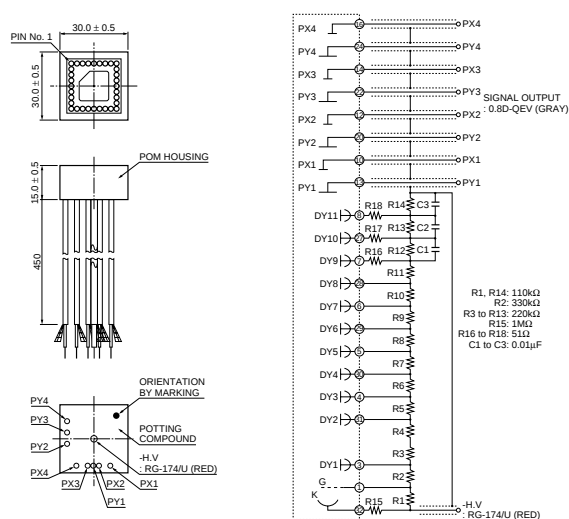
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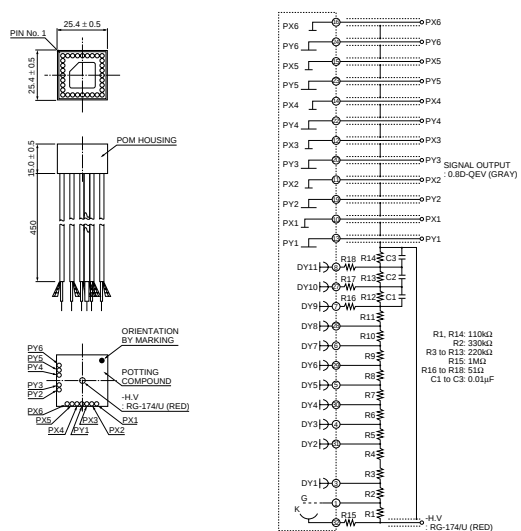
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25 E7514

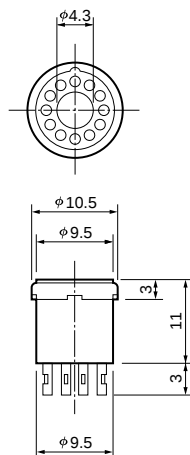


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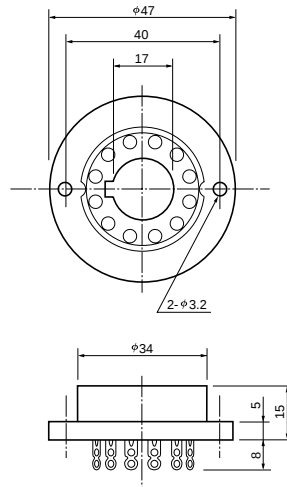
For E678 Series Sockets

