PHILIPS

Data handbook

PHILIPS Electronic components and materials

Electron tubes

Part 9 September 1982

Photomultiplier tubes

Photo tubes

Channel electron multipliers

ELECTRON TUBES

PART 9 - SEPTEMBER 1982

PHOTO AND ELECTRON MULTIPLIERS

DATA HANDBOOK SYSTEM

Our Data Handbook System is a comprehensive source of information on electronic components, sub-assemblies and materials; it is made up of four series of handbooks each comprising several parts.

ELECTRON TUBES	BLUE
SEMICONDUCTORS	RED
INTEGRATED CIRCUITS	PURPLE
COMPONENTS AND MATERIALS	GREEN

The several parts contain all pertinent data available at the time of publication, and each is revised and reissued periodically.

Where ratings or specifications differ from those published in the preceding edition they are pointed out by arrows. Where application information is given it is advisory and does not form part of the product specification.

If you need confirmation that the published data about any of our products are the latest available, please contact our representative. He is at your service and will be glad to answer your inquiries.

ELECTRON TUBES (BLUE SERIES)

The blue series of data handbooks is comprised of the following parts:

T1 **Tubes for r.f. heating**

T2 **Transmitting tubes for communications**

T3 **Klystrons, travelling-wave tubes, microwave diodes**

ET3 **Special Quality tubes, miscellaneous devices** (will not be reprinted)

T4 **Magnetrons**

T5 **Cathode-ray tubes**
Instrument tubes, monitor and display tubes, C.R. tubes for special applications

T6 **Geiger-Müller tubes**

T7 **Gas-filled tubes**
Segment indicator tubes, indicator tubes, dry reed contact units, thyratrons, industrial rectifying tubes, ignitrons, high-voltage rectifying tubes, associated accessories

T8 **Picture tubes and components**
Colour TV picture tubes, black and white TV picture tubes, colour monitor tubes for data graphic display, monochrome monitor tubes for data graphic display, components for colour television, components for black and white television and monochrome data graphic display

T9 **Photo and electron multipliers**
Photomultiplier tubes, phototubes, single channel electron multipliers, channel electron multiplier plates

T10 **Camera tubes and accessories, image intensifiers**

T11* **Microwave components and assemblies**

* Will become available in the course of 1982.

SEMICONDUCTORS (RED SERIES)

The red series of data handbooks is comprised of the following parts:

S1 **Diodes**
Small-signal germanium diodes, small-signal silicon diodes, voltage regulator diodes(< 1,5 W), voltage reference diodes, tuner diodes, rectifier diodes

S2 **Power diodes, thyristors, triacs**
Rectifier diodes, voltage regulator diodes (> 1,5 W), rectifier stacks, thyristors, triacs

S3 **Small-signal transistors**

S4 **Low-frequency power transistors and hybrid IC modules**

S5 **Field-effect transistors**

S6 **R.F. power transistors and modules**

S7 **Microminiature semiconductors for hybrid circuits**

S8 **Devices for optoelectronics**
Photosensitive diodes and transistors, light-emitting diodes, displays, photocouplers, infrared sensitive devices, photoconductive devices.

S9 Taken into handbook T11 of the blue series

S10 **Wideband transistors and wideband hybrid IC modules**

INTEGRATED CIRCUITS (PURPLE SERIES)

The purple series of data handbooks is comprised of the following parts:

IC1 **Bipolar ICs for radio and audio equipment**

IC2 **Bipolar ICs for video equipment**

IC3* **Digital ICs for radio, audio and video equipment**

IC4 **Digital integrated circuits**
LOCMOS HE4000B family

IC5 **Digital integrated circuits – ECL**
ECL10 000 (GX family), ECL100 000 (HX family), dedicated designs

IC6* **Professional analogue integrated circuits**

IC7 **Signetics bipolar memories**

IC8 **Signetics analogue circuits**

IC9* **Signetics TTL circuits**

* These handbooks will be available in the course of 1982.

COMPONENTS AND MATERIALS (GREEN SERIES)

The green series of data handbooks is comprised of the following parts:

C1 **Assemblies for industrial use**
PLC modules, PC20 modules, HNIL FZ/30 series, NORbits 60-, 61-, 90-series, input devices, hybrid ICs, peripheral devices

C2 **FM tuners, television tuners, video modulators, surface acoustic wave filters**

C3 **Loudspeakers**

C4 **Ferroxcube potcores, square cores and cross cores**

C5 **Ferroxcube for power, audio/video and accelerators**

C6 **Electric motors and accessories**
Permanent magnet synchronous motors, stepping motors, direct current motors

CM7a **Assemblies** (will not be reprinted)
Circuit blocks 40-series and CSA70(L), counter modules 50-series, input/output devices

C8 **Variable mains transformers**

C9 **Piezoelectric quartz devices**
Quartz crystal units, temperature compensated crystal oscillators, compact integrated oscillators, quartz crystal cuts for temperature measurements

C10 **Connectors**

C11 **Non-linear resistors**
Voltage dependent resistors (VDR), light dependent resistors (LDR), negative temperature coefficient thermistors (NTC), positive temperature coefficient thermistors (PTC)

C12 **Variable resistors and test switches**

C13 **Fixed resistors**

C14 **Electrolytic and solid capacitors**

C15 **Film capacitors, ceramic capacitors, variable capacitors**

C16 **Piezoelectric ceramics, permanent magnet materials**

PHOTOMULTIPLIER TUBES

SURVEY OF TYPES

photo cathode dia. mm	tube type	status	spectral response									socket type
			super A	S1 (C)	S20R	S11 (A)	S13 (U)	S20 (T)	TU	D	DU	
14	PM1911	N								X		FE1004
	XP1117	M						X				FE1004
	XP1920	M				X						FE1004
23	PM2962	N								X		FE1114
	PM2982	N								X		FE1114
	XP2972	N								X		FE1114
32	PM2018B	N					X					FE1012
	XP1017	M			X							FE1012
	XP2008	D	X									FE1012
	XP2008UB	D	X									FE1112
	XP2010	M	X									FE1012
	XP2012	D								X		FE1112
	XP2012B	D								X		FE1012
	XP2013B	D						X				FE1012
	XP2060	D	X									FE1112
	XP2060B	D	X									FE1012
	150CVP	M		X								FE1012
44	PM2242B	N								X		FE1020
	PM2254B	N							X			FE1020
	XP2020	D								X		FE1020
	XP2020Q	D									X	FE1020
	XP2202	D								X		FE2019
	XP2202B	D								X		FE1014
	XP2203B	N						X				FE1014
	XP2212	D								X		FE2019
	XP2212B	D								X		FE1020
	XP2230	D								X		FE2021
	XP2230B	D								X		FE1020
	XP2233B	D						X				FE1020
	XP2262	N								X		FE2019
	XP2262B	N								X		FE1020
46	PM2102	N								X		FE2019
	PM2102B	N								X		FE1014
56	PM2432	N								X		FE2019
	PM2432B	N								X		FE1014
56*	PM2422	N								X		FE2019
	PM2422B	N								X		FE1014

* Hexagonal shape; dimension across flats.

photo cathode dia. mm	tube type	status	spectral response									socket type
			super A	S1 (C)	S20R	S11 (A)	S13 (U)	S20 (T)	TU	D	DU	
59	PM2402	N								X		FE2019
	PM2402B	N								X		FE1014
68	PM2312	N								X		FE2019
	PM2312B	N								X		FE1020
70	PM2412	N								X		FE2019
	PM2412B	N								X		FE1014
70*	PM2442	N								X		FE2019
	PM2442B	N								X		FE1014
110	XP2040	M				X						FE1020
	XP2040Q	M				X						FE1020
	XP2041	D								X		FE1020
	XP2041Q	D								X		FE1020
	XP2050	D								X		FE1014

* Hexagonal shape; dimension across flats.

Status code

N = New design type. Recommended for new equipment design; production quantities available *after date of publication.*

D = Design type. Recommended for equipment design; production quantities available *at date of publication.*

M = Maintenance type. No longer recommended for equipment production; available for maintenance of existing equipment.

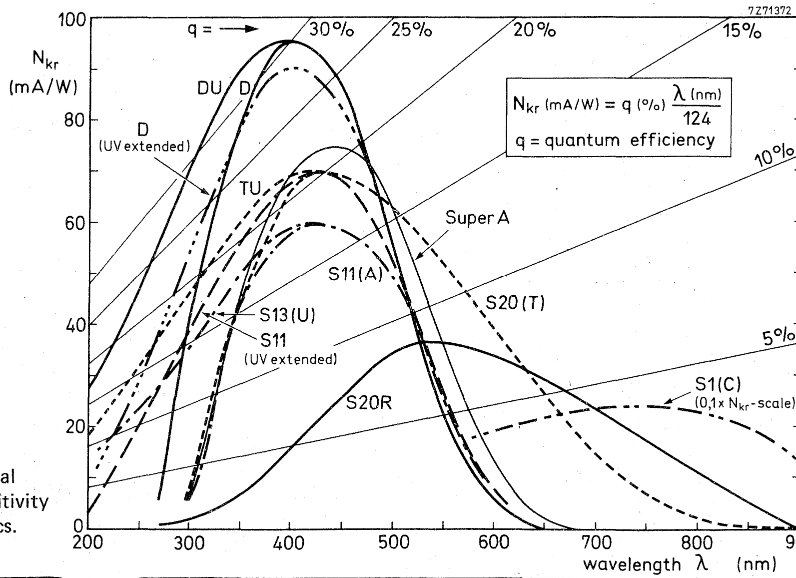


Fig. 1 Typical spectral sensitivity characteristics.

LIST OF SYMBOLS

		*
Photocathode	k	
Secondary emission electrode (dynode) n	S_n	d_n
Anode	a	
Accelerating electrode	acc	g
Grid	g	
Cathode luminous sensitivity	N_k	sk_v
Cathode spectral sensitivity	N_{kr}	$sk_{e(\lambda)}$
Luminous anode sensitivity	N_a	sa_v
Anode spectral sensitivity	N_{ar}	$sa_{e(\lambda)}$
Anode blue sensitivity		sa_F ←
Current amplification (gain)	G	
Total supply voltage	V_b	V_{ht}
Anode current	I_a	
Anode dark current	I_{ao}	i_{da}
Cathode current	I_k	
Wavelength	λ	
Internal connection (do not use)	i.c.	
Non-connected pin (may be used)	n.c.	←
External conductive coating	m	

* The symbols in the left-hand column are gradually being replaced by those in the right-hand column.

GENERAL OPERATIONAL RECOMMENDATIONS
PHOTOMULTIPLIER TUBES

1. GENERAL *)

1.1 A **photomultiplier tube** is a photosensitive vacuum device comprising a photo-emissive cathode, a photoelectron optical collection system, and one or more stages of electron multiplication using secondary emission electrodes (dynodes) between cathode and anode.

1.2 A **photoemissive cathode** consists of a light-sensitive film (the emission layer) deposited on a substrate.
Two types of cathode may be distinguished:

a. the opaque photocathode;

b. the semi-transparent photocathode.

In the first type, the emission is deposited on a metal surface. In the second, the photocathode is deposited on the inside of the glass window. Although opaque photocathodes can be made more easily, semi-transparent photocathodes are mostly used, since they are mainly placed in front of the tube, which has many advantages for the construction and use of the photomultiplier tubes.

1.3 The **photoelectron optical collection system** (electron-optical input system) is that part of the photomultiplier tube which focuses the photoelectrons onto the first dynode. The quality of the input optics can be measured by the spread in the electron transit times, and by the collection efficiency, i.e. the percentage of electrons emitted by the photocathode that land on the first dynode.
In most tubes the electron-optical input system consists of the photocathode itself and a focusing electrode, connected internally to the first dynode or externally to a suitable voltage between those of the photocathode and the first dynode.
In some photomultiplier tubes, such as XP2020, XP2040, XP2041, an improvement in time characteristics has been obtained by using additional electrodes.

1.4 Several **dynode system constructions** are possible such as linear focused or venetian blind structures.
Examples of materials used for dynodes are AgMg and CuBe, of which the latter offers the better stability.
Assuming that all dynodes have the same secondary emission factor, δ, the amplification of the tube is given by:

$$G = \delta^n$$

where n is the number of dynodes.

*) Where applicable reference is made to IEC Publication 306.

1.5 **Spectral response**

The materials used for the photocathode are of great importance to the spectral response. Many substances show photoemission, but often differ greatly in their spectral sensitivity and quantum yield.

1.5.1 The S11 (A-type) and Super A-type tubes are equipped with a semi-transparent caesium antimony photocathode on an MnO_2 layer, evaporated on the inside of a glass window. These types are sensitive to radiation in the visible region of the spectrum and have their maximum sensitivity at approximately 420 nm.

1.5.2 The S13 (U-type) tubes have the same photocathodes as the S11 tubes, but are provided with a fused silica (quartz) window, giving them a sensitivity that extends into the ultraviolet region of the spectrum.

1.5.3 The S1 (C-type) tubes have a semi-transparent caesium-on-silver-oxide photocathode on a glass window.
The sensitivity lies mainly in the red and near infrared regions of the spectrum, with a maximum at approximately 800 nm.

1.5.4 The S20 (T-type) tubes have a tri-alkaline (Sb-Na-K-Cs) semi-transparent photocathode on a glass window. This photocathode has a good sensitivity from the ultraviolet to the near infrared part of the spectrum, with a maximum at approximately 420 nm.

1.5.5 The S20R tubes have a tri-alkaline (Sb-Na-K-Cs) semi-transparent photocathode on a glass window.
The sensitivity extends from the visible into the near infrared part of the spectrum, with a maximum at approximately 550 nm.

1.5.6 The TU-type tubes have the same photocathode as the S20 tubes but are provided with a fused silica (quartz) window, giving them a sensitivity that extends into the ultraviolet region of the spectrum.

1.5.7 The D-type tubes have a bi-alkaline (Sb-K-Cs) semi-transparent photocathode on a glass window.
This photocathode has a high quantum efficiency in the blue region of the spectrum and a low thermionic emission. The maximum sensitivity is at approximately 400 nm.

1.5.8 The DU-type tubes have the same photocathode as the D-type tubes but are provided with a fused silica (quartz) window, giving them a sensitivity that extends into the ultraviolet region of the spectrum.

2. INTERPRETATION OF CHARACTERISTICS

In general the characteristics given in the data sheets are typical values. The "typical value" of a parameter is the median of the frequency distribution of the parameter measured on a large number of tubes.
In some cases maximum or minimum values are stated. These values are defined on test-limits carried out on each tube. Approximate values are given when these values are obtained from batch sample data.
Each tube is accompanied by a test card stating its test results.
The more important parameters are discussed below.

2.1 **Cathode luminous sensitivity**

The cathode luminous sensitivity is defined (IEC) as the quotient of the photocurrent of the cathode by the incident luminous flux, expressed in amperes per lumen.
For this measurement the photomultiplier tube is connected as a diode. The cathode current, I_k, (corrected for dark current) is about 100 nA.
The voltage used should be sufficient to ensure saturation.
The sensitivity is given by: $N_k = \frac{I_k}{\phi}$
where ϕ is the luminous flux, in lumen, of a tungsten filament lamp having a colour temperature of 2856 K.

2.2 **Cathode spectral sensitivity**

The cathode spectral sensitivity is the quotient of the photocurrent of the cathode by the value of the incident monochromatic radiant flux (IEC).

2.3 **Absolute spectral sensitivity**

The absolute spectral sensitivity is the radiant sensitivity for monochromatic radiation of a stated wavelength (IEC).
Measurements of this parameter are carried out with a tungsten filament lamp with a colour temperature of 2856 K and spectral filters. Tolerances of the spectral filters are stated in the tube data. The measuring equipment is calibrated by comparison with substandard light sources.

2.4 **Quantum efficiency**

The quantum efficiency (QE) is the ratio of the number of emitted photoelectrons to the number of incident photons (IEC) and is usually expressed in percent at a given wavelength.
At any given wavelength QE can be easily calculated from the following formula:

$$QE = N_{kr} \cdot \frac{1,24}{\lambda} \cdot 100\ (\%)$$

where N_{kr} is the cathode radiant sensitivity in mA/W at wavelength λ, and λ is the wavelength in nm.
In general the radiant sensitivity is given at the wavelength of maximum response. For other wavelengths the quantum efficiency may be calculated referring to the absolute spectral sensitivity characteristic. This is the relation, usually shown by a graph, between wavelength and absolute spectral sensitivity. Lines of constant quantum efficiency are shown in Fig. 1, page 10.

2.5 **Current amplification (gain) and anode luminous sensitivity**

The current amplification, G, is the ratio of the anode signal current, I_a, to the cathode signal current, I_k, at stated electrode voltages (IEC).

$$G = \frac{I_a}{I_k}.$$

Since the gain is usually very high (> 10^6), it is difficult to make this measurement because the cathode signal current has to be made extremely low to prevent the anode current exceeding the stated maximum.

Anode luminous sensitivity

The anode luminous sensitivity, N_a, can be obtained from the cathode luminous sensitivity, N_k, and the gain, G, by:

$$N_a = G \cdot N_k \text{ (A/lm)}.$$

Gain and anode luminous sensitivity measurements are usually taken at several values of applied voltage.

2.6 **Dark current and noise**

2.6.1 **Dark current** is the current flowing in a photoelectric device in the absence of irradiation (IEC).
The major component of the dark current is generally due to thermionic emission of the cathode and depends on the type of cathode and the temperature roughly according to the following table.

type of cathode		dark current emission at 20 °C (electrons · s^{-1} · cm^{-2})	activation energy (eV)	lowest useful temperature (°C)
AgOCs	(S1)	$5 . 10^6$	1	-100
$SbNa_2KCs$	(S20R)	10^3	1,3	-40
$SbNa_2KCs$	(S20)	300	1,3	-40
SbCs	(S11)	100	1,3	-20
SbKCs	(D)	10	1,2	0

At the lowest useful temperature the emission approaches the practical limit of approximately 1 electron.s^{-1}.cm^{-2}, due - at least partly - to ambient radioactivity.
When measured at the anode this current increases proportionally with the gain and can also be recorded with an adequate pulse amplifier as random pulses, each corresponding to 1 electron leaving the photocathode; this is then known as the **background noise or dark noise count rate.**
For a given charge threshold, there is generally a certain range of voltage, V_b, where this count rate is more or less constant.
Occasionally, and especially at high voltages, it may be observed that the dark current increases more rapidly than the gain and becomes unstable. Simultaneously the dark noise count rate increases strongly with the applied voltage. This is due to complex field emission phenomena associated with light emission, and related photoelectric emission by the cathode. This behaviour generally tends to improve when the voltage is applied for a long period (some hours).
Another cause for anomalous dark current is retarded fluorescence of the glass if the tube has been exposed (even without voltage applied) to ambient light, especially with blue and UV radiation.
After such an exposure the time required for stabilization can reach 12 h.

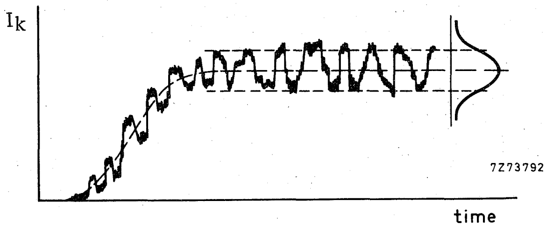
At very low supply voltage (V_b) the major component of the dark current is the - ohmic - leakage current between the pins; this component is proportional to the voltage and increases with dust and high relative humidity.

2.6.2 **Shot noise or Schottky effect**

If a photocathode under constant illumination gives a photocurrent, I_k, this current will show fluctuations the r.m.s. value of which is given by:

$$\overline{I_k}^2 = 2 \cdot e \cdot I_k \cdot \Delta f$$

in which $e = 1,6 \times 10^{-19}$ C, Δf is the bandwidth of the equipment connected to the anode and $\overline{I_k}$ and I_k are expressed in amperes. These fluctuations are directly related to the statistical fluctuations in the emission of photoelectrons.



Noise in photomultipliers.

When the photocurrent and the noise current are amplified by a factor G in the multiplier part of the tube, the anode current will be:

$$I_a = G \,.\, I_k \,,$$

and the noise:

$$\overline{I_a}^2 = 2 \cdot G \cdot e \cdot I_a \cdot \Delta f \left\{ 1 + \frac{\delta}{\delta_1(\delta - 1)} \right\} .$$

The term $\frac{\delta}{\delta_1(\delta - 1)}$ accounts for a noise contribution in the multiplier part due to statistical fluctuations in the secondary emission, δ being the average electron multiplication per stage and δ_1 being the electron multiplication of the first dynode.

The signal-to-noise ratio of the anode current is given by:

$$\frac{S}{N} = \frac{I_a}{\overline{\overline{I_a}}} = \sqrt{\frac{I_a}{2 \cdot G \cdot e \cdot \Delta f \left\{ 1 + \frac{\delta}{\delta_1(\delta - 1)} \right\}}} .$$

With typical values of $\delta = 4$ and $\delta_1 = 6$ the noise contribution of the multiplier is about 10% on the signal-to-noise ratio.

2.7 **Linearity and saturation**

The cathode and dynode currents should always be in the region of saturation, i.e. all electrons emitted by an electrode are collected by the next one, so as to guarantee the proportionality between the current and the cathode illumination over the whole operating range. When the tube is operated with a voltage $V_{S1/k}$, within the limiting values, saturation of the cathode is generally assured for cathode currents in the range of 10^{-8} A at room temperature.

Nevertheless for type-D photocathodes, departure from linearity can be observed for cathode currents in the range of 10^{-10} A, especially when operating at low temperatures.
The saturation current of the dynodes is generally reached under normal operating conditions even at the highest permissible luminous flux.
The saturation of the anode is different. The anode current causes a voltage drop across the load resistor. If the anode voltage decreases below a certain value this results in a non-linearity. Moreover, the current may be limited by space charge effects at the highest permissible anode currents.
That limit is reached for anode currents of 10 to 300 mA depending on the type of photomultiplier and on the voltage divider. The electrode currents should never be so high as to be detrimental to the tube's life, or cause excessive fatigue or aging.

2.8 Time characteristics (IEC)

2.8.1 The **signal transit time** of a photomultiplier tube is defined as the time interval between the arrival of a delta function light pulse of a stated amplitude at the entrance window of the device and the time at which the output pulse reaches a stated value.
Values given in the data sheet are obtained by measuring the instant at which the illuminating pulse at the cathode becomes maximum and the instant at which the anode pulse attains its maximum.

A **delta function light pulse** is a pulse having finite integrated light flux and infinitesimal duration (width).

2.8.2 The **anode pulse rise time** of a photomultiplier tube is defined as the time required for the amplitude to rise from a stated low percentage to a stated higher percentage of maximum value when the photocathode receives a delta function light pulse. Normally the 10% and 90% levels are considered.

2.8.3 The **anode pulse duration** at half height (response pulse duration, FWHM) is defined as the time duration between the half amplitude points of the output current pulse when the photocathode receives a delta function light pulse.

2.8.4 The **transit time difference** expresses a systematic relationship between transit time and position of illumination on the photocathode. The reference position is usually the centre of the photocathode.

2.8.5 The **transit time fluctuation** is the standard deviation of the transit time distribution of single electrons leaving the photocathode.

2.8.6 **Remark:** Rise time, pulse duration, and transit time vary as a function of high-tension supply voltage, V_b, approximately as $V_b^{-1/2}$.

2.9 Stability

The concept of stability refers to different behaviour of the gain of photomultipliers which may change as a function of current, voltage, time, temperature, and history.
For anode currents between 10 μA and absolute limiting value - which ranges from 100 to 500 μA - slow, irreversible changes of gain are observed. As an indication, for an anode current of 30 μA, a change of gain by a factor of 2 can be observed after about 5000 h for most tube types.

In the specific case of the S1 photocathode there is also a decrease in cathode sensitivity due to caesium desorption effect in the last stages, which requires a lower mean anode current. For anode currents below 1 μA, only reversible changes of gain are generally observed, but these changes may exhibit hysteresis effects with time constants ranging from some seconds to some hours, depending on the anode current. A change of gain in applications such as scintillation counting is very cumbersome because it is associated by a shift of the total absorption peak, strongly degrading the resolution.
According to ANSI-N42-9-1972 of IEEE there are two types of pulse amplitude (height) stability tests :

1. A test of long term **drift** in pulse amplitude measured at a constant count rate.
2. A measure of short-term pulse amplitude **shift** with change in count rate.

In the time stability test, a pulse amplitude analyser, a ^{137}Cs source, and an NaI (Tl) crystal are employed to measure the pulse amplitude. The ^{137}Cs source is located along the major axis of the tube and crystal so that a count rate of about 10^4 c/s is obtained. The entire system is allowed to warm up under operating conditions for a period of 30 minutes to one hour before readings are recorded. Following this period of stabilization, the pulse amplitude is recorded at 1 h intervals for a period of 16 h. The drift rate, D_g, is then calculated, in %, as the mean gain deviation, MGD, of the series of pulse amplitude measurements as follows :

$$D_g = \frac{\sum_{i=1}^{i=n} |p-p_i|}{n} \cdot \frac{100}{p}$$

where p is the mean pulse amplitude averaged over n readings; p_i is the pulse amplitude at the i^{th} reading; and n is the total number of readings.
Typical maximum MGD values for photomultiplier tubes with high-stability Cu-Be dynodes are usually less than 1% when measured under the conditions specified above. Gain stability becomes particularly important when photopeaks produced by nuclear disintegrations of nearly equal energy are being differentiated.

In the count-rate stability test, the photomultiplier tube is first operated at about 10^4 c/s. The count rate is then decreased to approximately 1000 c/s by increasing the source-to-crystal distance. The photopeak position is measured and compared with the last measurement made at a count rate of approximately 10^4 c/s. The count-rate stability is expressed as the % gain shift for the count-rate change. The average anode currents corresponding to a count rate of 10^4 c/s and 10^3 c/s respectively are stated in the notes given with each type.

3. OPERATING NOTES

3.1 The **overall supply voltage** (V_b) should be well stabilized, since the gain of a photomultiplier tube is strongly dependent on the voltage, expressed by the following relation :

$$\frac{dG}{G} = 0,75\ n \cdot \frac{dV_b}{V_b} .$$

The percentage change in gain is approximately ten times the percentage change in supply voltage. Thus to hold the gain stable within 1%, the power supply must be stabilized to within approximately 0, 1%.

When the radiant flux to be measured causes high anode currents, it is possible to replace the resistors of the last 3 or 4 stages in the voltage divider by voltage regulator diodes.

3.2 The **voltage divider** of a photomultiplier tube must be so designed that it does not cause an impermissible shift in the dynode voltage due to variation in incident radiation. The divider current (bleeder current), I_{b1}, must, therefore, be high compared to the anode current.
If this condition is not fulfilled, a high dynode current, accompanied by a high anode current, will seriously decrease the dynode voltages between the last stages. In any case, such variations of the dynode voltages introduce non-linearity of the photomultiplier tube.

3.2.1 In **continuous operation** a first approximation for the relative variation of the gain with a varying illumination of the cathode is :

$$\frac{\Delta G}{G} \approx \frac{I_k}{I_{b1}} \left\{ \delta^n - \frac{\delta^{n+1}}{(n+1)\cdot(\delta-1)} \right\} \approx \frac{I_a}{I_{b1}} \left\{ 1 - \frac{\delta}{(n+1)\cdot(\delta-1)} \right\}.$$

Thus the relative change in gain is approximately proportional to the ratio between the anode current and divider current. For example, to keep the gain stable within 1% when measuring a continuously luminous flux, the divider current should be at least 100 times the anode current.

3.2.2 In **pulsed operation**, as in scintillation counting, two calculations have to be made :
- The divider current should be at least 100 times the averaged integrated anode current $\overline{I_a}$. This is given by:

$$\overline{I_a} = I_a \cdot N \cdot T$$

where : I_a is the anode current pulse amplitude;
N is the anode pulse rate;
T is the anode pulse duration.

- The gain deviation caused by the current pulses must be restricted by decoupling at least the last four divider resistors. Calculations on capacitively stabilized voltage dividers are very complex and will not be dealt with here.
The minimum capacitance needed depends on the peak anode current and the pulse duration.
The value of C_{n+1} can be approximated when assuming that the charge Q_c which C_{n+1} should supply during the anode current pulse is much greater than the charge Q_a carried by the pulse

$$Q_a = \int I_a dT.$$

If the voltage across the last stage must be stable within 1%, that is $\Delta V/V_{S(n)} = 0,01$, and if the influence of the voltage divider resistor across the capacitor is neglected, then $Q_c = 100\,Q_a$, whence :

$$C_{n+1} = \frac{Q_c}{V_{S(n)}} = \frac{100 Q_a}{V_{S(n)}} = \frac{100}{V_{S(n)}} \int I_a dT.$$

As the current through the preceding stage is a factor δ lower, its bypass capacitance can be a factor δ smaller:

$$C_n = \frac{C_{n+1}}{\delta}.$$

The use of bypass capacitors gives the high voltage divider current a high time constant. When bursts of pulses occur, that is with short intervals between succeeding pulses, the capacitors will not fully recharge and the pulse effects will add up until the amplitude of the voltage fluctuations has become quite appreciable. In that case the voltage divider current has to be increased.

3.3 General remarks

On no account should the tube be exposed to ambient light when the supply voltage is applied. A luminous flux of less than 10^{-5} lm is sufficient to cause the maximum permissible anode current to be exceeded. To obtain maximum life from the photocathode, the tube should be protected from light as far as possible even when not in use.

After the application of supply voltage, the dark current takes approximately 15 to 30 minutes to fall to a stable value. For this reason it is recommended that the equipment be switched on half an hour before making any measurements requiring a high degree of accuracy.
The dark current may be further reduced by cooling the photocathode.

It is very important to ensure that no condensation occurs on the base or socket of the tube if air cooling is adopted.

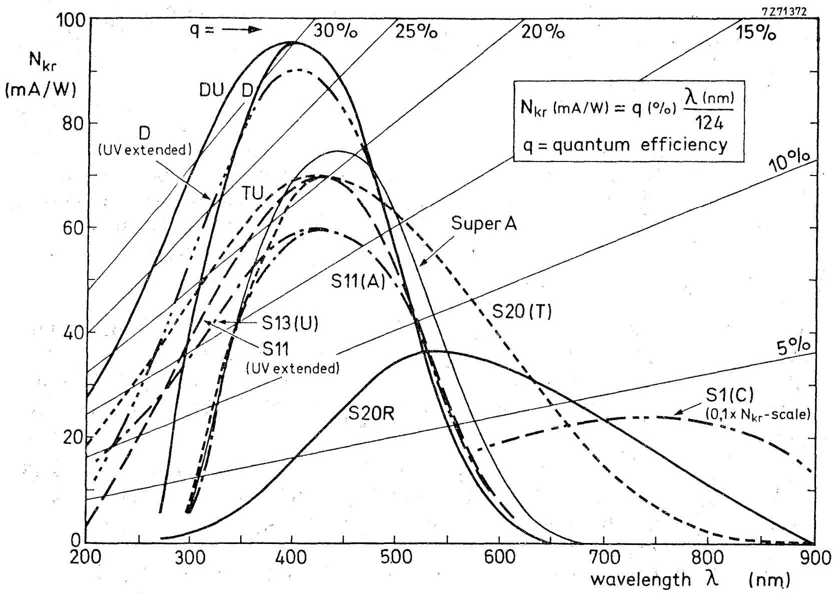


Fig. 1 Typical spectral sensitivity characteristics

The specific curve for each tube type is given in the data sheets.

RATING SYSTEM

As defined by IEC Publication 134

ABSOLUTE MAXIMUM RATING SYSTEM

Absolute maximum ratings are limiting values of operating and environmental conditions applicable to any electronic device of a specified type as defined by its published data, which should not be exceeded under the worst probable conditions.

These values are chosen by the device manufacturer to provide acceptable serviceability of the device, taking no responsibility for equipment variations, environmental variations, and the effects of changes in operating conditions due to variations in the characteristics of the device under consideration and of all other electronic devices in the equipment.

The equipment manufacturer should design so that, initially and throughout life, no absolute maximum value for the intended service is exceeded with any device under the worst probable operating conditions with respect to supply voltage variation, equipment component variation, equipment control adjustment, load variations, signal variation, environmental conditions, and variations in characteristics of the device under consideration and of all other electronic devices in the equipment.

10-STAGE PHOTOMULTIPLIER TUBE

- 14 mm useful diameter head-on type
- Flat window
- Semi-transparent bi-alkaline type D photocathode
- For high-energy physics, scintillation counting under limited dimensional conditions.

QUICK REFERENCE DATA *

Spectral sensitivity characteristic	type D	
Useful diameter of the photocathode	> 14 mm	
Cathode blue sensitivity	10 μA/lmF	note 1
Supply voltage for anode blue sensitivity = 10 A/lmF (note 1)	1250 V	
Anode pulse rise time (with voltage divider B)	≈ 2,4 ns	
Linearity with voltage divider A (Fig. 2) with voltage divider B (Fig. 3)	 ≈ 20 mA ≈ 80 mA	

To be read in conjunction with *General Operational Recommendations Photomultiplier Tubes.*

GENERAL CHARACTERISTICS *

Window

Material	lime glass	
Shape	plano-concave	
Refractive index at 550 nm	1,52	

Photocathode (note 2)

Semi-transparent, head-on

Material	Sb K Cs	
Useful diameter	> 14 mm	
Spectral sensitivity characteristic (Fig. 5)	type D	
Maximum spectral sensitivity	400 ± 30 nm	
Luminous sensitivity	≈ 60 μA/lm	note 3
Blue sensitivity	typ. 10 μA/lmF > 8,0 μA/lmF	note 1
Spectral sensitivity at 400 nm	≈ 70 mA/W	note 4

* Notes are given on page 5.

Multiplier system

Number of stages		10
Dynode structure		linear focused
Dynode material		CuBe
Capacitances		
anode to final dynode	≈	2 pF
anode to all	≈	4 pF

Magnetic field

When the photocathode is illuminated uniformly the anode current is halved (at V_{ht} = 1200 V, voltage divider A) at a magnetic flux density of: 0,3 mT perpendicular to axis a; 0,2 mT parallel to axis a; see Fig. 1.

It is recommended that the tube be screened from magnetic fields by a mu-metal shield protruding 15 mm beyond the photocathode.

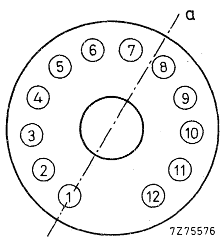


Fig. 1 Axis a with respect to base pins (bottom view).

DEVELOPMENT SAMPLE DATA

RECOMMENDED CIRCUITS

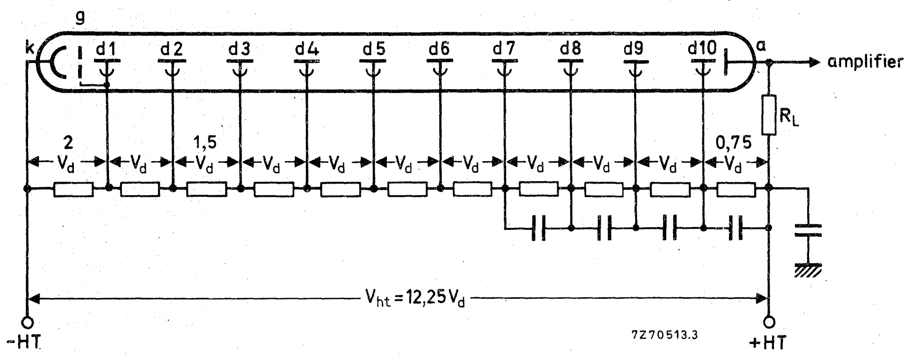


Fig. 2 Voltage divider A. Typical values of capacitors: 10 nF; k = cathode; g = accelerating electrode; d_n = dynode no.; a = anode; R_L = load resistor.

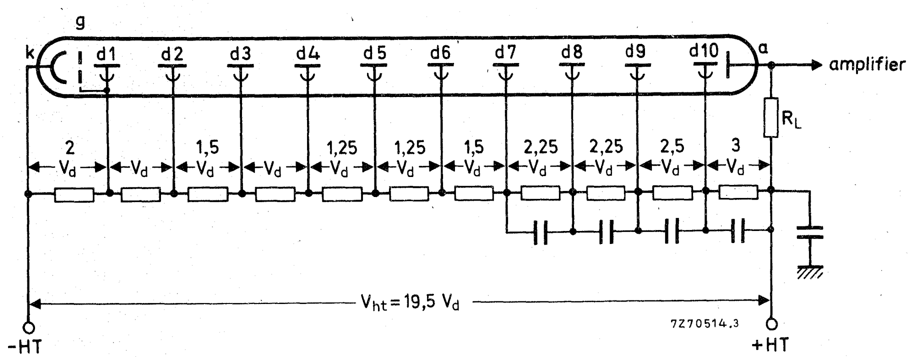


Fig. 3 Voltage divider B. Typical values of capacitors: 10 nF; k = cathode; g = accelerating electrode; d_n = dynode no.; a = anode; R_L = load resistor.

TYPICAL CHARACTERISTICS *

With voltage divider A (Fig. 2)

Supply voltage for an anode blue sensitivity of 10 A/lmF	< 1600 V typ. 1250 V	notes 1,5
Anode radiant sensitivity at 400 nm and V_{ht} = 1250 V	≈ 70 kA/W	
Gain at V_{ht} = 1250 V (Fig. 7)	≈ 1 x 10^6	
Anode dark current at an anode blue sensitivity of 10 A/lmF	< 10 nA typ. 2 nA	notes 1,6,7
after 30 min. of stabilization	≈ 0,3 nA	
Pulse amplitude resolution for ^{137}Cs at an anode blue sensitivity of 10 A/lmF	≈ 7,5 %	notes 1,8
Anode current linear within 2% at V_{ht} = 1500 V	up to ≈ 20 mA	
Mean anode sensitivity deviation		
long term (16 h)	≈ 1,5 %	note 9
after change of count rate	≈ 1,5 %	
Anode pulse rise time at V_{ht} = 1500 V	≈ 2,3 ns	note 10
Anode pulse duration at half height at V_{ht} = 1500 V	≈ 3,5 ns	note 10
Signal transit time at V_{ht} = 1500 V	≈ 22 ns	note 10

With voltage divider B (Fig. 3)

Gain at V_{ht} = 1700 V (Fig. 7)	≈ 3,5 x 10^6	
Anode pulse rise time at V_{ht} = 1700 V	≈ 2,4 ns	note 10
Anode pulse duration at half height at V_{ht} = 1700 V	≈ 3,8 ns	note 10
Signal transit time at V_{ht} = 1700 V	≈ 22 ns	note 10
Signal transit time difference between the centre of the photocathode and 7 mm from the centre at V_{ht} = 1700 V	≈ 1,5 ns	
Anode current linear within 2% at V_{ht} = 1700 V	up to ≈ 80 mA	

LIMITING VALUES (Absolute maximum rating system)*

Supply voltage	max. 1900 V	note 11
Continuous anode current	max. 0,2 mA	note 12
Voltage between first dynode and photocathode	max. 350 V min. 100 V	note 13
Voltage between consecutive dynodes	max. 250 V	
Voltage between anode and final dynode	max. 300 V min. 30 V	note 14
Ambient temperature range		
operational (for short periods of time)	max. +80 °C min. –30 °C	
continuous operation and storage	max. +50 °C min. –30 °C	

* Notes are given on page 5.

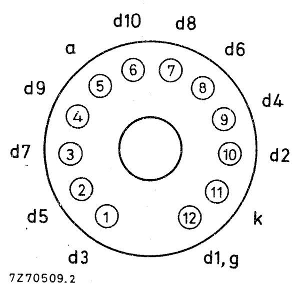
Notes

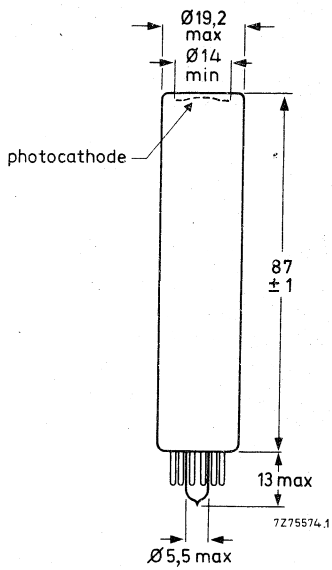
1. Blue sensitivity, expressed in μA/lmF, is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5K. Light is transmitted through a blue filter (Corning CS no. 5-58, polished to half stock thickness).
2. The bialkaline photocathode has a significant resistance which increases rapidly with reducing temperature. It is therefore recommended that it should not be exposed to light of too great an intensity; the cathode current should be limited, for example, to 1 nA at room temperature or 0,1 nA at −30 °C. If too high a photocurrent is passed, the cathode can no longer be considered an equipotential surface, and the focusing of electrons onto the first dynode will be affected, resulting in departure from linearity. In applications with short pulse times the photocathode is able to deliver pulses containing 10^6 to 10^7 photoelectrons without disturbance.
3. Luminous sensitivity is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5K.
4. Spectral sensitivity is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5K. Light is transmitted through an interferential filter. Spectral sensitivity at 400 nm, expressed in A/W, can be estimated by multiplying the blue sensitivity, expressed in A/lmF, by 7×10^3 for this type of tube.
5. To obtain a peak pulse current greater than that obtainable with divider A, it is necessary to increase the inter-dynode voltage of the stages progressively. Divider circuit B is an example of a "progressive" divider, giving a compromise between gain, speed, and linearity. Other dividers can be conceived to achieve other compromises. It is generally recommended that the voltage difference between one stage and the next is less than a factor of 2.
6. Wherever possible, the power supply should be arranged so that the cathode is earthed and the anode is at + HT, however, it is sometimes necessary to supply the tube with the anode earthed and the cathode at −HT. Under these circumstances, erratic noise and dark current are generally increased and unstable, particularly after application of voltage. The glass envelope of the tube should be supported only by insulators with an insulation resistance of $> 10^{15}$ ohm.
7. Dark current is measured at ambient temperature, after the tube has been in darkness for approx. 1 min. Lower values can be obtained after a longer stabilization period in darkness (approx. 30 min).
8. Pulse amplitude resolution for ^{137}Cs is measured with an NaI(Tl) cylindrical scintillator (Quartz et Silice serial no. 1118 or equivalent) with a diameter of 12 mm and a height of 12 mm. The count rate used is $\approx 10^4$ c/s.
9. The mean pulse amplitude deviation is measured by coupling an NaI(Tl) scintillator to the window of the tube. Long term (16 h) deviation is measured by placing a ^{137}Cs source at a distance from the scintillator such that the count rate is $\approx 10^4$ c/s corresponding to an anode current of $\approx$ 300 nA.

   Mean pulse amplitude deviation after change of count rate is measured with a ^{137}Cs source at a distance of the scintillator such that the count rate can be changed from 10^4 c/s to 10^3 c/s corresponding to an anode current of $\approx$ 1 μA and $\approx$ 0,1 μA respectively.
   Both tests are carried out according to ANSI–N42–9–1972 of IEEE recommendations.
10. Measured with a pulsed light source, with a pulse duration (FWHM) of < 1 ns; the cathode being completely illuminated. The rise time is determined between 10% and 90% of the amplitude of the anode pulse. The signal transit time is measured between the instant at which the illuminating pulse at the cathode becomes maximum, and the instant at which the anode pulse attains its maximum. Rise time, pulse duration and transit time vary as a function of high tension supply voltage V_{ht}, approximately as $V_{ht}^{-1/2}$.
11. Total HT supply voltage, or the voltage at which the tube has a gain of 1×10^7, whichever is lower.
12. A value of < 10 μA is recommended for applications requiring high stability.
13. Minimum value to obtain good collection in the input optics.
14. When calculating the anode voltage the voltage drop across the load resistor should be taken into account.

MECHANICAL DATA

Dimensions in mm





Pin positions equal to those of tube XP1910.

Fig. 4.

Base	12-pin all glass
Net mass	21 g

ACCESSORIES

Socket	type FE1004

DEVELOPMENT SAMPLE DATA

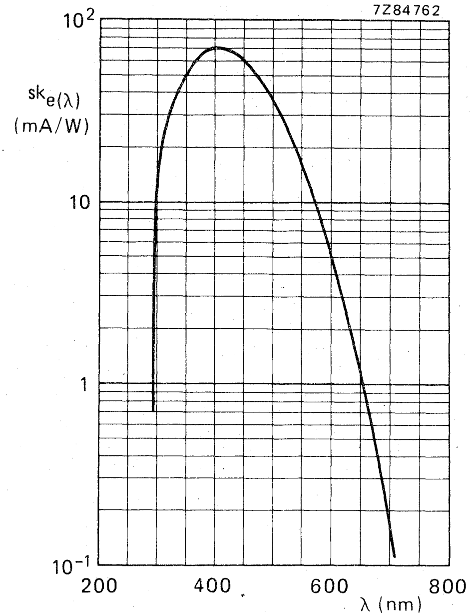


Fig. 5 Spectral sensitivity characteristic.

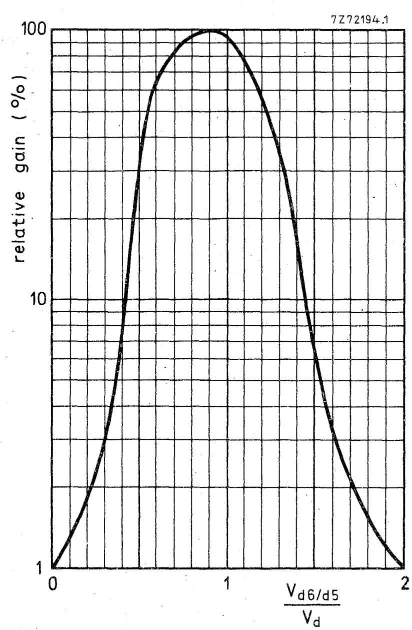


Fig. 6 Relative gain as a function of the voltage between d_6 and d_5, normalized to V_d; $V_{d7/d5}$ constant.

Note: Gain regulation by changing the voltage between d6 and d5 may cause a degradation of other parameters such as stability and linearity.

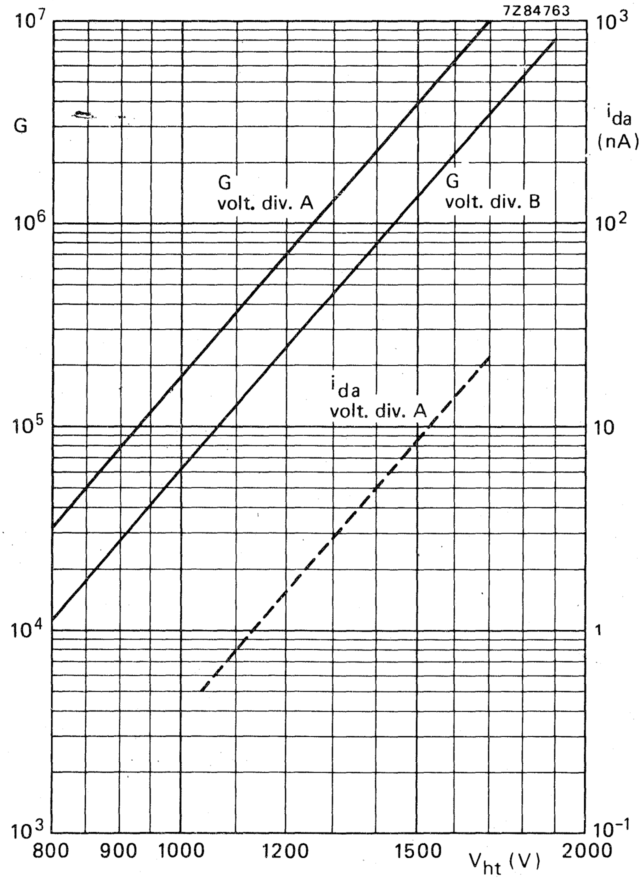


Fig. 7 Gain G and anode dark current I_{da} as a function of the supply voltage V_{ht}.

I_{da} is given as a dotted line to indicate its principle behaviour only.

10-STAGE PHOTOMULTIPLIER TUBE

The PM2018 B is a 32 mm useful diameter head-on photomultiplier tube with a flat window and a semi-transparent S13 (type U) photocathode. The tube is intended for use in applications where a high sensitivity in the ultraviolet region of the spectrum is required, such as spectrophotometry.

QUICK REFERENCE DATA

Spectral sensitivity characteristic		S13 (type U)
Useful diameter of the photocathode	>	32 mm
Cathode spectral sensitivity at 437 nm		75 mA/W
Supply voltage for an anode spectral sensitivity of 60 kA/W at 437 nm		1350 V
Anode pulse rise time (with voltage divider B)	≈	2,5 ns
Linearity		
with voltage divider A	up to ≈	100 mA
with voltage divider B	up to ≈	200 mA

To be read in conjunction with *General Operational Recommendations Photomultiplier Tubes.*

GENERAL CHARACTERISTICS

Window

Material		fused silica
Shape		plano-plano
Refractive index		
at 250 nm		1,50
at 400 nm		1,47

Photocathode

Semi-transparent, head-on

Material		Sb-Cs
Useful diameter	>	32 mm
Spectral sensitivity characteristic (Fig. 5)		S13 (type U)
Maximum spectral sensitivity at		400 ± 30 nm
Spectral sensitivity at 437 ± 5 nm	typ.	75 mA/W
	>	40 mA/W
Luminous sensitivity	≈	85 μA/lm

Multiplier system

Number of stages		10
Dynode structure		linear focused
Dynode material		Cu-Be
Capacitances		
anode to final dynode	≈	3 pF
anode to all	≈	5 pF

Magnetic field

When the photocathode is illuminated uniformly the anode current is halved (at V_b = 1200 V, voltage divider A) at a magnetic flux density of:

0,6 mT in the direction of the longitudinal axis;
0,35 mT perpendicular to axis a (see Fig. 1);
0,15 mT parallel to axis a.