E678-11N



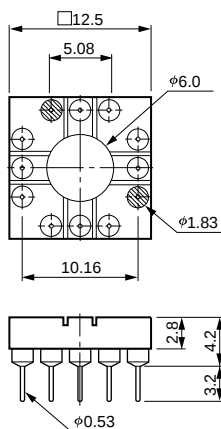
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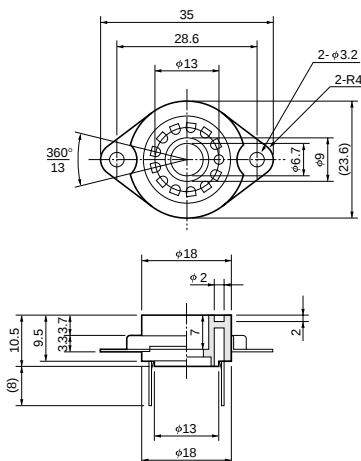
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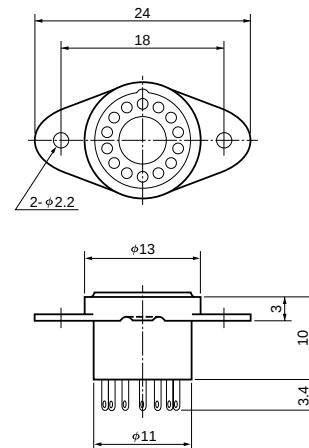
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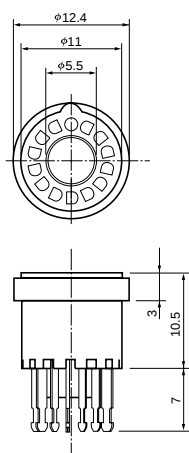
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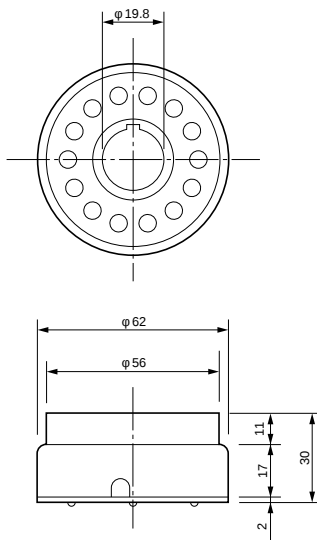
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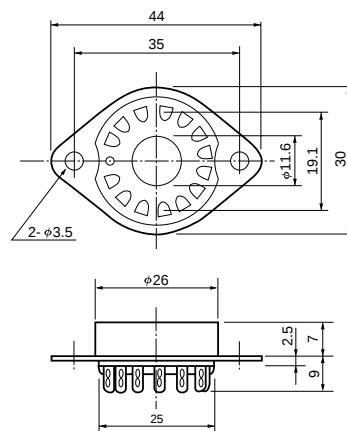
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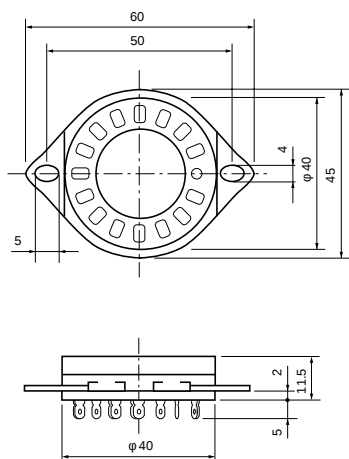
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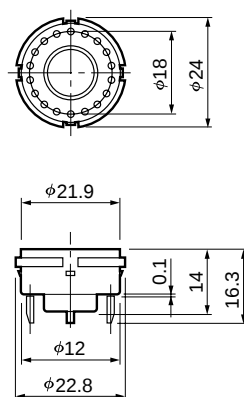
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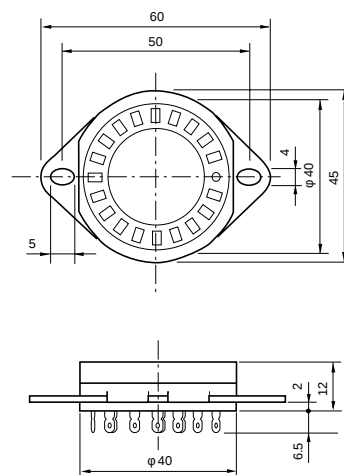
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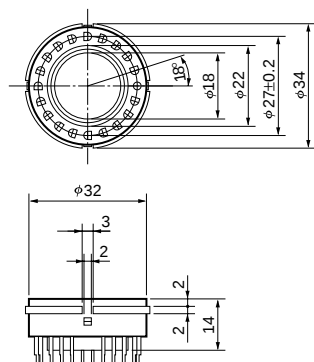
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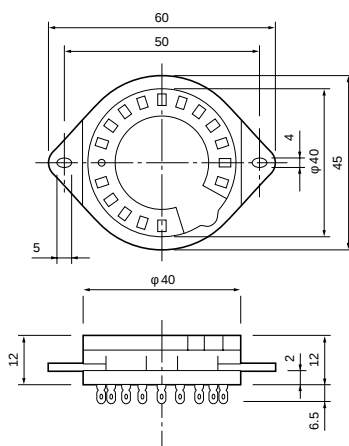
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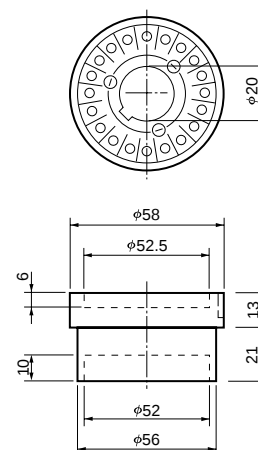
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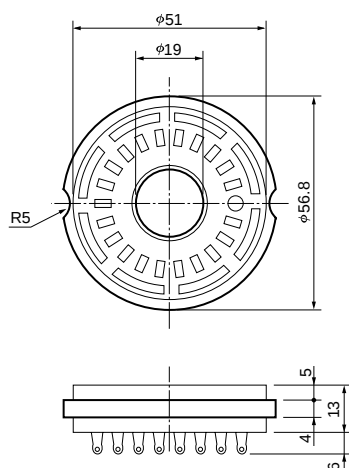
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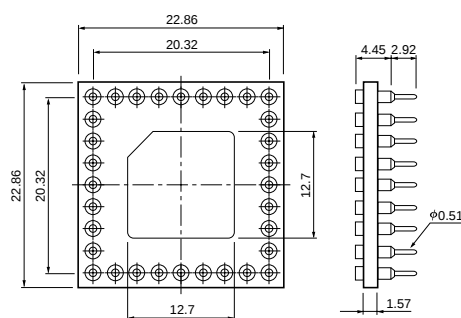
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E678-32B