It is recommended that the tube be screened against the influence of magnetic fields by a mu-metal shield protruding > 15 mm beyond the photocathode.

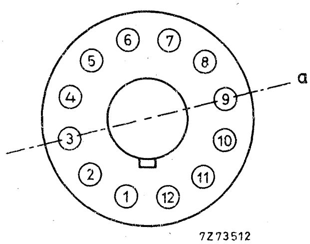


Fig. 1 Axis a with respect to base pins (bottom view).

RECOMMENDED CIRCUITS

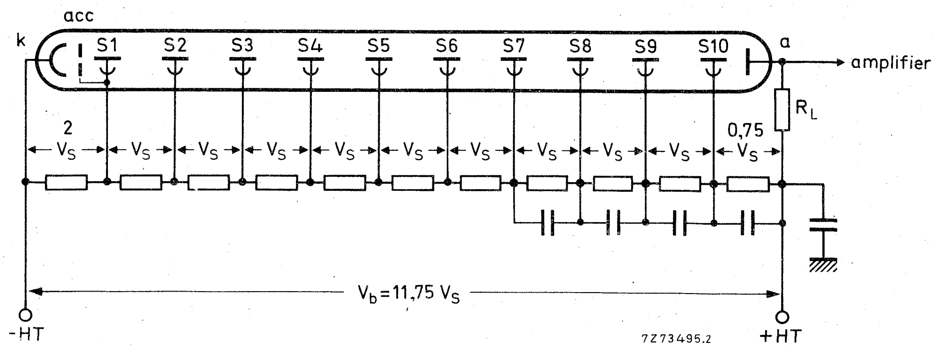


Fig. 2 Voltage divider A. Typical value of capacitors: 10 nF, k = cathode, acc = accelerating electrode, S_n = dynode no., a = anode, R_L = load resistor.

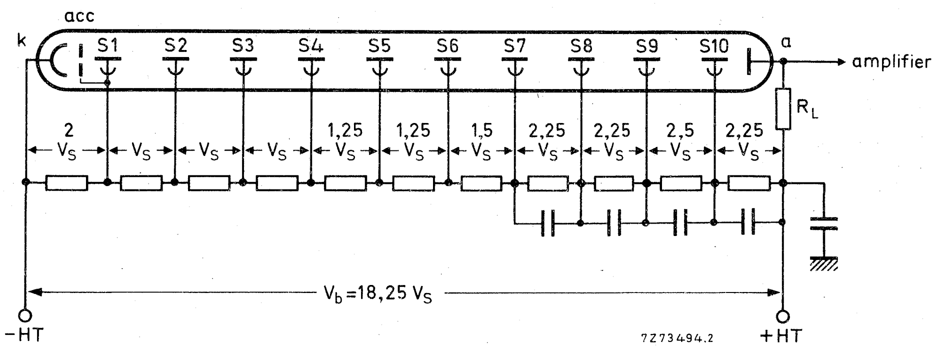


Fig. 3 Voltage divider B. Typical values of capacitors: 10 nF, k = cathode, acc = accelerating electrode, S_n = dynode no., a = anode, R_L = load resistor.

DEVELOPMENT SAMPLE DATA

TYPICAL CHARACTERISTICS

	note		
With voltage divider A (Fig. 2)	1		
Supply voltage for an anode spectral sensitivity N_{ar} = 60 kA/W at 437 nm (Fig. 7)		$<$ typ.	1600 V 1350 V
Anode dark current at an anode spectral sensitivity N_{ar} = 60 kA/W	2,3	$<$ typ.	50 nA 5 nA
Anode current linear within 2% at V_b = 1700 V		up to ≈	100 mA
With voltage divider B (Fig. 3)	1		
Anode spectral sensitivity at V_b = 1700 V (Fig. 7)		≈	50 kA/W
Anode pulse rise time at V_b = 1700 V	4	≈	2,5 ns
Anode pulse duration at half-height at V_b = 1700 V	4	≈	6 ns
Signal transit time at V_b = 1700 V	4	≈	26 ns
Anode current linear within 2% at V_b = 1700 V		up to ≈	200 mA

LIMITING VALUES (absolute maximum rating system)

Supply voltage	5	max.	1800 V
Continuous anode current	9	max.	0,2 mA
Voltage between first dynode and photocathode	6	max. min.	500 V 150 V
Voltage between consecutive dynodes		max.	300 V
Voltage between anode and final dynode	7	max. min.	300 V 30 V
Ambient temperature range			
operational (for short periods of time)	8	max. min.	+80 °C −30 °C
continuous operation and storage		max. min.	+50 °C −30 °C

Notes see page 5.

DEVELOPMENT SAMPLE DATA

Notes

1. To obtain a peak pulse current greater than that obtainable with divider A, it is necessary to increase the inter-dynode voltage of the stages progressively. Divider circuit B is an example of a "progressive" divider, giving a compromise between gain, speed, and linearity. Other dividers can be conceived to achieve other compromises. It is generally recommended that the increase in voltage between one stage and the next be kept less than a factor of 2.
2. Wherever possible, the photomultiplier power supply should be arranged so that the cathode is earthed and the anode is at +HT, however, it is sometimes necessary to supply the tube with the anode earthed and the cathode at −HT. Under these circumstances, erratic noise and dark current are generally increased and unstable, particularly immediately after application of voltage. The glass envelope of the tube should be supported only by isolators having an insulation resistance of $> 10^{15}\ \Omega$.
3. Dark current is measured at ambient temperature, after a stabilization period of the tube in darkness ($\approx$ 1/4 h).
4. Measured with a pulsed-light source, with a pulse duration (FWHM) of < 1 ns, the cathode being completely illuminated. The rise time is determined between 10% and 90% of the amplitude of the anode pulse. The signal transit time is measured between the instant at which the illuminating pulse at the cathode becomes maximum, and the instant at which the anode pulse attains its maximum. Rise time, pulse duration and transit time vary as a function of high tension supply voltage V_b, approximately as $V_b^{-1/2}$.
5. Total HT supply voltage or the voltage at which the tube has an anode spectral sensitivity of 600 kA/W, whichever is lower.
6. Minimum value to obtain good collection in the input optics.
7. When calculating the anode voltage the voltage drop across the load resistor should be taken into account.
8. This range of temperature is limited principally by stresses in the sealing layer of the base to the glass bulb. Where low temperature operation is contemplated, the supplier should be consulted.
9. A value of $< 10\ \mu A$ is recommended for applications requiring good stability.

MECHANICAL DATA

Dimensions in mm

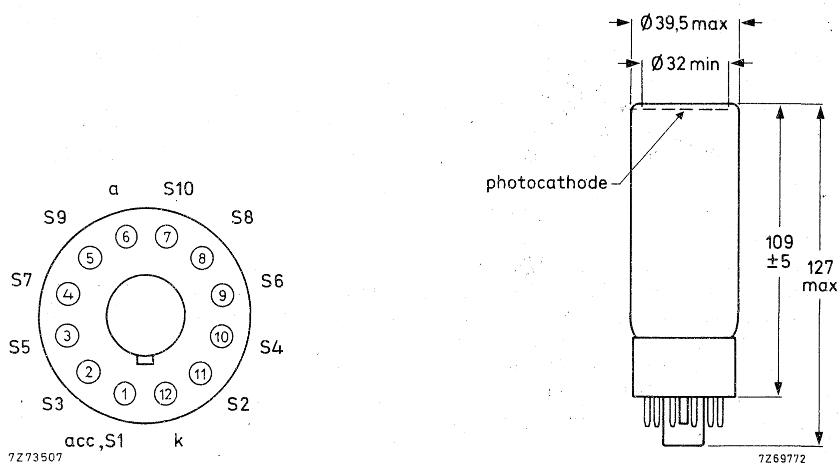


Fig. 4.

Base	12-pin (JEDEC B12–43)
Net mass	78 g

ACCESSORIES

Socket	type FE1012

DEVELOPMENT SAMPLE DATA

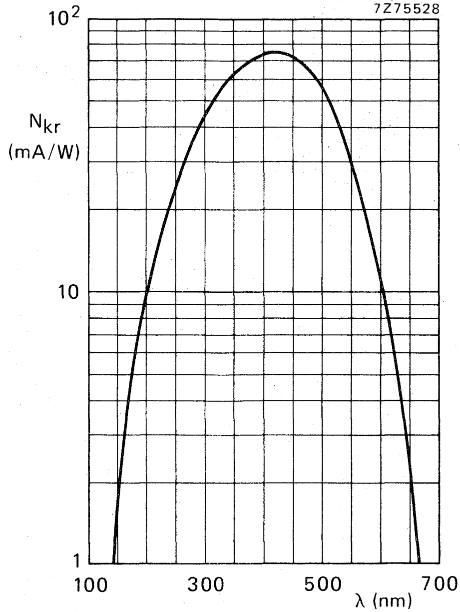


Fig. 5 Spectral sensitivity characteristic.

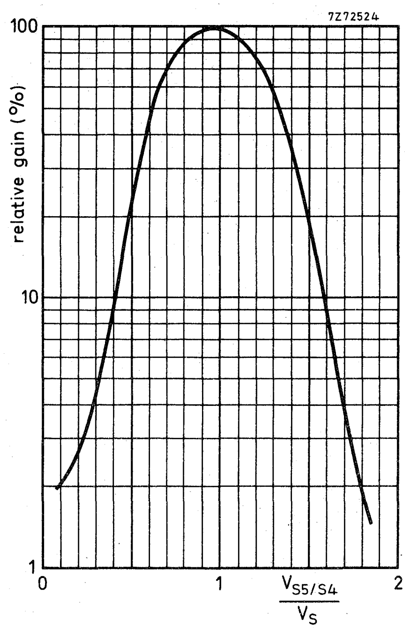


Fig. 6 Relative gain as a function of the voltage between S_5 and S_4, normalized to V_S. $V_{S6/S4}$ constant.

Note: Gain regulation by changing the voltage between S5 and S4 may cause a degradation of other parameters such as stability and linearity.

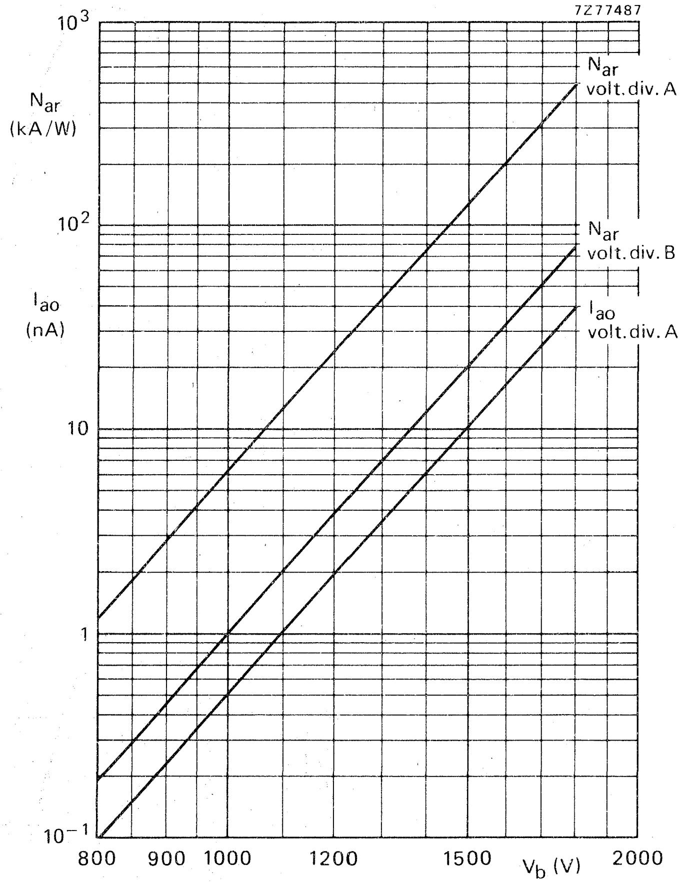


Fig. 7 Anode spectral sensitivity N_{ar}, and anode dark current I_{ao} as a function of the supply voltage V_b.

PM2102 replaces XP2000UB
PM2102B replaces XP2000

10-STAGE VENETIAN BLIND PHOTOMULTIPLIER TUBES

- 46 mm useful diameter head-on type
- Flat window
- Semi-transparent bi-alkaline type D photocathode
- High cathode sensitivity; excellent collection from the entire cathode
- Very good pulse amplitude resolution
- Very low dark current
- Very good stability
- For scintillation detection applications, e.g. gamma cameras

QUICK REFERENCE DATA*

Spectral sensitivity characteristic	type D	
Useful diameter of the photocathode	> 46 mm	
Cathode blue sensitivity	11,5 μA/lmF	note 1
Supply voltage		
for anode blue sensitivity = 1,5 A/lmF (note 1)	1250 V	
Anode dark current		
at anode blue sensitivity = 1,5 A/lmF (note 1)	0,5 nA	
Pulse amplitude resolution (^{57}Co)	≈ 9,5%	
Mean anode sensitivity deviation (30 days)	≈ 1%	

To be read in conjunction with *General Operational Recommendations Photomultiplier Tubes.*

GENERAL CHARACTERISTICS *

Window

Material	lime glass	
Shape	plano-plano	
Refractive index at 550 nm	1,52	

Photocathode (note 2)

Semi-transparent, head-on		
Material	Sb K Cs	
Useful diameter	> 46 mm	
Spectral sensitivity characteristic (Fig. 4)	type D	
Maximum spectral sensitivity	400 ± 30 nm	
Luminous sensitivity	≈ 70 μA/lm	note 3
Blue sensitivity	typ. 11,5 μA/lmF > 9,0 μA/lmF	note 1
Spectral sensitivity at 400 nm	≈ 85 mA/W	note 4

* Notes are given on page 4.

Multiplier system

Number of stages	10
Dynode structure	venetian blind
Dynode material	CuBe
Capacitances	
anode to final dynode	≈ 7 pF
anode to all	≈ 8,5 pF

Magnetic field

When the photocathode is uniformly illuminated the anode current is halved (at V_{ht} = 1500 V) at a magnetic flux density of 0,4 mT perpendicular to the tube axis.

A mu-metal shield extending more than 15 mm beyond the cathode is recommended for magnetic screening.

RECOMMENDED CIRCUIT

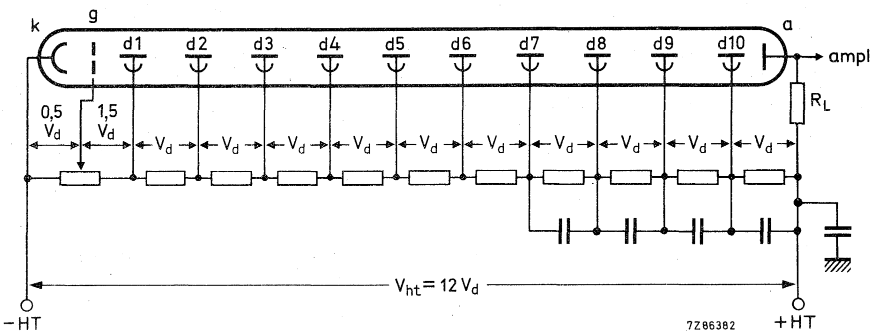


Fig. 1 Voltage divider A. Typical values of capacitors: 10 nF; k = cathode; g = accelerating electrode; d_n = dynode no.; a = anode; R_L = load resistor.

Note

For optimum pulse amplitude resolution, the accelerating-electrode potential should be between the cathode and first dynode potentials. If the tube is used in a socket wired for the XP2000UB or XP2000 with the accelerating electrode connected to the first dynode, the pulse amplitude resolution for ^{57}Co is about 9,7%.

DEVELOPMENT SAMPLE DATA

TYPICAL CHARACTERISTICS *

With voltage divider A (Fig. 1) — note 5

Supply voltage for an anode blue sensitivity of 1,5 A/lmF (Fig. 5)	< 1450 V typ. 1250 V	note 1
Anode radiant sensitivity at 400 nm and V_{ht} = 1250 V	≈ 12 kA/W	
Gain at V_{ht} = 1250 V	≈ $1,3 \times 10^5$	
Anode dark current at an anode blue sensitivity of 1,5 A/lmF (Fig. 5)	< 5 nA typ. 0,5 nA	notes 1, 6
Pulse amplitude resolution for ^{137}Cs at an anode blue sensitivity of 1,5 A/lmF	≈ 7%	notes 1, 7
Pulse amplitude resolution for ^{57}Co at an anode blue sensitivity of 1,5 A/lmF	≈ 9,5%	notes 1, 7
Pulse amplitude resolution for ^{55}Fe at an anode blue sensitivity of 7,5 A/lmF	≈ 38%	notes 1, 8
Peak-to-valley ratio for ^{55}Fe at an anode blue sensitivity of 7,5 A/lmF	≈ 40	notes 1, 8
Mean anode sensitivity deviation		note 9
long term (16 h)	≈ 0,5%	
long term (30 days)	≈ 1%	
after change of count rate	≈ 0,8%	
versus temperature between 20 and 60 °C at 450 nm	≈ 0,1% per °C	
Anode pulse rise time at V_{ht} = 1500 V	≈ 10 ns	note 10
Anode pulse duration at half height at V_{ht} = 1500 V	≈ 20 ns	note 10
Signal transit time at V_{ht} = 1500 V	≈ 46 ns	note 10
Anode current linear within 2% at V_{ht} = 1500 V	up to ≈ 10 mA	note 11

LIMITING VALUES (absolute maximum rating system)

Supply voltage	max. 2000 V	note 12
Continuous anode current	max. 0,2 mA	note 13
Voltage between first dynode and photocathode	max. 500 V min. 150 V	note 14
Voltage between accelerating electrode and photocathode	max. 500 V	
Voltage between consecutive dynodes	max. 300 V	
Voltage between anode and final dynode	max. 300 V	note 15
Ambient temperature range		
operational (for short periods)	max. + 80 °C min. −30 °C	note 16
continuous operation and storage	max. + 50 °C min. −30 °C	

* Notes are given on page 4.

Notes

1. Blue sensitivity, expressed in μA/lmF, is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5K. Light is transmitted through a blue filter (Corning CS no. 5-58, polished to half stock thickness).
2. The bialkaline photocathode has a significant resistance which increases rapidly with reducing temperature. It is therefore recommended that it should not be exposed to light of too great an intensity; the cathode current should be limited, for example, to 1 nA at room temperature or 0,1 nA at −30 °C. If too high a photocurrent is passed, the cathode can no longer be considered an equipotential surface, and the focusing of electrons onto the first dynode will be affected, resulting in departure from linearity.
3. Luminous sensitivity is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5K.
4. Spectral sensitivity is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5K. Light is transmitted through an interferential filter. Spectral sensitivity at 400 nm, expressed in A/W, can be estimated by multiplying the blue sensitivity, expressed in A/lmF, by $7,7 \times 10^3$ for this type of tube.
5. Wherever possible, the power supply should be arranged so that the cathode is earthed and the anode is at + HT, however, it is sometimes necessary to supply the tube with the anode earthed and the cathode at −HT. Under these circumstances, erratic noise and dark current are generally increased and unstable, particularly after application of voltage. The glass envelope of the tube should be supported only by insulators with an insulation resistance of $> 10^{15}$ ohm.
6. Dark current is measured at ambient temperature, after the tube has been in darkness for approx. 1 min. Lower values can be obtained after a longer stabilization period in darkness (approx. 30 min).
7. Pulse amplitude resolution for ^{137}Cs and ^{57}Co is measured with an NaI(Tl) cylindrical scintillator (Quartz et Silice serial no. 4856 or equivalent) with a diameter of 50 mm and a height of 50 mm (2″ x 2″). The count rate used is $\approx 10^4$ c/s.
8. Pulse amplitude resolution for ^{55}Fe is measured with an NaI(Tl) cylindrical scintillator with a diameter of 25 mm and a height of 1 mm provided with a beryllium window. The count rate used is $\approx 2 \times 10^3$ c/s.
9. The mean anode sensitivity deviation is measured by coupling an NaI(Tl) scintillator to the window of the tube. Long term (16 h) deviation is measured by placing a ^{137}Cs source at a distance from the scintillator such that the count rate is $\approx 10^4$ c/s corresponding to an average anode current of ≈ 300 nA. Anode sensitivity deviation after change of count rate is measured with a ^{137}Cs source at a distance of the scintillator such that the count rate can be changed from 10^4 c/s to 10^3 c/s corresponding to an average anode current of ≈ 1 μA and ≈ 0,1 μA respectively. Both tests are carried out according to ANSI—N42—9—1972 of IEEE recommendations.
10. Measured with a pulsed light source, with a pulse duration (FWHM) of < 1 ns; the cathode being completely illuminated. The rise time is determined between 10% and 90% of the amplitude of the anode pulse. The signal transit time is measured between the instant at which the illuminating pulse at the cathode becomes maximum, and the instant at which the anode pulse attains its maximum. Rise time, pulse duration and transit time vary as a function of high tension supply voltage V_{ht}, approximately as $V_{ht}^{-1/2}$.
11. To obtain a peak pulse current greater than that obtainable with divider A, it is necessary to increase the inter-dynode voltage of the stages progressively. Other dividers can be conceived to achieve other compromises. It is generally recommended that the voltage difference between one stage and the next is less than a factor of 2.

(continued on page 6)

DEVELOPMENT SAMPLE DATA

MECHANICAL DATA

Dimensions in mm

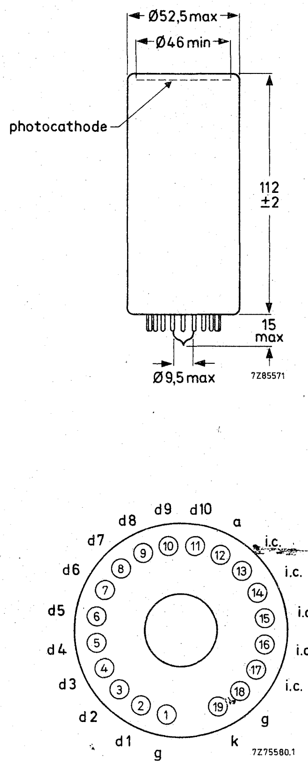


Fig. 2 PM2102.

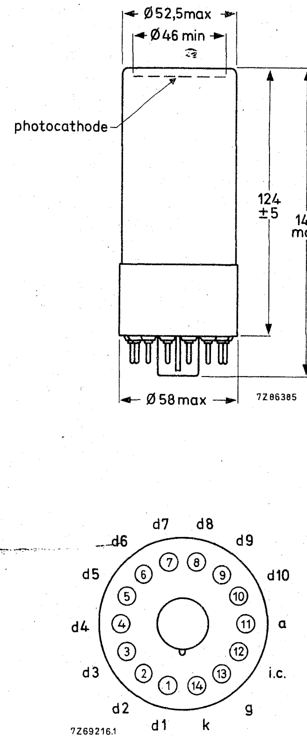


Fig. 3 PM2102B.

Base 19-pin all-glass
Net mass 120 g

Base 14-pin IEC67-1-16a (JEDEC B14-38)
Net mass 163 g

ACCESSORIES

Socket
- for PM2102 type FE2019
- for PM2102B type FE1014

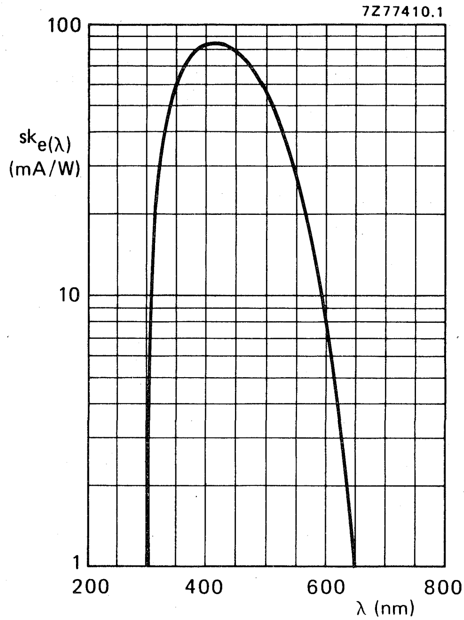


Fig. 4 Spectral sensitivity characteristic.

Notes (continued)

12. Total HT supply voltage, or the voltage at which the tube has an anode blue sensitivity of 40 A/lmF, whichever is lower.
13. A value of $< 10\ \mu A$ is recommended for applications requiring good stability.
14. Minimum value to obtain good collection in the input optics.
15. When calculating the anode voltage the voltage drop across the load resistor should be taken into account.
16. For type PM2102B this range of temperatures is limited principally by stresses in the sealing layer of the base to the glass bulb. Where low temperature operation is contemplated, the supplier should be consulted.

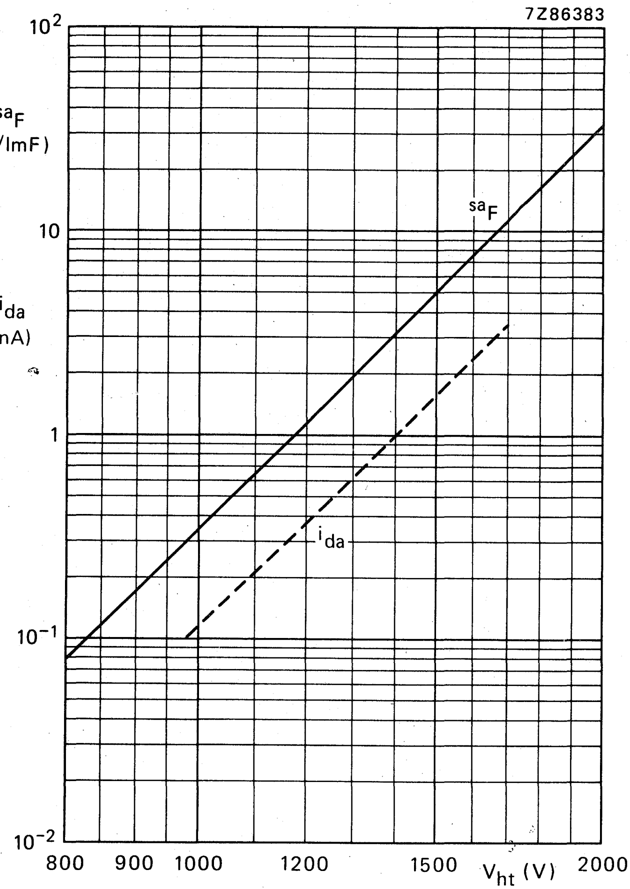


Fig. 5 Anode blue sensitivity sa_F, and anode dark current i_{da} as a function of supply voltage V_{ht}.
i_{da} is given as a dotted line to indicate its principle behaviour only.

DEVELOPMENT SAMPLE DATA

6-STAGE PHOTOMULTIPLIER TUBE

- 44 mm useful diameter head-on type
- plano-concave window
- semi-transparent bi-alkaline type D photocathode
- high cathode sensitivity
- low gain
- very good pulse linearity and time characteristics of high amplitude pulses at high count rates

QUICK REFERENCE DATA *

Spectral sensitivity characteristic	type D	
Useful diameter of the photocathode	> 44 mm	
Quantum efficiency at 400 nm	25 %	
Cathode blue sensitivity	10,5 μA/lmF	note 1 ←
Supply voltage for a gain of 2 x 10^4	2000 V	
Anode pulse rise time (with voltage divider B)	≈ 1,6 ns	
Linearity (with voltage divider B)	up to 350 mA	

To be read in conjunction with *General Operational Recommendations Photomultiplier Tubes.*

GENERAL CHARACTERISTICS *

Window

Material	lime-glass	
Shape	plano-concave	
Refractive index at 550 nm	1,52	

Photocathode (note 2)

Semi-transparent, head-on		
Material	Sb K Cs	
Useful diameter	> 44 mm	
Spectral sensitivity characteristic (Fig. 5)	type D	
Maximum spectral sensitivity	400 ± 30 nm	
Luminous sensitivity	≈ 70 μA/lm	note 3
Blue sensitivity	typ. 10,5 μA/lmF > 8,0 μA/lmF	note 1
Spectral sensitivity at 400 nm	≈ 80 mA/W	note 4
Quantum efficiency at 400 nm	25%	

* Notes are given on page 5.

Multiplier system

Number of stages	6
Dynode structure	linear focused
Dynode material	Cu Be
Capacitances	
anode to final dynode	≈ 3 pF
anode to all	≈ 5 pF

Magnetic field

When the photocathode is illuminated uniformly, the anode current is halved at V_{ht} = 1100 V, voltage divider A, at a magnetic flux density of:
0,2 mT perpendicular to axis a (see Fig. 1);
0,1 mT parallel with axis a.

It is recommended that the tube be screened against the influence of magnetic fields by a mu-metal shield protruding > 15 mm beyond the photocathode.

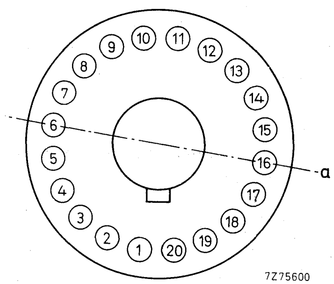


Fig. 1 Axis a with respect to base pins (bottom view).

RECOMMENDED CIRCUITS

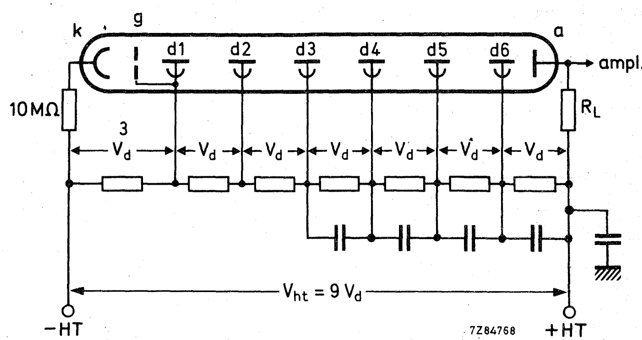


Fig. 2 Voltage divider A.

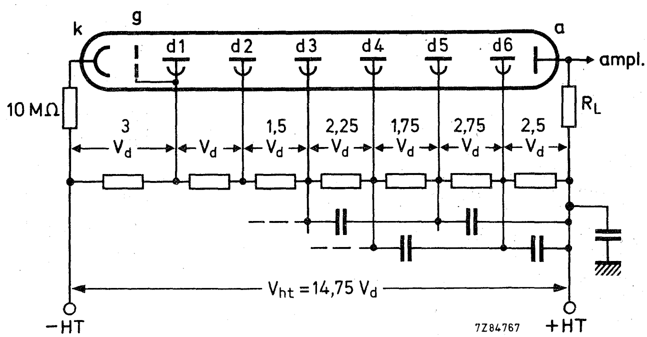


Fig. 3 Voltage divider B.

DEVELOPMENT SAMPLE DATA

k = cathode;
g = accelerating electrode;
d_n = dynode no.;
R_L = load resistor;
a = anode.

Typical values of capacitors 1 nF

The cathode resistor of 10 MΩ limits the current should there be unintentional contact between tl coating and earth when the anode is earthed.

TYPICAL CHARACTERISTICS *

With voltage divider A (Fig. 2)		note 5
Supply voltage for a gain of 1×10^4 (Fig. 6)	< 1600 V typ. 1100 V	
Anode dark current at a gain of 1×10^4 (Fig. 6)	< 5 nA typ. 1 nA	notes 6, 7
With voltage divider B (Fig. 3)		note 5
Supply voltage for a gain of 2×10^4 (Fig. 6)	≈ 2000 V	
Anode pulse rise time at V_{ht} = 2000 V	≈ 1,6 ns	note 8
Anode pulse duration at half height at V_{ht} = 2000 V	≈ 2,4 ns	note 8
Signal transit time at V_{ht} = 2000 V	≈ 16,5 ns	note 8
Anode current linear within 2% at V_{ht} = 2000 V	up to ≈ 350 mA	

LIMITING VALUES (absolute maximum rating system) *

Supply voltage	max. 2200 V	
Continuous anode current	max. 0,2 mA	note 9
Voltage between first dynode and photocathode	max. 800 V min. 300 V	note 10
Voltage between consecutive dynodes	max. 400 V	
Voltage between anode and final dynode	max. 600 V min. 80 V	note 11
Ambient temperature range operational (for short periods of time)	max. +80 °C min. −30 °C	note 12
continuous operation and storage	max. +50 °C min. −30 °C	

* Notes are given on page 5.

NOTES

1. Blue sensitivity, expressed in μA/lmF, is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5 K. Light is transmitted through a blue filter (Corning CS no. 5-58, polished to half stock thickness).
2. The bialkaline photocathode has a significant resistance which increases rapidly with reducing temperature. It is therefore recommended that it should not be exposed to light of too great an intensity; the cathode current should be limited, for example, to 10 nA at room temperature or 0,1 nA at −100 °C. If too high a photocurrent is passed, the cathode can no longer be considered an equipotential surface, and the focusing of electrons onto the first dynode will be affected, resulting in departure from linearity.
3. Luminous sensitivity is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5 K.
4. Spectral sensitivity is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5 K. Light is transmitted through an interferential filter. Spectral sensitivity at 400 nm, expressed in A/W, can be estimated by multiplying the blue sensitivity, expressed in A/lmF, by $7,6 \times 10^3$ for this type of tube.
5. To obtain a peak pulse current greater than that obtainable with divider A, it is necessary to increase the inter-dynode voltage of the stages progressively. Divider circuit B is an example of a "progressive" divider, giving a compromise between gain, speed, and linearity. Other dividers can be conceived to achieve other compromises. It is generally recommended that the increase in voltage between one stage and the next be kept less than a factor of 2.
6. Wherever possible, the power supply should be arranged so that the cathode is earthed and the anode is at +HT, however, it is sometimes necessary to supply the tube with the anode earthed and the cathode at −HT. Under these circumstances, erratic noise and dark current are generally increased and unstable, particularly immediately after application of voltage. The tube is provided with a conductive coating connected to the cathode. It is recommended that, if a metal shield is used this be kept at photocathode potential. This implies safety precautions to protect the user. The glass envelope of the tube should be supported only by insulators with an insulation resistance of $> 10^{15}\ \Omega$.
7. Dark current is measured at ambient temperature, after the tube has been in darkness for approx. 1 min. Lower values can be obtained after a longer stabilization period in darkness (approx. 30 min).
8. Measured with a pulsed-light source, with a pulse duration (FWHM) of < 1 ns, the cathode being completely illuminated. The rise time is determined between 10% and 90% of the amplitude of the anode pulse. The signal transit time is measured between the instant at which the illuminating pulse at the cathode becomes maximum, and the instant at which the anode pulse attains its maximum. Rise time, pulse duration and transit time vary as a function of high tension supply voltage V_{ht}, approximately as $V_{ht}^{-1/2}$.
9. For applications which require good stability a value of $< 10\ \mu A$ is recommended. Use of high anode currents limits tube life; see also General Operational Recommendations Photomultiplier Tubes.
10. Minimum value to obtain good collection in the input optics.
11. When calculating the anode voltage the voltage drop across the load resistor should be taken into account.
12. This range of temperatures is limited principally by stresses in the sealing layer of the base to the glass bulb. Where low temperature operation is contemplated, the supplier should be consulted.

MECHANICAL DATA

Dimensions in mm

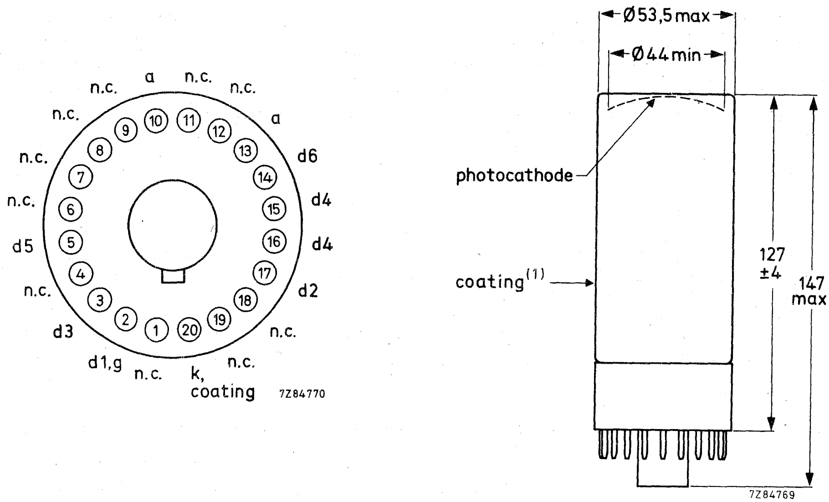


Fig. 4.

Note: Both anode contacts (pins 10 and 13) must be connected to prevent ringing of the anode pulse signal.

Base	20-pin (IEC67-1-42a, JEDEC B20-102)
Net mass	151 g

ACCESSORIES

Socket type FE1020

(1) **Warning:**

The envelope of the tube is covered with a conductive coating, connected to the cathode. On top of this a black paint is applied which is neither guaranteed to be light tight nor isolating.
Care should be taken to avoid hazard due to electric shock.

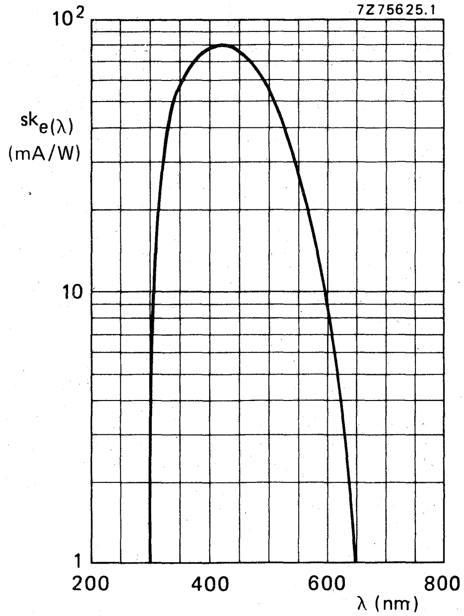


Fig. 5 Spectral sensitivity characteristic.

DEVELOPMENT SAMPLE DATA

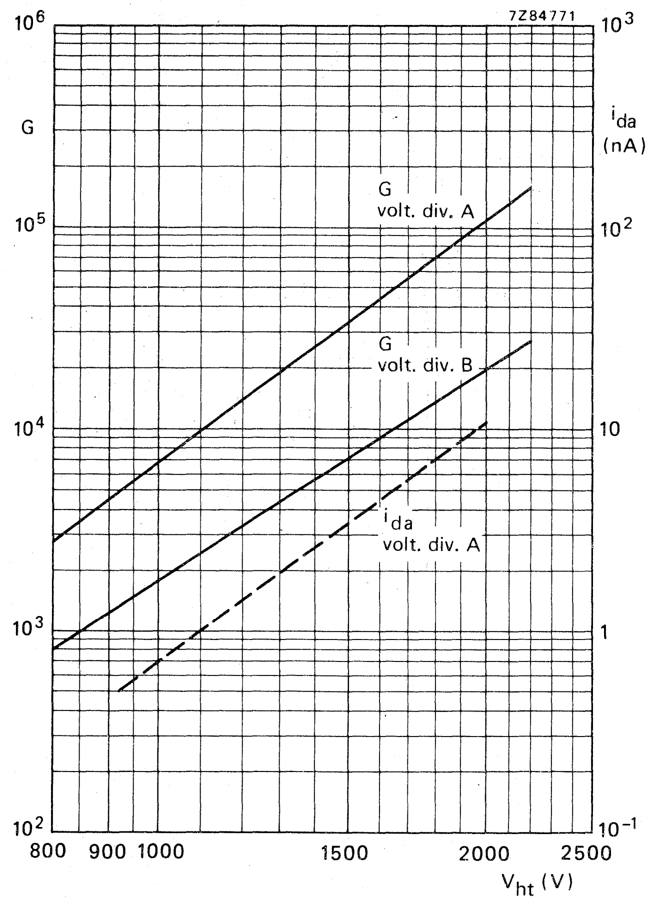


Fig. 6 Gain G and anode dark current, i_{da}, as a function of supply voltage V_{ht}.

I_{da} is given as a dotted line to indicate its principle behaviour only.

12-STAGE PHOTOMULTIPLIER TUBE

The PM2254B is a 44 mm useful diameter head-on photomultiplier tube with a plano-concave fused silica window and a semi-transparent trialkaline type TU photocathode.
The tube is intended for use in optical applications where a high sensitivity in the region from ultraviolet to the near infrared is required combined with good time characteristics. The PM2254B is unilaterally interchangeable with 56AVP-family tubes.

QUICK REFERENCE DATA

Spectral sensitivity characteristic		type TU		
Useful diameter of the photocathode		>	44	mm
Spectral sensitivity of the photocathode at 698 nm			15	mA/W
Supply voltage for a gain of 3×10^7			2300	V
Anode pulse rise time (with voltage divider B′)		≈	1,5	ns
Linearity, with voltage divider B	up to	≈	280	mA

To be read in conjunction with *General Operational Recommendations Photomultiplier Tubes.*

GENERAL CHARACTERISTICS

Window

Material	fused silica		
Shape	plano-concave		
Refractive index			
at 400 nm	1,47		
at 250 nm	1,50		

Photocathode

Semi-transparent, head-on			
Material	Sb Na K Cs		
Useful diameter	>	44	mm
Spectral sensitivity characteristic (Fig. 6)	type TU		
Maximum spectral sensitivity at		420 ± 30	nm
Spectral sensitivity at 698 ± 7 nm	typ.	15	mA/W
	>	7	mA/W
Luminous sensitivity	≈	150	µA/lm

Multiplier system

Number of stages	12
Dynode structure	linear focused
Dynode material	CuBe

Capacitances

Grid 1 to k + S_1 + acc + g_2 + S_5	≈	20 pF
Anode to final dynode	≈	4 pF
Anode to all	≈	7 pF

Magnetic field

See Fig. 9.

It is recommended that the tube be screened against the influence of magnetic fields by a mu-metal shield protruding > 15 mm beyond the photocathode.

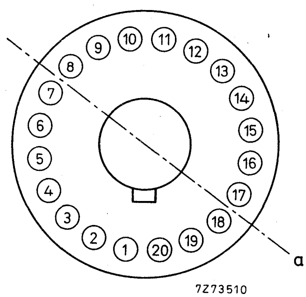


Fig. 1 Axis a with respect to base pins (bottom view).

RECOMMENDED CIRCUITS

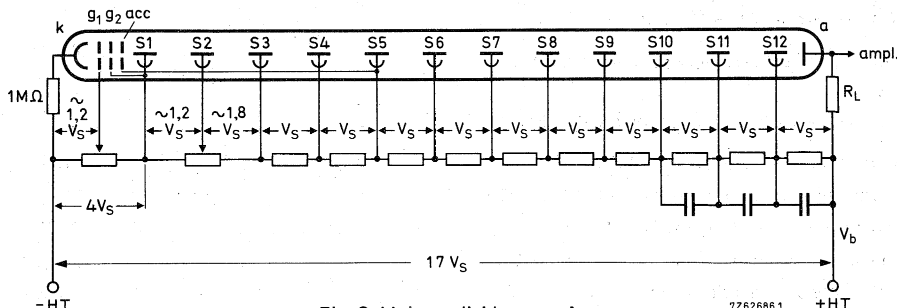


Fig. 2 Voltage divider type A.

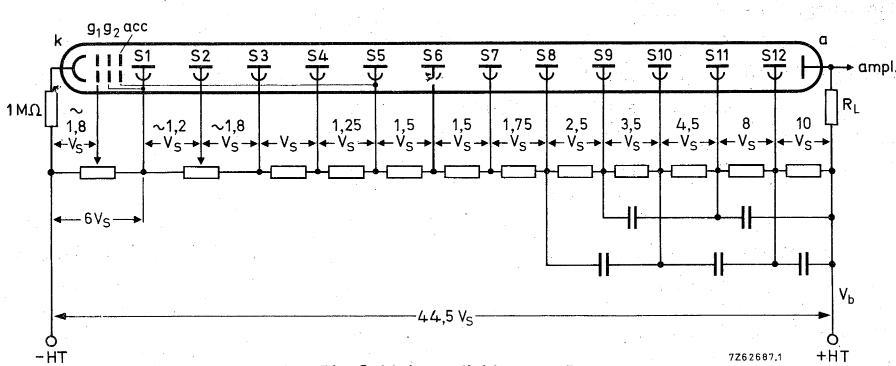


Fig. 3 Voltage divider type B.

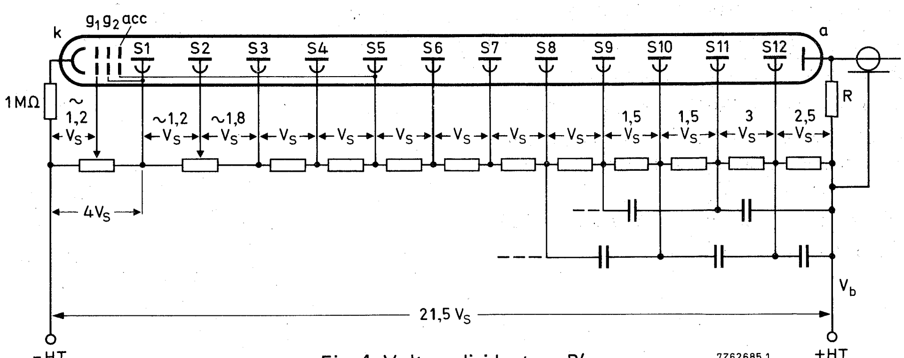


Fig. 4 Voltage divider type B'.

DEVELOPMENT SAMPLE DATA

k	= cathode
g_1, g_2	= focusing electrodes
acc	= accelerating electrode
S_n	= dynode no. n
a	= anode
R_L	= load resistor

R = This resistor connects the anode when the output cable is not terminated. Recommended value: 10 kΩ.

The cathode resistor of 1 MΩ limits the current in case of unintentional contact between the conductive coating and earth when the anode is earthed.
Typical value of capacitors: 1 nF.

TYPICAL CHARACTERISTICS

	note			
With voltage divider A (Fig. 2)	1			
Supply voltage for a gain of 3×10^7 (Fig. 10)			typ.	2300 V
			<	2700 V
Anode dark current at a gain of 3×10^7 (Fig. 10)	2, 3		typ.	60 nA
			<	1500 nA
Anode pulse rise time at V_b = 2000 V	4, 5		≈	1,6 ns
Anode pulse duration at half height at V_b = 2000 V	4, 5		≈	3,7 ns
Signal transit time at V_b = 2000 V	4, 5		≈	28 ns
Anode current linear within 2% at V_b = 2000 V		up to	≈	25 mA
Obtainable peak anode current			≈	100 mA
With voltage divider B (Fig. 3)	1			
Gain at V_b = 2800 V (Fig. 10)			≈	$1,5 \times 10^6$
Anode pulse rise time at V_b = 2800 V	4, 5		≈	1,7 ns
Anode pulse duration at half height at V_b = 2800 V	4, 5		≈	2,7 ns
Signal transit time at V_b = 2800 V	4, 5		≈	31 ns
Signal transit time difference between the centre of the photocathode and 18 mm from the centre at V_b = 2800 V			≈	0,25 ns
Anode current linear within 2% at V_b = 2800 V		up to	≈	280 mA
Obtainable peak anode current			≈	0,5 to 1 A
With voltage divider B' (Fig. 4)	1			
Gain at V_b = 2500 V (Fig. 10)			≈	$1,5 \times 10^7$
Anode pulse rise time at V_b = 2500 V	4, 5		≈	1,5 ns
Anode pulse duration at half height at V_b = 2500 V	4, 5		≈	2,4 ns
Signal transit time at V_b = 2500 V	4, 5		≈	30 ns
Signal transit time distribution at V_b = 2500 V	5, 6	σ	≈	0,25 ns
Signal transit time difference between the centre of the photocathode and 18 mm from the centre at V_b = 2500 V			≈	0,25 ns
Anode current linear within 2% at V_b = 2500 V		up to	≈	70 mA
Obtainable peak anode current			≈	250 mA

Notes see page 6.

LIMITING VALUES (Absolute maximum rating system)

	note		
Supply voltage	7	max.	3000 V
Continuous anode current	8	max.	0,2 mA
Voltage between focusing electrode, g_1 and photocathode		max.	300 V
Voltage between first dynode and photocathode	9	max. min.	800 V 210 V
Voltage between consecutive dynodes (except S_{11} and S_{12})		max.	400 V
Voltage between dynodes S_{11} and S_{12}	5	max.	600 V
Voltage between anode and final dynode	10	max. min.	700 V 80 V
Ambient temperature range	11		
operational (for short periods of time)		max. min.	+80 °C −30 °C
continuous operation and storage		max. min.	+50 °C −30 °C

DEVELOPMENT SAMPLE DATA

Notes see page 6.