MATERIAL: Glass Epoxy

TACCA0094ED

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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 appropriate interlocks to protect the operator and service personnel.

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

PRECAUTIONS FOR USE

● Handle tubes with extreme care

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

● Keep faceplate and base clean

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

● Do not expose to strong light

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

● Handling of tubes with a glass base

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

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

● Cooling of tubes

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

● Helium permeation through silica bulb

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

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

WARRANTY

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

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

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

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

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

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

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

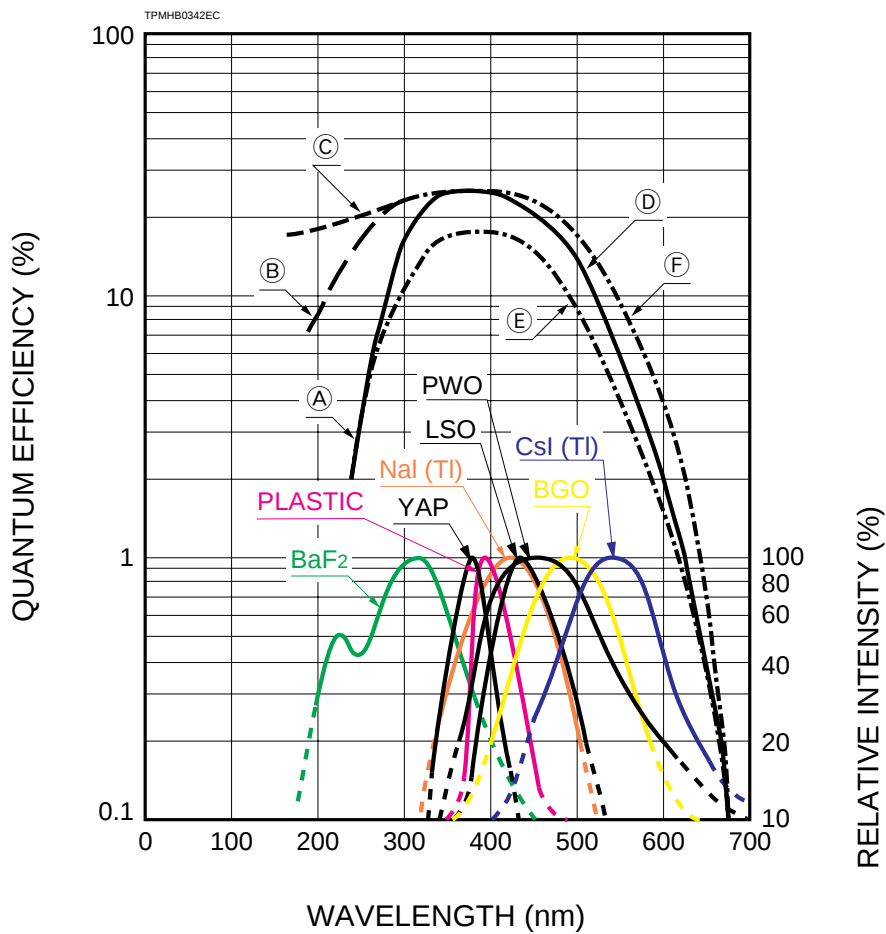
MEMO

Handwriting practice lines consisting of 20 horizontal dashed lines.

MEMO

Handwriting practice lines consisting of 20 horizontal dashed lines.

Typical Photocathode Spectral Response and Emission Spectrum of Scintillators



- (A): Borosilicate Glass
- (B): UV Glass
- (C): Synthetic Silica
- (D): Bi-alkali Photocathode
- (E): High Temp. Bi-alkali Photocathode
- (F): Extended Green Bi-alkali Photocathode

HAMAMATSU

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