Notes to pages 4 and 5

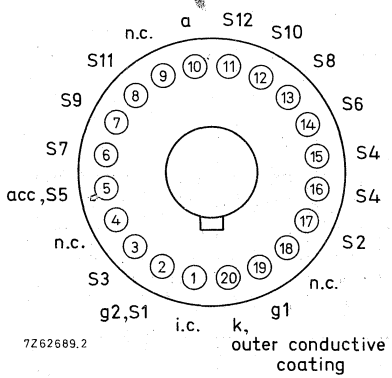
1. To obtain a peak pulse current greater than that obtainable with divider A, it is necessary to increase the inter-dynode voltages of the stages progressively. Dividers B and B′ are examples of "progressive" dividers, each giving a compromise between gain, speed, and linearity. Other dividers can be conceived to achieve other compromises. It is generally recommended that the increase in voltage between one stage and the next be kept less than a factor of 2.
2. Wherever possible, the power supply should be arranged so that the cathode is earthed and the anode is at + HT, however, it is sometimes necessary to supply the tube with the anode earthed and the cathode at −HT. Under these circumstances, erratic noise and dark current are generally increased and unstable, particularly immediately after application of voltage. The tube is provided with a conductive coating connected to the cathode. It is recommended that, if a metal shield is used, this should be kept at cathode potential. This implies safety precautions to protect the user. The envelope of the tube should be supported only by isolators having an insulation resistance of $> 10^{15}\ \Omega$.
3. Dark current is measured at ambient temperature, after a stabilization period of the tube in darkness ($\approx$ ¼ h).
4. Measured with a pulsed light source, with a pulse duration (FWHM) of < 1 ns, the cathode being completely illuminated. The rise time is determined between 10% and 90% of the amplitude of the anode pulse. The signal transit time is measured between the instant at which the illuminating pulse at the cathode becomes maximum, and the instant at which the anode pulse attains its maximum. Rise time, pulse duration and transit time vary as a function of high tension supply voltage V_b, approximately as $V_b^{-1/2}$.
5. Non-inductive resistors of 51 Ω are incorporated in the base connected to S_{11} and S_{12}. See also *General Operational Recommendations Photomultiplier Tubes.*
6. Transit time fluctuations of single electrons leaving the photocathode result in a transit time distribution at the anode. This distribution is characterized by its standard deviation (σ).
7. Total HT supply voltage, or the voltage at which the tube has a gain of 2×10^8, whichever is lower.
8. A value of $< 10\ \mu A$ is recommended for applications requiring good stability.
9. Minimum value to obtain good collection in the input optics.
10. When calculating the anode voltage the voltage drop across the load resistor should be taken into account.
11. This range of temperatures is limited principally by stresses in the sealing layer of the base to the glass bulb. Where low temperature operation is contemplated, the supplier should be consulted.

DEVELOPMENT SAMPLE DATA

MECHANICAL DATA

Dimensions in mm

(1) **Warning:** The envelope of the tube is covered with a conductive coating, connected to the cathode. Care should be taken to avoid hazard due to electric shock.



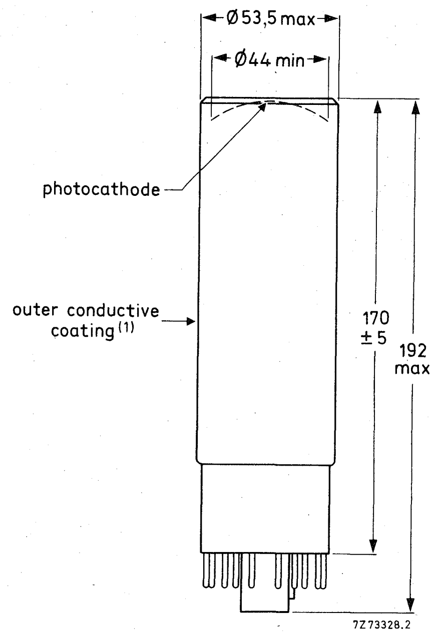


Fig. 5.

The base connections of the PM2254B are such that the tube is unilaterally interchangeable with the 56AVP-family tubes.

Base	20-pin (JEDEC B20-102)
Net mass	240 g

ACCESSORIES

Socket	type FE1020

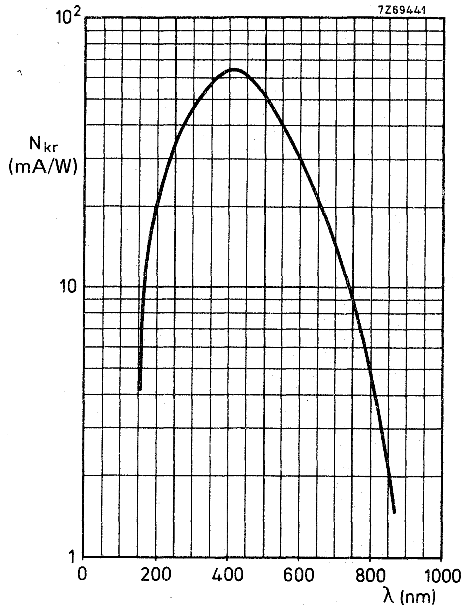


Fig. 6
Spectral sensitivity characteristic.

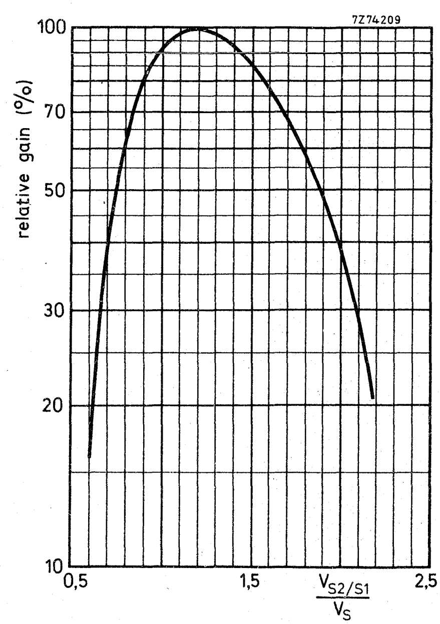


Fig. 7
Relative gain as a function of the voltage between S2 and S1, normalized to V_S
$V_{S3/S1}$ constant.

DEVELOPMENT SAMPLE DATA

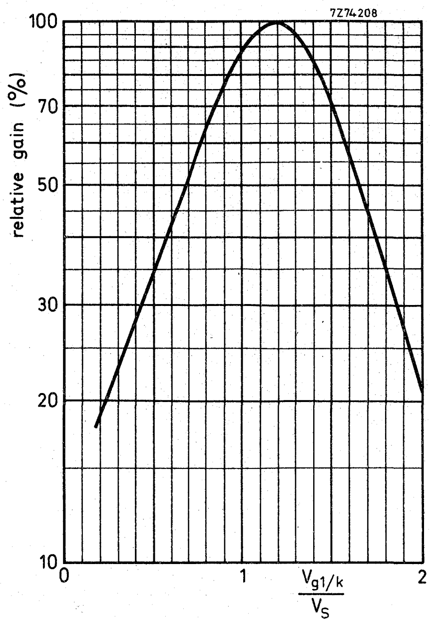


Fig. 8
Relative gain as a function of the voltage between grid 1 and cathode, normalized to V_S. $V_{S1/k}$ constant.

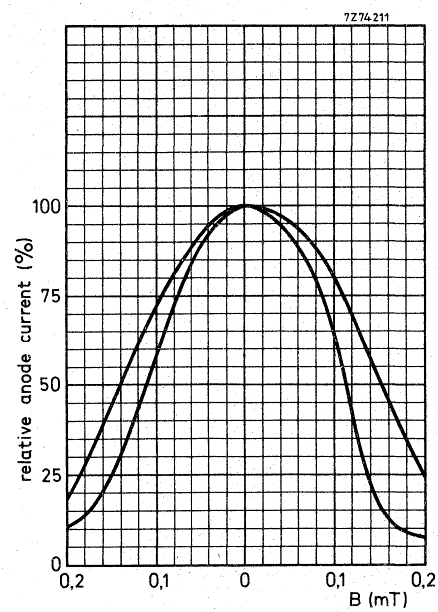


Fig. 9
Relative anode current as a function of the magnetic flux density B.

1. ⊥ axis a
2. // axis a

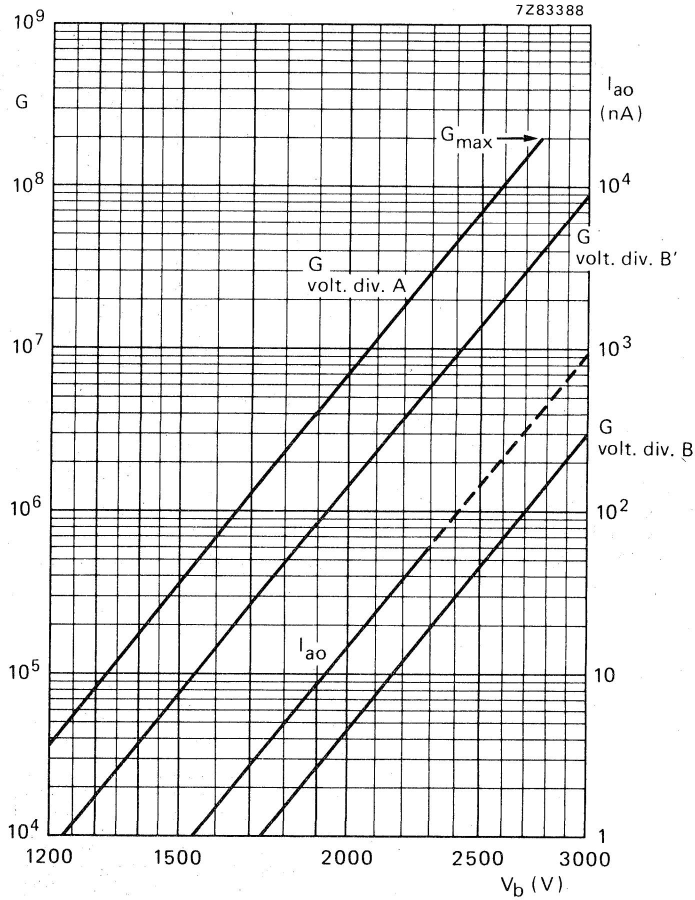


Fig. 10 Gain, G, and anode dark current, I_{ao}, as a function of supply voltage V_b.

12-STAGE PHOTOMULTIPLIER TUBE

The PM2312 and PM2312B are 68 mm useful diameter head-on photomultiplier tubes with a plano-concave window and a semi-transparant bialkaline type D photocathode. The tubes are intended for use in nuclear physics where the number of photons to be detected is very low and where good time characteristics and a good linearity are required (coincidence measurements, Cerenkov counters). The PM2312B is provided with a 20-pin plastic base. The PM2312 has a 19-pin all-glass base.

QUICK REFERENCE DATA

Spectral sensitivity characteristic		type D
Useful diameter of the photocathode		> 68 mm
Quantum efficiency at 401 nm		26 %
Cathode spectral sensitivity at 401 nm		85 mA/W
Supply voltage for a gain of 3 x 10^7		2000 V
Pulse amplitude resolution for ^{137}Cs		≈ 8,0 %
Anode pulse rise time (with voltage divider B)		≈ 2,5 ns
Linearity		
with voltage divider A	up to	≈ 100 mA
with voltage divider B	up to	≈ 250 mA

To be read in conjunction with *General Operational Recommendations Photomultiplier Tubes.*

GENERAL CHARACTERISTICS

Window

Material	borosilicate
Shape	plano-concave
Refractive index at 550 nm	1,48

Photocathode (note 1)

Semi-transparent, head on	
Material	SbKCs
Useful diameter	> 68 mm
Spectral sensitivity characteristic (Fig. 6)	type D
Maximum spectral sensitivity at	400 ± 30 nm
Quantum efficiency at 401 nm	26 %
Spectral sensitivity at 401 ± 3 nm	typ. 85 mA/W > 65 mA/W

Note
See page 5.

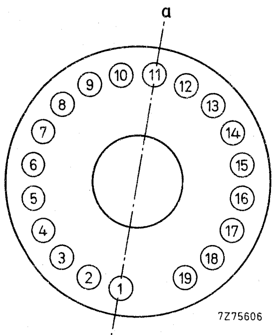
Multiplier system

Number of stages		12
Dynode structure		linear focused
Dynode material		Cu-Be
Capacitances		
anode to final dynode	≈	3 pF
anode to all	≈	5 pF

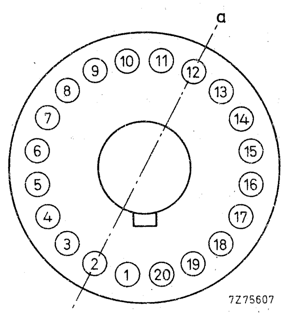
Magnetic field

When the photocathode is illuminated uniformly, the anode current is halved (at V_b = 1500 V, voltage divider A) at a magnetic flux density of:
0,2 mT perpendicular to axis a (see Fig. 1);
0,1 mT parallel with axis a

It is recommended that the tube be screened against the influence of magnetic fields by a mu-metal shield protruding > 15 mm beyond the photocathode.



PM2312



PM2312B

Fig. 1 Axis a with respect to base pins (bottom view).

RECOMMENDED CIRCUITS

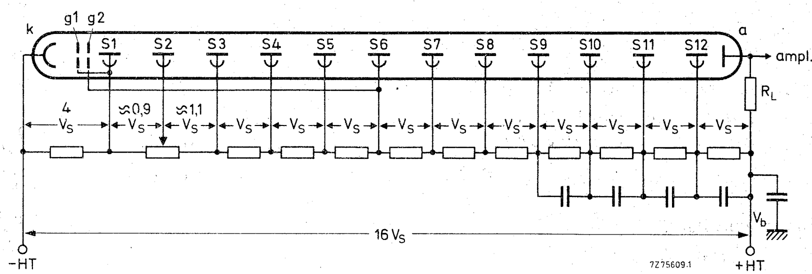


Fig. 2 Voltage divider A. Typical value of capacitors: 1 nF; k = cathode; g_1,g_2 = accelerating electrodes; S_n = dynode no.; a = anode; R_L = load resistor.

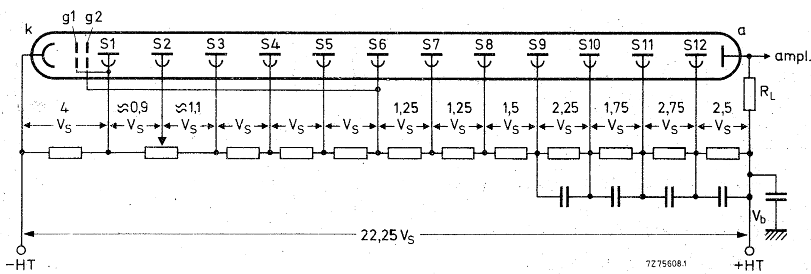


Fig. 3 Voltage divider B. Typical value of capacitors: 1 nF; k = cathode; g_1,g_2 = accelerating electrodes; S_n = dynode no.; a = anode; R_L = load resistor.

DEVELOPMENT SAMPLE DATA

TYPICAL CHARACTERISTICS

	notes		
With voltage divider A (Fig. 2)	2		
Supply voltage for a gain of 3×10^7 (Fig. 7)		typ.	2000 V
		<	2500 V
Anode dark current at a gain of 3×10^7 (Fig. 7)	3,4	typ.	25 nA
		<	250 nA
Background noise at a gain of 3×10^7 (Fig. 7)	5	≈	2000 c/s
Pulse amplitude resolution for ^{137}Cs at an anode spectral sensitivity of 12 kA/W	6	≈	8,0 %
Anode current linear within 2% at V_b = 2000 V	up to	≈	100 mA
With voltage divider B (Fig. 3)	2		
Gain at V_b = 2000 V (Fig. 7)		≈	6×10^6
Anode pulse rise time at V_b = 2000 V	7	≈	2,5 ns
Anode pulse duration at half height at V_b = 2000 V	7	≈	3,5 ns
Signal transit time at V_b = 2000 V	7	≈	35 ns
Signal transit time difference between the centre of the photocathode and 30 mm from the centre at V_b = 1800 V		≈	0,7 ns
Anode current linear within 2% at V_b = 2000 V	up to	≈	250 mA

LIMITING VALUES (absolute maximum rating system)

	notes		
Supply voltage	8	max.	2500 V
Continuous anode current	12	max.	0,2 mA
Voltage between first dynode and photocathode	9	max.	700 V
		min.	300 V
Voltage between consecutive dynodes		max.	400 V
Voltage between g_2 and photocathode (g_2 normally connected to S6)		max.	1500 V
Voltage between anode and final dynode	10	max.	600 V
		min.	80 V
Ambient temperature range	11		
operational (for short periods of time)		max.	+ 80 °C
		min.	−30 °C
continuous operation and storage		max.	+ 50 °C
		min.	−30 °C

Notes see page 5.

DEVELOPMENT SAMPLE DATA

Notes

1. The bialkaline photocathode has a significant resistance which increases rapidly with reducing temperature. It is thus recommended that it should not be subjected to light of too great an intensity; the cathode current should be limited to, for example, 1 nA at room temperature or 0,1 nA at −30 °C. If too high a photocurrent is passed, the cathode can no longer be considered to be an equipotential surface, and the focusing of electrons onto the first dynode will be affected, resulting in departures of linearity.
2. To obtain a peak pulse current greater than that obtainable with divider A, it is necessary to increase the inter-dynode voltages of the stages progressively. Dividers B and B′ are examples of "progressive" dividers, each giving a compromise between gain, speed, and linearity.
   Other dividers can be conceived to achieve other compromises. It is generally recommended that the increase in voltage between one stage and the next be kept less than a factor of 2.
3. Wherever possible, the power supply should be arranged so that the cathode is earthed and the anode is at +HT, however, it is sometimes necessary to supply the tube with the anode earthed and the cathode at −HT. Under these circumstances, erratic noise and dark current are generally increased and unstable, particularly immediately after application of voltage. The glass envelope of the tube should be supported only by isolators having an insulation resistance of $> 10^{15}$ Ω.
4. Dark current is measured at ambient temperature, after a stabilization period of the tube in darkness (≈ 1/4 h).
5. After having been stored with its protective hood, the tube is placed in darkness with V_b set to a value to give a gain of 3×10^7 . After a 30 min stabilization period noise pulses with a threshold of $1{,}4 \times 10^{-12}$ C (corresponding to 0,3 photoelectron) are recorded (Fig. 7).
6. Pulse amplitude resolution for ^{137}Cs is measured with a NaI(Tl) cylindrical scintillator (Quartz et Silice ser. no. 4170 or equivalent) with a diameter of 75 mm and a height of 75 mm. The count rate used is $\approx 10^4$ c/s.
7. Measured with a pulsed-light source, with a pulse duration (FWHM) of < 1 ns, the cathode being completely illuminated.
   The rise time is determined between 10% and 90% of the amplitude of the anode pulse.
   The signal transit time is measured between the instant at which the illuminating pulse at the cathode becomes maximum, and the instant at which the anode pulse attains its maximum. Rise time, pulse duration and transit time vary as a function of high tension supply voltage V_b, approximately as $V_b^{-1/2}$.

   Non-inductive resistors of 51 Ω are connected in the base of type PM2312B to S_{11} and S_{12}.
   See also *General Operational Recommendations Photomultiplier Tubes.*
8. Total HT supply voltage, or the voltage at which the tube has a gain of 2×10^8, whichever is lower.
9. Minimum value to obtain good collection in the input optics.
10. When calculating the anode voltage, the voltage drop across the load resistor should be taken into account.
11. For type PM2312B this range of temperatures is limited principally by stresses in the sealing layer of the base to the glass bulb. Where low temperature operation is contemplated, the supplier should be consulted.

MECHANICAL DATA

Dimensions in mm

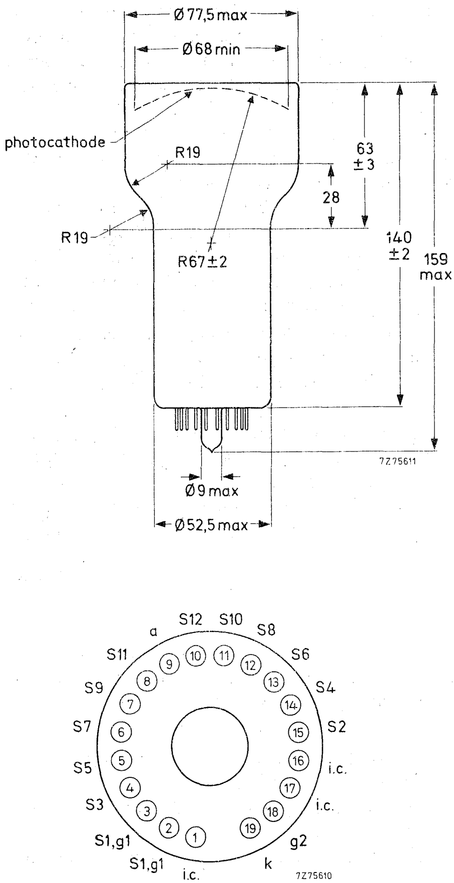


Fig. 4 PM2312.

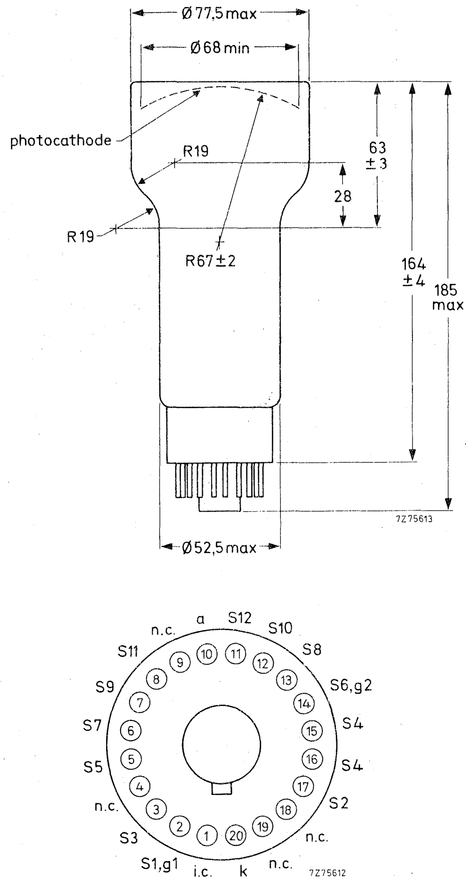


Fig. 5 PM2312B.

Base	19-pin all-glass
Net mass	215 g

Base*	20-pin IEC 67-1-42a, Jedec B20-102
Net mass	252 g

ACCESSORIES

Socket

for PM 2312	type FE2019
for PM 2312B	type FE1020

* This tube can be inserted in sockets, wired for type XP2020 or 56AVP-family tubes.

DEVELOPMENT SAMPLE DATA

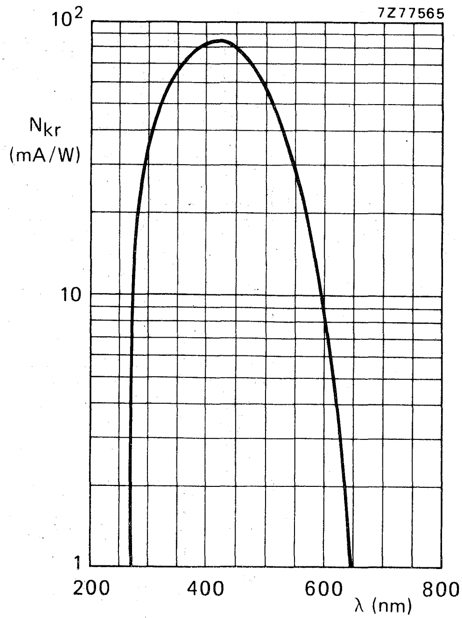


Fig. 6 Spectral sensitivity characteristic.

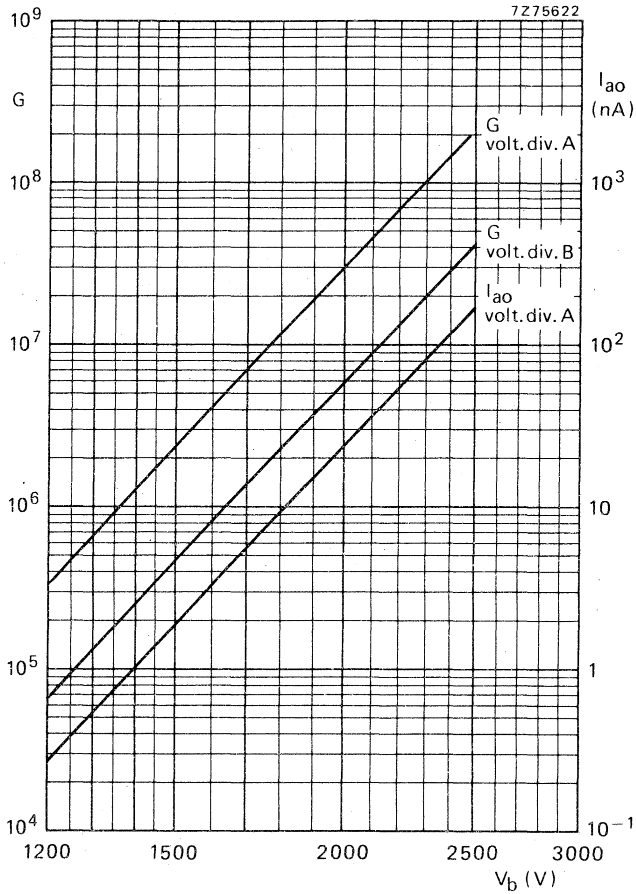


Fig. 7 Gain G, and anode dark current I_{ao} as a function of the supply voltage V_b.

10-STAGE VENETIAN BLIND PHOTOMULTIPLIER TUBES

- 59 mm useful diameter head-on type
- Flat window
- Semi-transparent bi-alkaline type D photocathode
- High cathode sensitivity; excellent collection from the entire cathode
- Very good pulse amplitude resolution
- Very low dark current
- Very good stability
- For nuclear medicine applications, e.g. gamma cameras

QUICK REFERENCE DATA *

Spectral sensitivity characteristic	type D	
Useful diameter of the photocathode	> 59 mm	
Cathode blue sensitivity	12,5 μA/lmF	note 1
Supply voltage		
for anode blue sensitivity = 1,5 A/lmF (note 1)	1250 V	
Anode dark current		
at anode blue sensitivity = 1,5 A/lmF (note 1)	0,5 nA	
Pulse amplitude resolution (^{57}Co)	≈ 9,2%	
Mean anode sensitivity deviation (30 days)	≈ 1%	

To be read in conjunction with *General Operational Recommendations Photomultiplier Tubes.*

GENERAL CHARACTERISTICS *

Window

Material	lime glass	
Shape	plano-plano	
Refractive index at 550 nm	1,52	

Photocathode (note 2)

Semi-transparent, head-on		
Material	Sb K Cs	
Useful diameter	> 59 mm	
Spectral sensitivity characteristic (Fig. 4)	type D	
Maximum spectral sensitivity	400 ± 30 nm	
Luminous sensitivity	≈ 75 μA/lm	note 3
Blue sensitivity	typ. 12,5 μA/lmF > 9,5 μA/lmF	note 1
Spectral sensitivity at 400 nm	≈ 90 mA/W	note 4

* Notes are given on page 4.

Multiplier system

Number of stages	10
Dynode structure	venetian blind
Dynode material	CuBe
Capacitances	
anode to final dynode	≈ 7 pF
anode to all	≈ 8,5 pF

Magnetic field

When the photocathode is uniformly illuminated the anode current is halved (at V_{ht} = 1500 V) at a magnetic flux density of 0,3 mT perpendicular to the tube axis.

A mu-metal shield extending more than 15 mm beyond the cathode is recommended for magnetic screening.

RECOMMENDED CIRCUIT

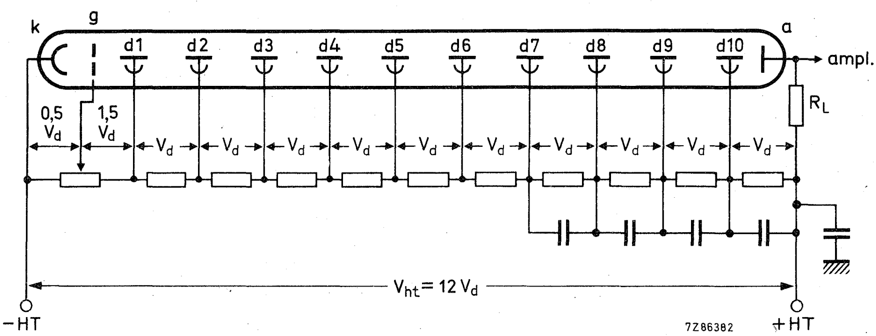


Fig. 1 Voltage divider A. Typical values of capacitors: 10 nF; k = cathode; g = accelerating electrode; d_n = dynode no.; a = anode; R_L = load resistor.

Note

For optimum pulse amplitude resolution, the accelerating-electrode potential should be between the cathode and first dynode potentials. If the tube is used in a socket wired for a previous type PM2402 or PM2402B with the accelerating electrode connected the first dynode, the pulse amplitude resolution for ^{57}Co is about 9,4%.

DEVELOPMENT SAMPLE DATA

TYPICAL CHARACTERISTICS *

With voltage divider A (Fig. 1)		note 5
Supply voltage for an anode blue sensitivity of 1,5 A/lmF (Fig. 5)	< 1450 V typ. 1250 V	note 1
Anode radiant sensitivity at 400 nm and V_{ht} = 1250 V	≈ 11 kA/W	
Gain at V_{ht} = 1250 V	≈ 1,3 x 10^5	
Anode dark current at an anode blue sensitivity of 1,5 A/lmF (Fig. 5)	< 5 nA typ. 0,5 nA	notes 1, 6
Pulse amplitude resolution for ^{137}Cs at an anode blue sensitivity of 1,5 A/lmF	≈ 7%	notes 1, 7
Pulse amplitude resolution for ^{57}Co at an anode blue sensitivity of 1,5 A/lmF	≈ 9,2% ≈11,5%	notes 1, 7 notes 1, 17
Pulse amplitude resolution for ^{55}Fe at an anode blue sensitivity of 7,5 A/lmF	≈ 38%	notes 1, 8
Peak to valley ratio for ^{55}Fe at an anode blue sensitivity of 7,5 A/lmF	≈ 40	notes 1, 8
Mean anode sensitivity deviation		note 9
long term (16 h)	≈ 0,5%	
long term (30 days)	≈ 1%	
after change of count rate	≈ 0,8%	
versus temperature between 20 and 60 °C at 450 nm	≈ 0,1% per °C	
Anode pulse rise time at V_{ht} = 1500 V	≈ 10 ns	note 10
Anode pulse duration at half height at V_{ht} = 1500 V	≈ 20 ns	note 10
Signal transit time at V_{ht} = 1500 V	≈ 46 ns	note 10
Anode current linear within 2% at V_{ht} = 1500 V	up to ≈ 10 mA	note 11

LIMITING VALUES (absolute maximum rating system)

Supply voltage	max. 2000 V	note 12
Continuous anode current	max. 0,2 mA	note 13
Voltage between first dynode and photocathode	max. 500 V min. 150 V	note 14
Voltage between accelerating electrode and photocathode	max. 500 V	
Voltage between consecutive dynodes	max. 300 V	
Voltage between anode and final dynode	max. 300 V	note 15
Ambient temperature range		
operational (for short periods)	max. +80 °C min. −30 °C	note 16
continuous operation and storage	max. +50 °C min. −30 °C	

* Notes are given on page 4.

Notes

1. Blue sensitivity, expressed in μA/lmF, is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5K. Light is transmitted through a blue filter (Corning CS no. 5-58, polished to half stock thickness).
2. The bialkaline photocathode has a significant resistance which increases rapidly with reducing temperature. It is therefore recommended that it should not be exposed to light of too great an intensity; the cathode current should be limited, for example, to 1 nA at room temperature or 0,1 nA at −30 °C. If too high a photocurrent is passed, the cathode can no longer be considered an equipotential surface, and the focusing of electrons onto the first dynode will be affected, resulting in departure from linearity.
3. Luminous sensitivity is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5K.
4. Spectral sensitivity is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5K. Light is transmitted through an interferential filter. Spectral sensitivity at 400 nm, expressed in A/W, can be estimated by multiplying the blue sensitivity, expressed in A/lmF, by $7{,}7 \times 10^3$ for this type of tube.
5. Wherever possible, the power supply should be arranged so that the cathode is earthed and the anode is at +HT, however, it is sometimes necessary to supply the tube with the anode earthed and the cathode at −HT. Under these circumstances, erratic noise and dark current are generally increased and unstable, particularly after application of voltage. The glass envelope of the tube should be supported only by insulators with an insulation resistance of $> 10^{15}$ ohm.
6. Dark current is measured at ambient temperature, after the tube has been in darkness for approx. 1 min. Lower values can be obtained after a longer stabilization period in darkness (approx. 30 min).
7. Pulse amplitude resolution for ^{137}Cs and ^{57}Co is measured with an NaI(Tl) cylindrical scintillator (Quartz et Silice serial no. 4856 or equivalent) with a diameter of 50 mm and a height of 50 mm (2″ x 2″). The count rate used is $\approx 10^4$ c/s.
8. Pulse amplitude resolution for ^{55}Fe is measured with an NaI(Tl) cylindrical scintillator with a diameter of 25 mm and a height of 1 mm provided with a beryllium window. The count rate used is $\approx 2 \times 10^3$ c/s.
9. The mean anode sensitivity deviation is measured by coupling an NaI(Tl) scintillator to the window of the tube. Long term (16 h) deviation is measured by placing a ^{137}Cs source at a distance from the scintillator such that the count rate is $\approx 10^4$ c/s corresponding to an average anode current of ≈ 300 nA. Anode sensitivity deviation after change of count rate is measured with a ^{137}Cs source at a distance of the scintillator such that the count rate can be changed from 10^4 c/s to 10^3 c/s corresponding to an average anode current of ≈ 1 μA and ≈ 0,1 μA respectively. Both tests are carried out according to ANSI–N42–9–1972 of IEEE recommendations.
10. Measured with a pulsed light source, with a pulse duration (FWHM) of < 1 ns; the cathode being completely illuminated. The rise time is determined between 10% and 90% of the amplitude of the anode pulse. The signal transit time is measured between the instant at which the illuminating pulse at the cathode becomes maximum, and the instant at which the anode pulse attains its maximum. Rise time, pulse duration and transit time vary as a function of high tension supply voltage V_{ht}, approximately as $V_{ht}^{-1/2}$.
11. To obtain a peak pulse current greater than that obtainable with divider A, it is necessary to increase the inter-dynode voltage of the stages progressively. Other dividers can be conceived to achieve other compromises. It is generally recommended that the voltage difference between one stage and the next is less than a factor of 2.

(continued on page 6)

MECHANICAL DATA

Dimensions in mm

DEVELOPMENT SAMPLE DATA

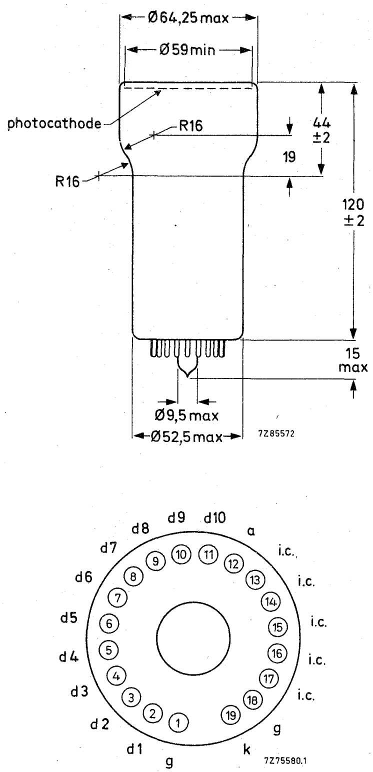


Fig. 2 PM2402.

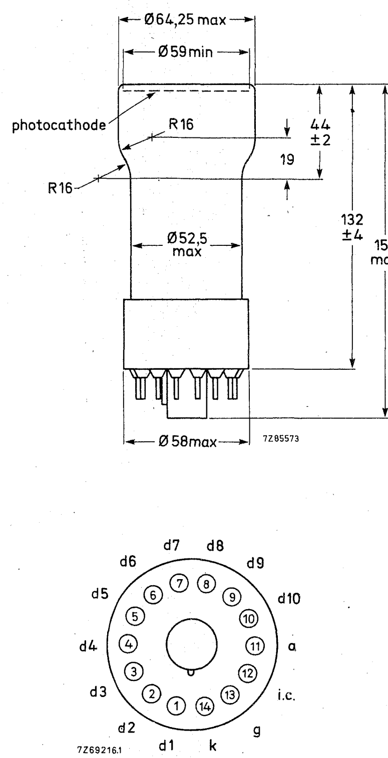


Fig. 3 PM2402B.

Base	19-pin all-glass
Net mass	150 g

Base	14-pin IEC67-1-16a (JEDEC B14-38)
Net mass	193 g

ACCESSORIES

Socket
- for PM2402 type FE2019
- for PM2402B type FE1014

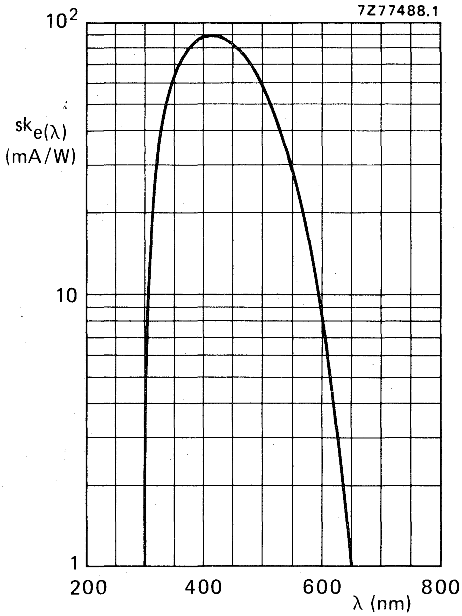


Fig. 4 Spectral sensitivity characteristic.

12. Total HT supply voltage, or the voltage at which the tube has an anode blue sensitivity of 40 A/lmF, whichever is lower.
13. A value of $< 10\ \mu A$ is recommended for applications requiring good stability.
14. Minimum value to obtain good collection in the input optics.
15. When calculating the anode voltage the voltage drop across the load resistor should be taken into account.
16. For type PM2402B this range of temperatures is limited principally by stresses in the sealing layer of the base to the glass bulb. Where low temperature operation is contemplated, the supplier should be consulted.
17. Pulse amplitude resolution is measured with an NaI(Tl) cylindrical scintillator (Quartz et Silice serial no. 4186 or equivalent) with a diameter of 76 mm and a height of 76 mm (3" x 3"). The count rate used is $\approx 10^4$ c/s.

DEVELOPMENT SAMPLE DATA

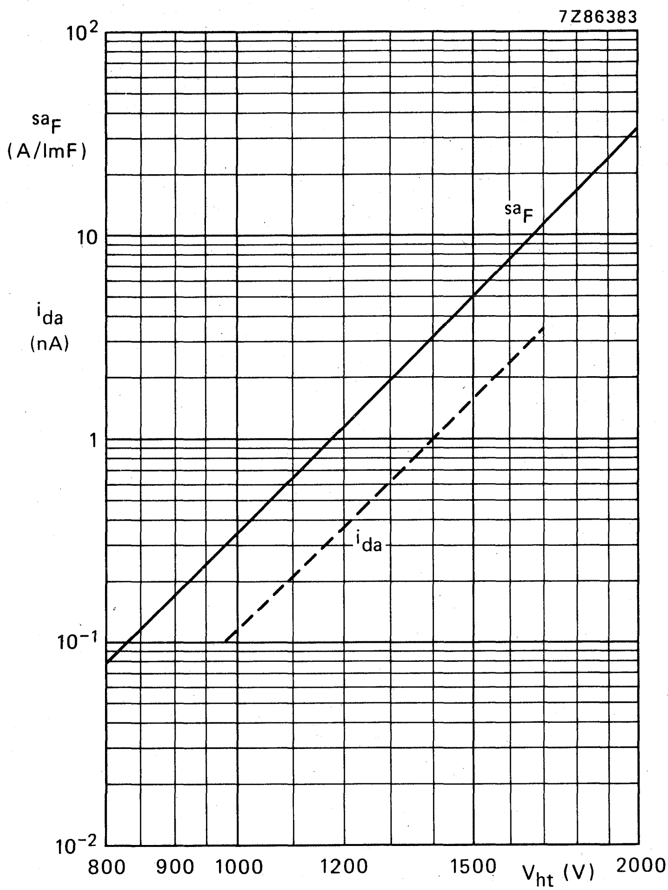


Fig. 5 Anode blue sensitivity sa_F, and anode dark current i_{da} as a function of supply voltage V_{ht}.

i_{da} is given as a dotted line to indicate its principle behaviour only.

PM2412 replaces XP2030UB
PM2412B replaces XP2030

10-STAGE VENETIAN BLIND PHOTOMULTIPLIER TUBES

- 70 mm useful diameter head-on type
- Flat window
- Semi-transparent bi-alkaline type D photocathode
- High cathode sensitivity; excellent collection from the entire cathode
- Very good pulse amplitude resolution
- Very low dark current
- Very good stability
- For scintillation detection applications, e.g. gamma cameras, high energy physics experiments

QUICK REFERENCE DATA*

Spectral sensitivity characteristic	type D	
Useful diameter of the photocathode	> 70 mm	
Cathode blue sensitivity	13 μA/lmF	note 1
Supply voltage		
for anode blue sensitivity = 1,5 A/lmF (note 1)	1250 V	
Anode dark current		
at anode blue sensitivity = 1,5 A/lmF (note 1)	0,5 nA	
Pulse amplitude resolution (^{57}Co)	≈ 10%	
Mean anode sensitivity deviation (30 days)	≈ 1%	

To be read in conjunction with *General Operational Recommendations Photomultiplier Tubes.*

GENERAL CHARACTERISTICS*

Window

Material	lime glass
Shape	plano-plano
Refractive index at 550 nm	1,52

Photocathode (note 2)

Semi-transparent, head-on		
Material	Sb K Cs	
Useful diameter	> 70 mm	
Spectral sensitivity characteristic (Fig. 4)	type D	
Maximum spectral sensitivity	400 ± 30 nm	
Luminous sensitivity	≈ 78 μA/lm	note 3
Blue sensitivity	typ. 13 μA/lmF > 10 μA/lmF	note 1
Spectral sensitivity at 400 nm	≈ 105 mA/W	note 4

* Notes are given on page 4.

Multiplier system

Number of stages	10
Dynode structure	venetian blind
Dynode material	CuBe
Capacitances	
anode to final dynode	≈ 7 pF
anode to all	≈ 8,5 pF

Magnetic field

When the photocathode is uniformly illuminated the anode current is halved (at V_{ht} = 1500 V) at a magnetic flux density of 0,3 mT perpendicular to the tube axis.

A mu-metal shield extending more than 15 mm beyond the cathode is recommended for magnetic screening.

RECOMMENDED CIRCUIT

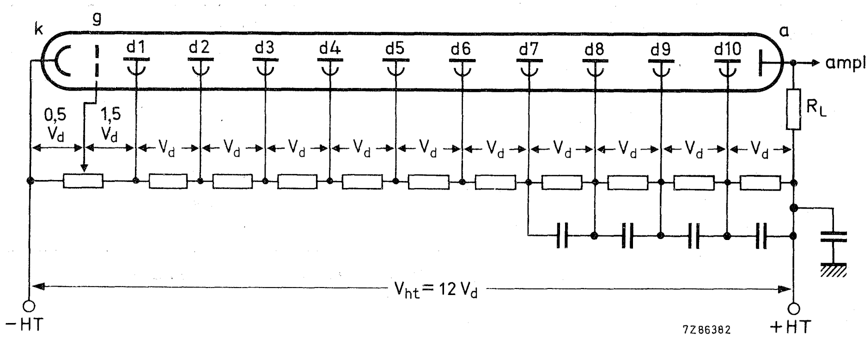


Fig. 1 Voltage divider A. Typical values of capacitors: 10 nF; k = cathode; g = accelerating electrode; d_n = dynode no.; a = anode; R_L = load resistor.

Note

For optimum pulse-amplitude resolution, the accelerating-electrode potential should be between the cathode and first dynode potentials. If the tube is used in a socket wired for an XP2030UB or XP2030 with the accelerating electrode connected to the first dynode, the pulse amplitude resolution for ^{57}Co is about 10,2%.

DEVELOPMENT SAMPLE DATA

TYPICAL CHARACTERISTICS*

With voltage divider A (Fig. 1) — note 5

Supply voltage for an anode blue sensitivity of 1,5 A/lmF (Fig. 5)	< 1450 V typ. 1250 V	note 1
Anode radiant sensitivity at 400 nm and V_{ht} = 1250 V	≈ 12 kA/W	
Gain at V_{ht} = 1250 V	≈ $1,2 \times 10^5$	
Anode dark current at an anode blue sensitivity of 1,5 A/lmF (Fig. 5)	< 5 nA typ. 0,5 nA	notes 1, 6
Pulse amplitude resolution for ^{137}Cs at an anode blue sensitivity of 1,5 A/lmF	≈ 7%	notes 1, 7
Pulse amplitude resolution for ^{57}Co at an anode blue sensitivity of 1,5 A/lmF	≈ 10%	notes 1, 7
Pulse amplitude resolution for ^{55}Fe at an anode blue sensitivity of 7,5 A/lmF	≈ 38%	notes 1, 8
Peak to valley ratio for ^{55}Fe at an anode blue sensitivity of 7,5 A/lmF	≈ 40	notes 1, 8
Mean anode sensitivity deviation		note 9
long term (16 h)	≈ 0,5%	
long term (30 days)	≈ 1%	
after change of count rate	≈ 0,8%	
versus temperature between 20 and 60 °C at 450 nm	≈ 0,1% per °C	
Anode pulse rise time at V_{ht} = 1500 V	≈ 11 ns	note 10
Anode pulse duration at half height at V_{ht} = 1500 V	≈ 22 ns	note 10
Signal transit time at V_{ht} = 1500 V	≈ 54 ns	note 10
Anode current linear within 2% at V_{ht} = 1500 V	up to ≈ 10 mA	note 11

LIMITING VALUES (absolute maximum rating system)

Supply voltage	max. 2000 V	note 12
Continuous anode current	max. 0,2 mA	note 13
Voltage between first dynode and photocathode	max. 500 V min. 150 V	note 14
Voltage between accelerating electrode and photocathode	max. 500 V	
Voltage between consecutive dynodes	max. 300 V	
Voltage between anode and final dynode	max. 300 V	note 15
Ambient temperature range operational (for short periods)	max. +80 °C min. −30 °C	note 16
continuous operation and storage	max. +50 °C min. −30 °C	

* Notes are given on page 4.

Notes

1. Blue sensitivity, expressed in µA/lmF, is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5K. Light is transmitted through a blue filter (Corning CS No. 5-58, polished to half stock thickness).
2. The bialkaline photocathode has a significant resistance which increases rapidly with reducing temperature. It is therefore recommended that it should not be exposed to light of too great an intensity; the cathode current should be limited, for example, to 1 nA at room temperature or 0,1 nA at –30 °C. If too high a photocurrent is passed, the cathode can no longer be considered an equipotential surface, and the focusing of electrons onto the first dynode will be affected, resulting in departure from linearity.
3. Luminous sensitivity is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5K.
4. Spectral sensitivity is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5K. Light is transmitted through an interferential filter. Spectral sensitivity at 400 nm, expressed in A/W, can be estimated by multiplying the blue sensitivity, expressed in A/lmF, by $7{,}7 \times 10^3$ for this type of tube.
5. Wherever possible, the power supply should be arranged so that the cathode is earthed and the anode is at + HT, however, it is sometimes necessary to supply the tube with the anode earthed and the cathode at –HT. Under these circumstances, erratic noise and dark current generally increased and unstable, particularly after application of voltage. The glass envelope of the tube should be supported only by insulators with an insulation resistance of $> 10^{15}$ ohm.
6. Dark current is measured at ambient temperature, after the tube has been in darkness for approx. 1 min. Lower values can be obtained after a longer stabilization period in darkness (approx. 30 min).
7. Pulse amplitude resolution for ^{137}Cs and ^{57}Co is measured with an NaI(Tl) cylindrical scintillator (Quartz et Silice serial no. 4186 or equivalent) with a diameter of 76 mm and a height of 76 mm (3" x 3"). The count rate used is $\approx 10^4$ c/s.
8. Pulse amplitude resolution for ^{55}Fe is measured with an NaI(Tl) cylindrical scintillator with a diameter of 25 mm and a height of 1 mm provided with a beryllium window. The count rate used is $\approx 2 \times 10^3$ c/s.
9. The mean anode sensitivity deviation is measured by coupling an NaI(Tl) scintillator to the window of the tube. Long term (16 h) deviation is measured by placing a ^{137}Cs source at a distance from the scintillator such that the count rate is $\approx 10^4$ c/s corresponding to an average anode current of $\approx$ 300 nA. Anode sensitivity deviation after change of count rate is measured with a ^{137}Cs source at a distance of the scintillator such that the count rate can be changed from 10^4 c/s to 10^3 c/s corresponding to an average anode current of $\approx$ 1 µA and $\approx$ 0,1 µA respectively. Both tests are carried out according to ANSI–N42–9–1972 of IEEE recommendations.
10. Measured with a pulsed light source, with a pulse duration (FWHM) of $<$ 1 ns; the cathode being completely illuminated. The rise time is determined between 10% and 90% of the amplitude of the anode pulse. The signal transit time is measured between the instant at which the illuminating pulse at the cathode becomes maximum, and the instant at which the anode pulse attains its maximum. Rise time, pulse duration and transit time vary as a function of high tension supply voltage V_{ht}, approximately as $V_{ht}^{-1/2}$.
11. To obtain a peak pulse current greater than that obtainable with divider A, it is necessary to increase the inter-dynode voltage of the stages progressively. Other dividers can be conceived to achieve other compromises. It is generally recommended that the voltage difference between one stage and the next is less than a factor of 2.

(continued on page 6)

DEVELOPMENT SAMPLE DATA

MECHANICAL DATA

Dimensions in mm

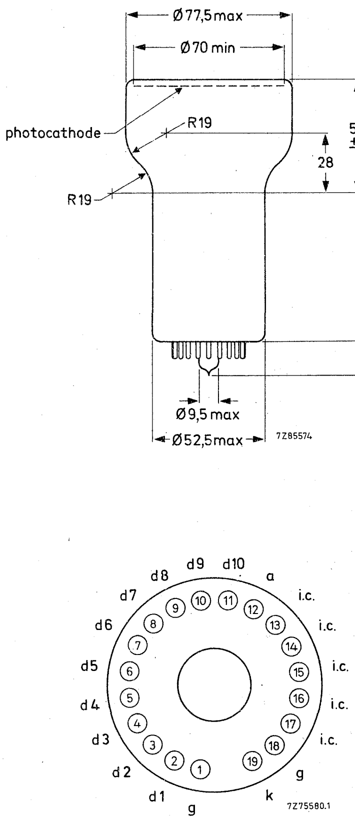


Fig. 2 PM2412.

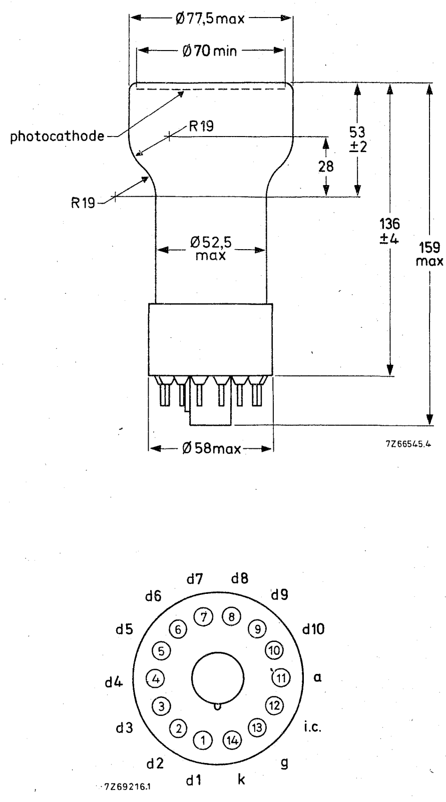


Fig. 3 PM2412B.

Base	19-pin all-glass	Base	14-pin IEC67-1-16a (JEDEC B14-38)
Net mass	163 g	Net mass	206 g

ACCESSORIES

Socket
- for PM2412 type FE2019
- for PM2412B type FE1014

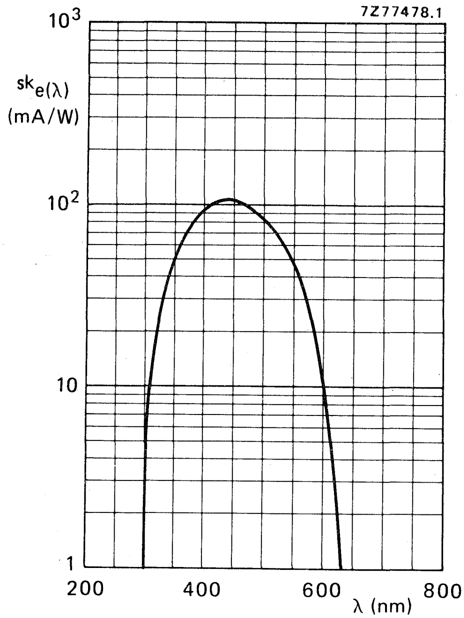


Fig. 4 Spectral sensitivity characteristic.

Notes (continued)

12. Total HT supply voltage, or the voltage at which the tube has an anode blue sensitivity of 40 A/lmF, whichever is lower.
13. A value of $< 10\ \mu A$ is recommended for applications requiring good stability.
14. Minimum value to obtain good collection in the input optics.
15. When calculating the anode voltage the voltage drop across the load resistor should be taken into account.
16. For type PM2412B this range of temperatures is limited principally by stresses in the sealing layer of the base to the glass bulb. Where low temperature operation is contemplated, the supplier should be consulted.

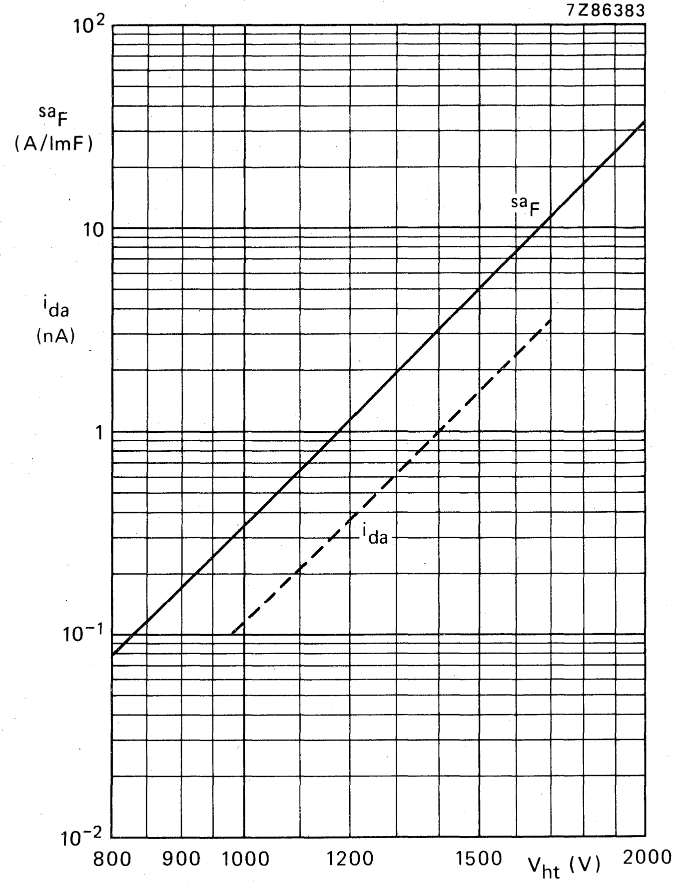


Fig. 5 Anode blue sensitivity sa_F, and anode dark current i_{da} as a function of supply voltage V_{ht}.
i_{da} is given as a dotted line to indicate its principle behaviour only.

DEVELOPMENT SAMPLE DATA

10-STAGE VENETIAN BLIND PHOTOMULTIPLIER TUBES

- Hexagonal head-on type; useful size 56 mm across flats
- Flat window
- Semi-transparent bi-alkaline type D photocathode
- High cathode sensitivity; excellent collection from the entire cathode
- Very good pulse amplitude resolution
- Very low dark current
- Very good stability
- For nuclear medicine applications, e.g. gamma cameras

QUICK REFERENCE DATA *

Spectral sensitivity characteristic	type D	
Useful size of the photocathode	> 56 mm across flats	
Cathode blue sensitivity	12 μA/lmF	note 1
Supply voltage for anode blue sensitivity = 1,5 A/lmF (note 1)	1250 V	
Anode dark current at anode blue sensitivity = 1,5 A/lmF (note 1)	0,5 nA	
Pulse amplitude resolution (^{57}Co)	≈ 9,2%	
Mean anode sensitivity deviation (30 days)	≈ 1%	

To be read in conjunction with *General Operational Recommendations Photomultiplier Tubes.*

GENERAL CHARACTERISTICS *

Window

Material	lime glass
Shape	hexagonal, plano-plano
Refractive index at 550 nm	1,52

Photocathode (note 2)

Semi-transparent, head-on		
Material	Sb K Cs	
Useful size	> 56 mm across flats	
Spectral sensitivity characteristic (Fig. 4)	type D	
Maximum spectral sensitivity	400 ± 30 nm	
Luminous sensitivity	≈ 72 μA/lm	note 3
Blue sensitivity	typ. 12 μA/lmF > 9,0 μA/lmF	note 1
Spectral sensitivity at 400 nm	≈ 90 mA/W	note 4

* Notes are given on page 4.

Multiplier system

Number of stages	10
Dynode structure	venetian blind
Dynode material	CuBe
Capacitances	
anode to final dynode	≈ 7 pF
anode to all	≈ 8,5 pF

Magnetic field

When the photocathode is uniformly illuminated the anode current is halved (at V_{ht} = 1500 V) at a magnetic flux density of 0,35 mT perpendicular to the tube axis.

A mu-metal shield extending more than 15 mm beyond the cathode is recommended for magnetic screening.

RECOMMENDED CIRCUIT

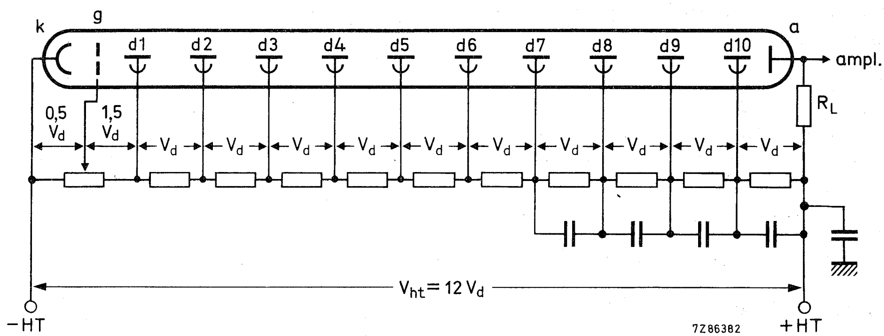


Fig. 1 Voltage divider A. Typical values of capacitors: 10 nF; k = cathode; g = accelerating electrode; d_n = dynode no.; a = anode; R_L = load resistor.

Note

For optimum pulse-amplitude resolution, the accelerating-electrode potential should be between the cathode and first dynode potentials. If the accelerating electrode is connected to the first dynode, the pulse-amplitude resolution for ^{57}Co is about 9,4%.

DEVELOPMENT SAMPLE DATA

TYPICAL CHARACTERISTICS *

With voltage divider A (Fig. 1)		note 5
Supply voltage for an anode blue sensitivity of 1,5 A/lmF (Fig. 5)	$<$ 1450 V typ. 1250 V	note 1
Anode radiant sensitivity at 400 nm and V_{ht} = 1250 V	≈ 11 kA/W	
Gain at V_{ht} = 1250 V	≈ 1,3 x 10^5	
Anode dark current at an anode blue sensitivity of 1,5 A/lmF (Fig. 5)	$<$ 5 nA typ. 0,5 nA	notes 1, 6
Pulse amplitude resolution for ^{137}Cs at an anode blue sensitivity of 1,5 A/lmF	≈ 7%	notes 1, 7
Pulse amplitude resolution for ^{57}Co at an anode blue sensitivity of 1,5 A/lmF	≈ 9,2% ≈ 11,5%	notes 1, 7 notes 1, 17
Pulse amplitude resolution for ^{55}Fe at an anode blue sensitivity of 7,5 A/lmF	≈ 38%	notes 1, 8
Peak to valley ratio for ^{55}Fe at an anode blue sensitivity of 7,5 A/lmF	≈ 40	notes 1, 8
Mean anode sensitivity deviation		note 9
long term (16 h)	≈ 0,5%	
long term (30 days)	≈ 1%	
after change of count rate	≈ 0,8%	
versus temperature between 20 and 60 °C at 450 nm	≈ 0,1% per °C	
Anode pulse rise time at V_{ht} = 1500 V	≈ 10 ns	note 10
Anode pulse duration at half height at V_{ht} = 1500 V	≈ 20 ns	note 10
Signal transit time at V_{ht} = 1500 V	≈ 46 ns	note 10
Anode current linear within 2% at V_{ht} = 1500 V	up to ≈ 10 mA	note 11

LIMITING VALUES (absolute maximum rating system)

Supply voltage	max. 2000 V	note 12
Continuous anode current	max. 0,2 mA	note 13
Voltage between first dynode and photocathode	max. 500 V min. 150 V	note 14
Voltage between accelerating electrode and photocathode	max. 500 V	
Voltage between consecutive dynodes	max. 300 V	
Voltage between anode and final dynode	max. 300 V	note 15
Ambient temperature range		
operational (for short periods)	max. +80 °C min. −30 °C	note 16
continuous operation and storage	max. +50 °C min. −30 °C	

* Notes are given on page 4.

Notes

1. Blue sensitivity, expressed in µA/lmF, is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5K. Light is transmitted through a blue filter (Corning CS no. 5-58, polished to half stock thickness).
2. The bialkaline photocathode has a significant resistance which increases rapidly with reducing temperature. It is therefore recommended that it should not be exposed to light of too great an intensity; the cathode current should be limited, for example, to 1 nA at room temperature or 0,1 nA at −30 °C. If too high a photocurrent is passed, the cathode can no longer be considered an equipotential surface, and the focusing of electrons onto the first dynode will be affected, resulting in departure from linearity.
3. Luminous sensitivity is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5K.
4. Spectral sensitivity is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5K. Light is transmitted through an interferential filter. Spectral sensitivity at 400 nm, expressed in A/W, can be estimated by multiplying the blue sensitivity, expressed in A/lmF, by $7{,}7 \times 10^3$ for this type of tube.
5. Wherever possible, the power supply should be arranged so that the cathode is earthed and the anode is at +HT, however, it is sometimes necessary to supply the tube with the anode earthed and the cathode at −HT. Under these circumstances, erratic noise and dark current are generally increased and unstable, particularly after application of voltage. The glass envelope of the tube should be supported only by insulators with an insulation resistance of $> 10^{15}$ ohm.
6. Dark current is measured at ambient temperature, after the tube has been in darkness for approx. 1 min. Lower values can be obtained after a longer stabilization period in darkness (approx. 30 min).
7. Pulse amplitude resolution for ^{137}Cs and ^{57}Co is measured with an NaI(Tl) cylindrical scintillator (Quartz et Silice serial no. 4856 or equivalent) with a diameter of 50 mm and a height of 50 mm (2″ x 2″). The count rate used is $\approx 10^4$ c/s.
8. Pulse amplitude resolution for ^{55}Fe is measured with an NaI(Tl) cylindrical scintillator with a diameter of 25 mm and a height of 1 mm provided with a beryllium window. The count rate used is $\approx 2 \times 10^3$ c/s.
9. The mean anode sensitivity deviation is measured by coupling an NaI(Tl) scintillator to the window of the tube. Long term (16 h) deviation is measured by placing a ^{137}Cs source at a distance from the scintillator such that the count rate is $\approx 10^4$ c/s corresponding to an average anode current of ≈ 300 nA. Anode sensitivity deviation after change of count rate is measured with a ^{137}Cs source at a distance of the scintillator such that the count rate can be changed from 10^4 c/s to 10^3 c/s corresponding to an average anode current of ≈ 1 µA and ≈ 0,1 µA respectively. Both tests are carried out according to ANSI−N42−9−1972 of IEEE recommendations.
10. Measured with a pulsed light source, with a pulse duration (FWHM) of < 1 ns; the cathode being completely illuminated. The rise time is determined between 10% and 90% of the amplitude of the anode pulse. The signal transit time is measured between the instant at which the illuminating pulse at the cathode becomes maximum, and the instant at which the anode pulse attains its maximum. Rise time, pulse duration and transit time vary as a function of high tension supply voltage V_{ht}, approximately as $V_{ht}^{-1/2}$.
11. To obtain a peak pulse current greater than that obtainable with divider A, it is necessary to increase the inter-dynode voltage of the stages progressively. Other dividers can be conceived to achieve other compromises. It is generally recommended that the voltage difference between one stage and the next is less than a factor of 2.

(continued on page 6)

DEVELOPMENT SAMPLE DATA

MECHANICAL DATA

Dimensions in mm

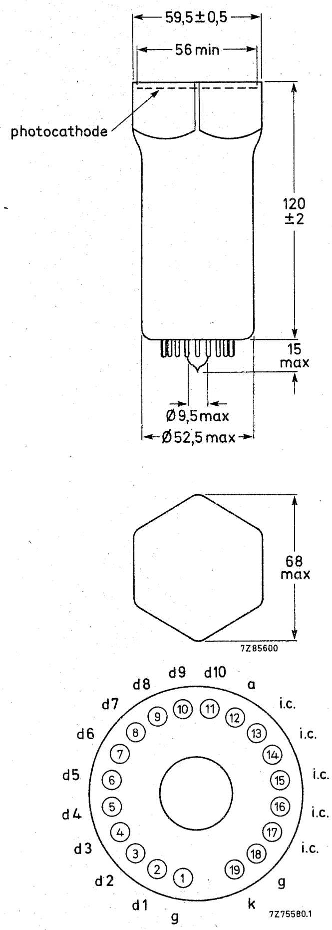


Fig. 2 PM2422

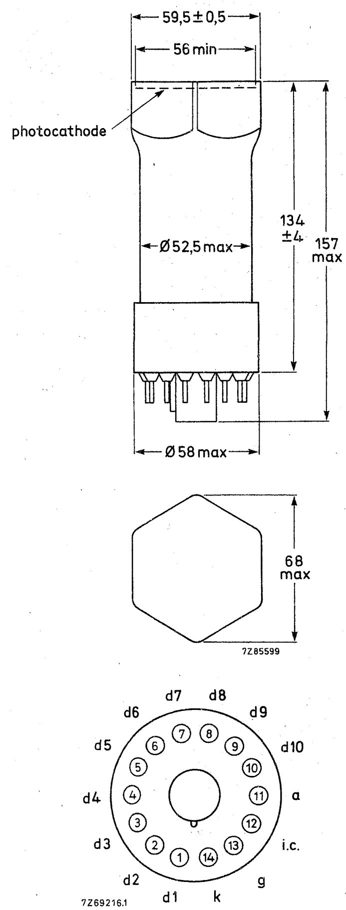


Fig. 3 PM2422B

Base	19-pin all-glass
Net mass	148 g

Base	14-pin IEC67-1-16a (JEDEC B14-38)
Net mass	191 g

ACCESSORIES

Socket
- for PM2422 type FE2019
- for PM2422B type FE1014

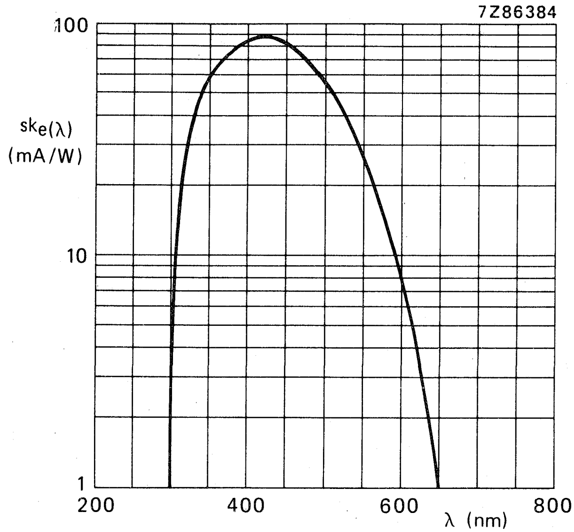


Fig. 4 Spectral sensitivity characteristic.

12. Total HT supply voltage, or the voltage at which the tube has an anode blue sensitivity of 40 A/lmF, whichever is lower.
13. A value of $< 10\ \mu A$ is recommended for applications requiring good stability.
14. Minimum value to obtain good collection in the input optics.
15. When calculating the anode voltage the voltage drop across the load resistor should be taken into account.
16. For type PM2422B this range of temperatures is limited principally by stresses in the sealing layer of the base to the glass bulb. Where low temperature operation is contemplated, the supplier should be consulted.
17. Pulse amplitude resolution is measured with an NaI(Tl) cylindrical scintillator (Quartz et Silice serial no. 4186 or equivalent) with a diameter of 76 mm and a height of 76 mm (3" x 3"). The count rate used is $\approx 10^4$ c/s.

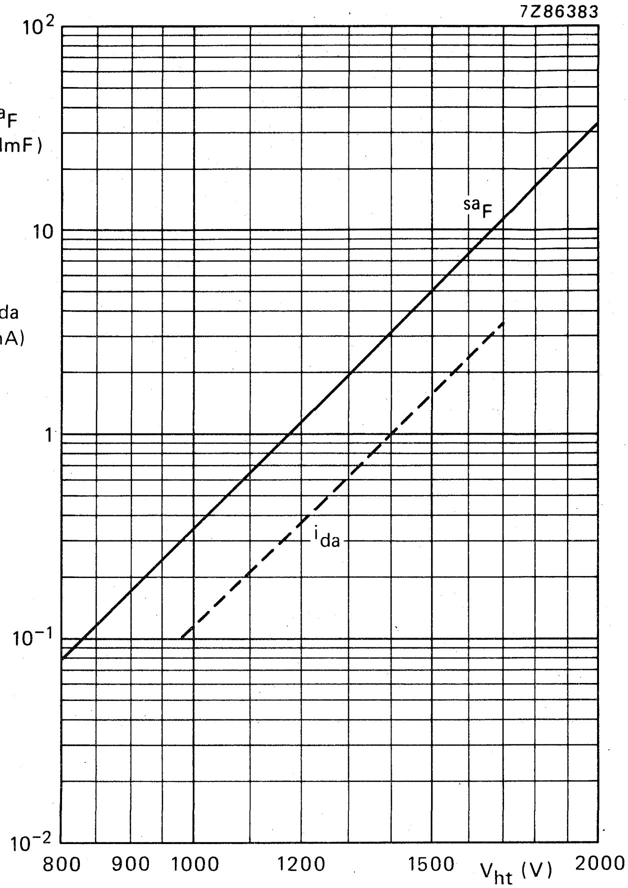


Fig. 5 Anode spectral sensitivity sa_F, and anode dark current i_{da} as a function of supply voltage V_{ht}.

i_{da} is given as a dotted line to indicate its principle behaviour only.

DEVELOPMENT SAMPLE DATA

10-STAGE VENETIAN BLIND PHOTOMULTIPLIER TUBES

- 56 mm useful diameter head-on type
- Flat window
- Semi-transparent bi-alkaline type D photocathode
- High cathode sensitivity; excellent collection from the entire cathode
- Very good pulse amplitude resolution
- Very low dark current
- Very good stability
- For nuclear medicine applications, e.g. gamma cameras

QUICK REFERENCE DATA *

Spectral sensitivity characteristic	type D	
Useful diameter of the photocathode	> 56 mm	
Cathode blue sensitivity	12 μA/lmF	note 1
Supply voltage for anode blue sensitivity = 1,5 A/lmF (note 1)	1250 V	
Anode dark current at anode blue sensitivity = 1,5 A/lmF (note 1)	0,5 nA	
Pulse amplitude resolution (^{57}Co)	≈ 9,2%	
Mean anode sensitivity deviation (30 days)	≈ 1%	

To be read in conjunction with *General Operational Recommendations Photomultiplier Tubes.*

GENERAL CHARACTERISTICS *

Window

Material	lime glass	
Shape	plano-plano	
Refractive index at 550 nm	1,52	

Photocathode (note 2)

Semi-transparent, head-on		
Material	Sb K Cs	
Useful diameter	> 56 mm	
Spectral sensitivity characteristic (Fig. 4)	type D	
Maximum spectral sensitivity	400 ± 30 nm	
Luminous sensitivity	≈ 72 μA/lm	note 3
Blue sensitivity	typ. 12 μA/lmF > 9,0 μA/lmF	note 1
Spectral sensitivity at 400 nm	≈ 90 mA/W	note 4

* Notes are given on page 4.

Multiplier system

Number of stages	10
Dynode structure	venetian blind
Dynode material	CuBe
Capacitances	
anode to final dynode	≈ 7 pF
anode to all	≈ 8,5 pF

Magnetic field

When the photocathode is uniformly illuminated the anode current is halved (at V_{ht} = 1500 V) at a magnetic flux density of 0,35 mT perpendicular to the tube axis.

A mu-metal shield extending more than 15 mm beyond the cathode is recommended for magnetic screening.

RECOMMENDED CIRCUIT

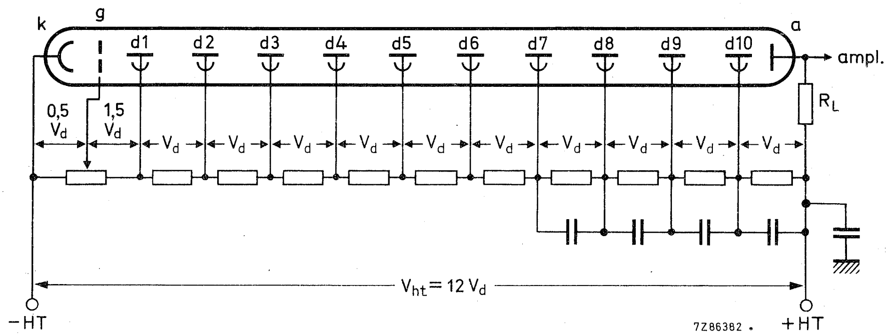


Fig. 1 Voltage divider A. Typical values of capacitors: 10 nF; k = cathode; g = accelerating electrode; d_n = dynode no.; a = anode; R_L = load resistor.

Note

For optimum pulse amplitude resolution, the accelerating-electrode potential should be between the cathode and first dynode potentials. If the accelerating electrode is connected to the first dynode, the pulse amplitude resolution for ^{57}Co is about 9,4%.

TYPICAL CHARACTERISTICS *

With voltage divider A (Fig. 1)		note 5
Supply voltage for an anode blue sensitivity of 1,5 A/lmF (Fig.5)	< 1450 V typ. 1250 V	note 1
Anode radiant sensitivity at 400 nm and V_{ht} = 1250 V	≈ 12 kA/W	
Gain at V_{ht} = 1250 V	≈ 1,3 x 10^5	
Anode dark current at an anode blue sensitivity of 1,5 A/lmF (Fig. 5)	< 5 nA typ. 0,5 nA	notes 1, 6
Pulse amplitude resolution for ^{137}Cs at an anode blue sensitivity of 1,5 A/lmF	≈ 7%	notes 1, 7
Pulse amplitude resolution for ^{57}Co at an anode blue sensitivity of 1,5 A/lmF	≈ 9,2%	notes 1, 7
Pulse amplitude resolution for ^{55}Fe at an anode blue sensitivity of 7,5 A/lmF	≈ 38%	notes 1, 8
Peak to valley ratio for ^{55}Fe at an anode blue sensitivity of 7,5 A/lmF	≈ 40	notes 1,8
Mean anode sensitivity deviation		note 9
long term (16 h)	≈ 0,5%	
long term (30 days)	≈ 1%	
after change of count rate	≈ 0,8%	
versus temperature between 20 and 60 °C at 450 nm	≈ 0,1% per °C	
Anode pulse rise time at V_{ht} = 1500 V	≈ 10 ns	note 10
Anode pulse duration at half height at V_{ht} = 1500 V	≈ 20 ns	note 10
Signal transit time at V_{ht} = 1500 V	≈ 46 ns	note 10
Anode current linear within 2% at V_{ht} = 1500 V	up to ≈ 10 mA	note 11

LIMITING VALUES (absolute maximum rating system)

Supply voltage	max. 2000 V	note 12
Continuous anode current	max. 0,2 mA	note 13
Voltage between first dynode and photocathode	max. 500 V min. 150 V	note 14
Voltage between accelerating electrode and photocathode	max. 500 V	
Voltage between consecutive dynodes	max. 300 V	
Voltage between anode and final dynode	max. 300 V	note 15
Ambient temperature range		
operational (for short periods)	max. +80 °C min. −30 °C	note 16
continuous operation and storage	max. +50 °C min. −30 °C	

DEVELOPMENT SAMPLE DATA

* Notes are given on page 4.

Notes

1. Blue sensitivity, expressed in µA/lmF, is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5K. Light is transmitted through a blue filter (Corning CS no. 5-58, polished to half stock thickness).
2. The bialkaline photocathode has a significant resistance which increases rapidly with reducing temperature. It is therefore recommended that it should not be exposed to light of too great an intensity; the cathode current should be limited, for example, to 1 nA at room temperature or 0,1 nA at −30 °C. If too high a photocurrent is passed, the cathode can no longer be considered an equipotential surface, and the focusing of electrons onto the first dynode will be affected, resulting in departure from linearity.
3. Luminous sensitivity is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5K.
4. Spectral sensitivity is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5K. Light is transmitted through an interferential filter. Spectral sensitivity at 400 nm, expressed in A/W, can be estimated by multiplying the blue sensitivity, expressed in A/lmF, by $7{,}7 \times 10^3$ for this type of tube.
5. Wherever possible, the power supply should be arranged so that the cathode is earthed and the anode is at +HT, however, it is sometimes necessary to supply the tube with the anode earthed and the cathode at −HT. Under these circumstances, erratic noise and dark current are generally increased and unstable, particularly after application of voltage. The glass envelope of the tube should be supported only by insulators with an insulation resistance of $> 10^{15}$ ohm.
6. Dark current is measured at ambient temperature, after the tube has been in darkness for approx. 1 min. Lower values can be obtained after a longer stabilization period in darkness (approx. 30 min).
7. Pulse amplitude resolution for ^{137} Cs and ^{57} Co is measured with an NaI(Tl) cylindrical scintillator (Quartz et Silice serial no. 4856 or equivalent) with a diameter of 50 mm and a height of 50 mm (2" x 2"). The count rate used is $\approx 10^4$ c/s.
8. Pulse amplitude resolution for ^{55}Fe is measured with an NaI(Tl) cylindrical scintillator with a diameter of 25 mm and a height of 1 mm provided with a beryllium window. The count rate used is $\approx 2 \times 10^3$ c/s.
9. The mean anode sensitivity deviation is measured by coupling an NaI(Tl) scintillator to the window of the tube. Long term (16 h) deviation is measured by placing a ^{137} Cs source at a distance from the scintillator such that the count rate is $\approx 10^4$ c/s corresponding to an average anode current of ≈ 300 nA. Anode sensitivity deviation after change of count rate is measured with a ^{137} Cs source at a distance of the scintillator such that the count rate can be changed from 10^4 c/s to 10^3 c/s corresponding to an average anode current of ≈ 1 µA and ≈ 0,1 µA respectively. Both tests are carried out according to ANSI−N42−9−1972 of IEEE recommendations.
10. Measured with a pulsed light source, with a pulse duration (FWHM) of < 1 ns; the cathode being completely illuminated. The rise time is determined between 10% and 90% of the amplitude of the anode pulse. The signal transit time is measured between the instant at which the illuminating pulse at the cathode becomes maximum, and the instant at which the anode pulse attains its maximum. Rise time, pulse duration and transit time vary as a function of high tension supply voltage V_{ht}, approximately as $V_{ht}^{-1/2}$.
11. To obtain a peak pulse current greater than that obtainable with divider A, it is necessary to increase the inter-dynode voltage of the stages progressively. Other dividers can be conceived to achieve other compromises. It is generally recommended that the voltage difference between one stage and the next is less than a factor of 2.

(continued on page 6)

MECHANICAL DATA

Dimensions in mm

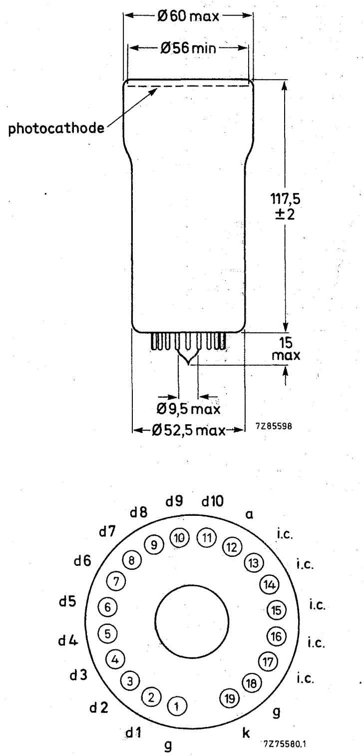


Fig. 2 PM2432.

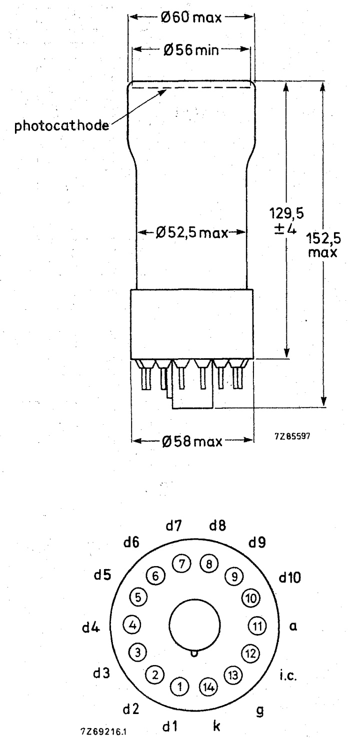


Fig. 3 PM2432B.

Base	19-pin all-glass
Net mass	146 g

Base	14-pin IEC67-1-16a (JEDEC B14-38)
Net mass	189 g

ACCESSORIES

Socket
- for PM2432 type FE2019
- for PM2432B type FE1014

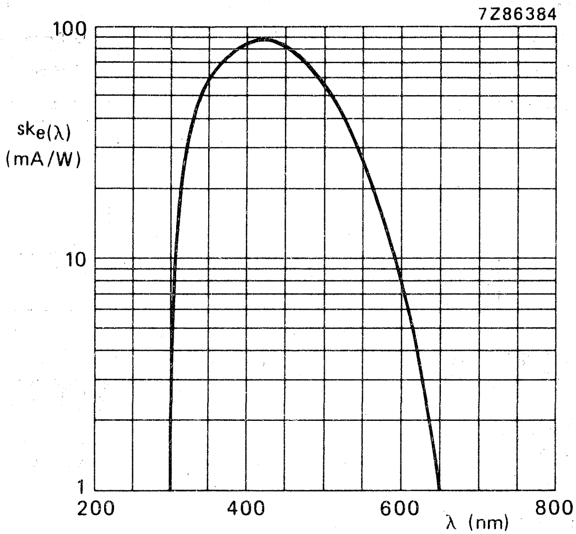


Fig. 4 Spectral sensitivity characteristic.

12. Total HT supply voltage, or the voltage at which the tube has an anode blue sensitivity of 40 A/lm whichever is lower.
13. A value of < 10 μA is recommended for applications requiring good stability.
14. Minimum value to obtain good collection in the input optics.
15. When calculating the anode voltage the voltage drop across the load resistor should be taken into account.
16. For type PM2432B this range of temperatures is limited principally by stresses in the sealing layer of the base to the glass bulb. Where low temperature operation is contemplated, the supplier should be consulted.

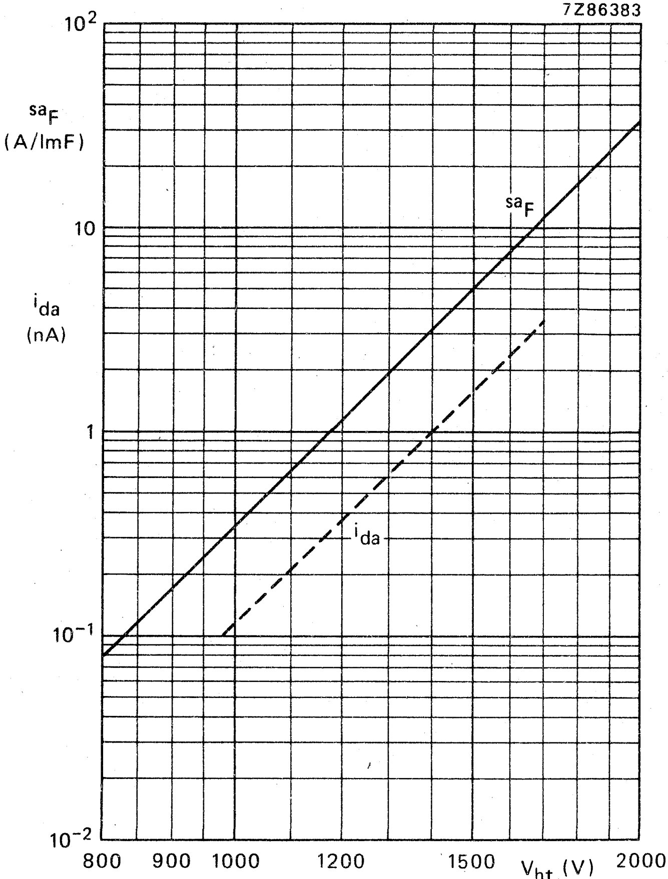


Fig. 5 Anode spectral sensitivity sa_F, and anode dark current i_{da} as a function of supply voltage V_{ht}.

i_{da} is given as a dotted line to indicate its principle behaviour only.

DEVELOPMENT SAMPLE DATA

10-STAGE VENETIAN BLIND PHOTOMULTIPLIER TUBES

- Hexagonal head-on type; useful size 70 mm across flats
- Flat window
- Semi-transparent bi-alkaline type D photocathode
- High cathode sensitivity; excellent collection from the entire cathode
- Very good pulse amplitude resolution
- Very low dark current
- Very good stability
- For nuclear medicine applications, e.g. gamma cameras

QUICK REFERENCE DATA*

Spectral sensitivity characteristic	type D	
Useful size of the photocathode	> 70 mm across flats	
Cathode blue sensitivity	13 μA/lmF	note 1
Supply voltage for anode blue sensitivity = 1,5 A/lmF (note 1)	1250 V	
Anode dark current at anode blue sensitivity = 1,5 A/lmF (note 1)	0,5 nA	
Pulse amplitude resolution (^{57}Co)	≈ 10%	
Mean anode sensitivity deviation (30 days)	≈ 1%	

To be read in conjunction with *General Operational Recommendations Photomultiplier Tubes.*

GENERAL CHARACTERISTICS*

Window

Material	lime glass
Shape	hexagonal, plano-plano
Refractive index at 550 nm	1,52

Photocathode (note 2)

Semi-transparent, head-on		
Material	Sb K Cs	
Useful size	> 70 mm across flats	
Spectral sensitivity characteristic (Fig. 4)	type D	
Maximum spectral sensitivity	400 ± 30 nm	
Luminous sensitivity	≈ 78 μA/lm	note 3
Blue sensitivity	typ. 13 μA/lmF > 10 μA/lmF	note 1
Spectral sensitivity at 400 nm	≈ 105 mA/W	note 4

* Notes are given on page 4.

Multiplier system

Number of stages	10
Dynode structure	venetian blind
Dynode material	CuBe
Capacitances	
anode to final dynode	≈ 7 pF
anode to all	≈ 8,5 pF

Magnetic field

When the photocathode is uniformly illuminated the anode current is halved (at V_{ht} = 1500 V) at a magnetic flux density of 0,3 mT perpendicular to the tube axis.

A mu-metal shield extending more than 15 mm beyond the cathode is recommended for magnetic screening.

RECOMMENDED CIRCUIT

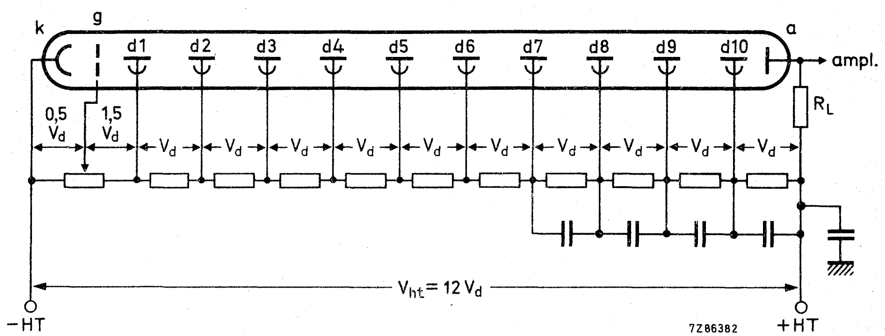


Fig. 1 Voltage divider A. Typical values of capacitors: 10 nF; k = cathode; g = accelerating electrode; d_n = dynode no.; a = anode; R_L = load resistor.

Note

For optimum pulse amplitude resolution, the accelerating-electrode potential should be between the cathode and first dynode potentials. If the accelerating electrode is connected to the first dynode, the pulse amplitude resolution for ^{57}Co is about 10,2%.

DEVELOPMENT SAMPLE DATA

TYPICAL CHARACTERISTICS*

With voltage divider A (Fig. 1) — note 5

Supply voltage for an anode blue sensitivity of 1,5 A/lmF (Fig. 5)	< 1450 V typ. 1250 V	note 1
Anode radiant sensitivity at 400 nm and V_{ht} = 1250 V	≈ 12 kA/W	
Gain at V_{ht} = 1250 V	≈ 1,2 x 10^5	
Anode dark current at an anode blue sensitivity of 1,5 A/lmF (Fig. 5)	< 5 nA typ. 0,5 nA	notes 1, 6
Pulse amplitude resolution for ^{137}Cs at an anode blue sensitivity of 1,5 A/lmF	≈ 7%	notes 1, 7
Pulse amplitude resolution for ^{57}Co at an anode blue sensitivity of 1,5 A/lmF	≈ 10%	notes 1, 7
Pulse amplitude resolution for ^{55}Fe at an anode blue sensitivity of 7,5 A/lmF	≈ 38%	notes 1, 8
Peak to valley ratio for ^{55}Fe at an anode blue sensitivity of 7,5 A/lmF	≈ 40	notes 1, 8
Mean anode sensitivity deviation		note 9
long term (16 h)	≈ 0,5%	
long term (30 days)	≈ 1%	
after change of count rate	≈ 0,8%	
versus temperature between 20 and 60 °C at 450 nm	≈ 0,1% per °C	
Anode pulse rise time at V_{ht} = 1500 V	≈ 11 ns	note 10
Anode pulse duration at half height at V_{ht} = 1500 V	≈ 22 ns	note 10
Signal transit time at V_{ht} = 1500 V	≈ 54 ns	note 10
Anode current linear within 2% at V_{ht} = 1500 V	up to ≈ 10 mA	note 11

LIMITING VALUES (absolute maximum rating system)

Supply voltage	max. 2000 V	note 12
Continuous anode current	max. 0,2 mA	note 13
Voltage between first dynode and photocathode	max. 500 V min. 150 V	note 14
Voltage between accelerating electrode and photocathode	max. 500 V	
Voltage between consecutive dynodes	max. 300 V	
Voltage between anode and final dynode	max. 300 V	note 15
Ambient temperature range		
operational (for short periods)	max. +80 °C min. −30 °C	note 16
continuous operation and storage	max. +50 °C min. −30 °C	

* Notes are given on page 4.

Notes

1. Blue sensitivity, expressed in µA/lmF, is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5K. Light is transmitted through a blue filter (Corning CS no. 5-58, polished to half stock thickness).
2. The bialkaline photocathode has a significant resistance which increases rapidly with reducing temperature. It is therefore recommended that it should not be exposed to light of too great an intensity; the cathode current should be limited, for example, to 1 nA at room temperature or 0,1 nA at –30 °C. If too high a photocurrent is passed, the cathode can no longer be considered an equipotential surface, and the focusing of electrons onto the first dynode will be affected, resulting in departure from linearity.
3. Luminous sensitivity is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5K.
4. Spectral sensitivity is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5K. Light is transmitted through an interferential filter. Spectral sensitivity at 400 nm, expressed in A/W, can be estimated by multiplying the blue sensitivity, expressed in A/lmF, by $7{,}7 \times 10^3$ for this type of tube.
5. Wherever possible, the power supply should be arranged so that the cathode is earthed and the anode is at + HT, however, it is sometimes necessary to supply the tube with the anode earthed and the cathode at –HT. Under these circumstances, erratic noise and dark current are generally increased and unstable, particularly after application of voltage. The glass envelope of the tube should be supported only by insulators with an insulation resistance of $> 10^{15}$ ohm.
6. Dark current is measured at ambient temperature, after the tube has been in darkness for approx. 1 min. Lower values can be obtained after a longer stabilization period in darkness (approx. 30 min).
7. Pulse amplitude resolution for ^{137}Cs and ^{57}Co is measured with an NaI(Tl) cylindrical scintillator (Quartz et Silice serial no. 4186 or equivalent) with a diameter of 76 mm and a height of 76 mm (3" x 3"). The count rate used is $\approx 10^4$ c/s.
8. Pulse amplitude resolution for ^{55}Fe is measured with an NaI(Tl) cylindrical scintillator with a diameter of 25 mm and a height of 1 mm provided with a beryllium window. The count rate used is $\approx 2 \times 10^3$ c/s.
9. The mean anode sensitivity deviation is measured by coupling an NaI(Tl) scintillator to the window of the tube. Long term (16 h) deviation is measured by placing a ^{137}Cs source at a distance from the scintillator such that the count rate is $\approx 10^4$ c/s corresponding to an average anode current of $\approx$ 300 nA. Anode sensitivity deviation after change of count rate is measured with a ^{137}Cs source at a distance of the scintillator such that the count rate can be changed from 10^4 c/s to 10^3 c/s corresponding to an average anode current of $\approx$ 1 µA and $\approx$ 0,1 µA respectively. Both tests are carried out according to ANSI–N42–9–1972 of IEEE recommendations.
10. Measured with a pulsed light source, with a pulse duration (FWHM) of < 1 ns; the cathode being completely illuminated. The rise time is determined between 10% and 90% of the amplitude of the anode pulse. The signal transit time is measured between the instant at which the illuminating pulse at the cathode becomes maximum, and the instant at which the anode pulse attains its maximum. Rise time, pulse duration and transit time vary as a function of high tension supply voltage V_{ht}, approximately as $V_{ht}^{-1/2}$.
11. To obtain a peak pulse current greater than that obtainable with divider A, it is necessary to increase the inter-dynode voltage of the stages progressively. Other dividers can be conceived to achieve other compromises. It is generally recommended that the voltage difference between one stage and the next is less than a factor of 2.

(continued on page 6)

MECHANICAL DATA

Dimensions in mm

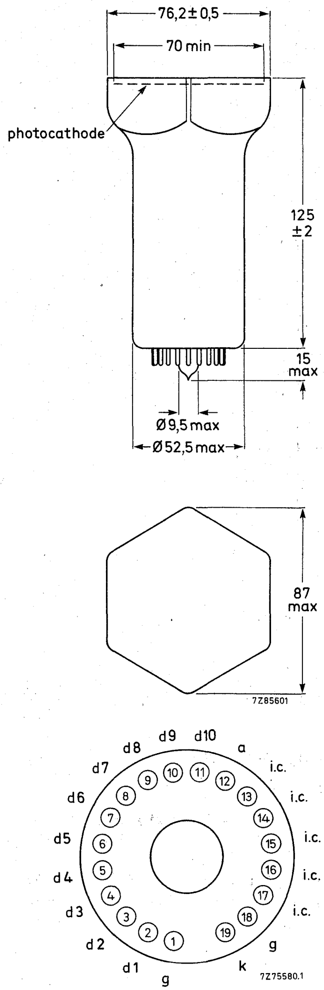


Fig. 2 PM2442.

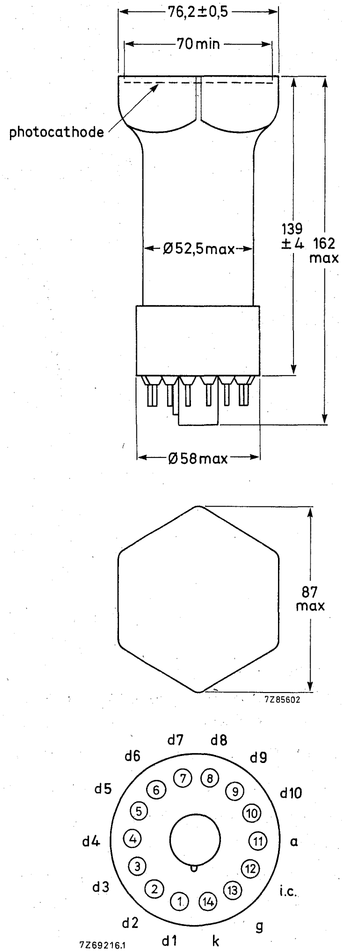


Fig. 3 PM2442B.

Base	19-pin all-glass
Net mass	165 g

Base	14-pin IEC 67-1-16a (JEDEC B14-38)
Net mass	228 g

ACCESSORIES

Socket
- for PM2442 type FE2019
- for PM2442B type FE1014

DEVELOPMENT SAMPLE DATA

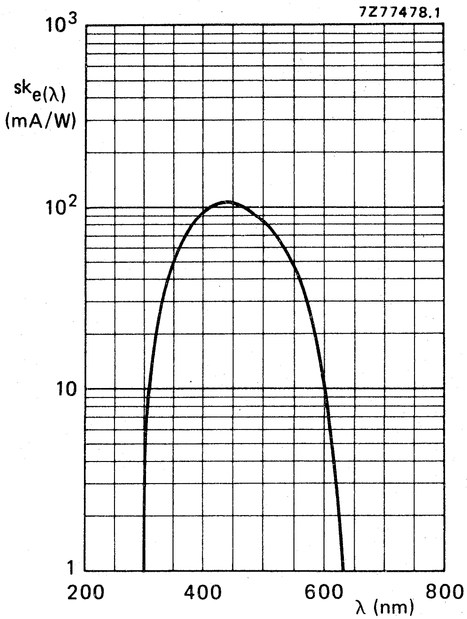


Fig. 4 Spectral sensitivity characteristic.

Notes (continued)

12. Total HT supply voltage, or the voltage at which the tube has an anode blue sensitivity of 40 A/lmF, whichever is lower.
13. A value of $< 10\ \mu A$ is recommended for applications requiring good stability.
14. Minimum value to obtain good collection in the input optics.
15. When calculating the anode voltage the voltage drop across the load resistor should be taken into account.
16. For type PM2442B this range of temperatures is limited principally by stresses in the sealing layer of the base to the glass bulb. Where low temperature operation is contemplated, the supplier should be consulted.

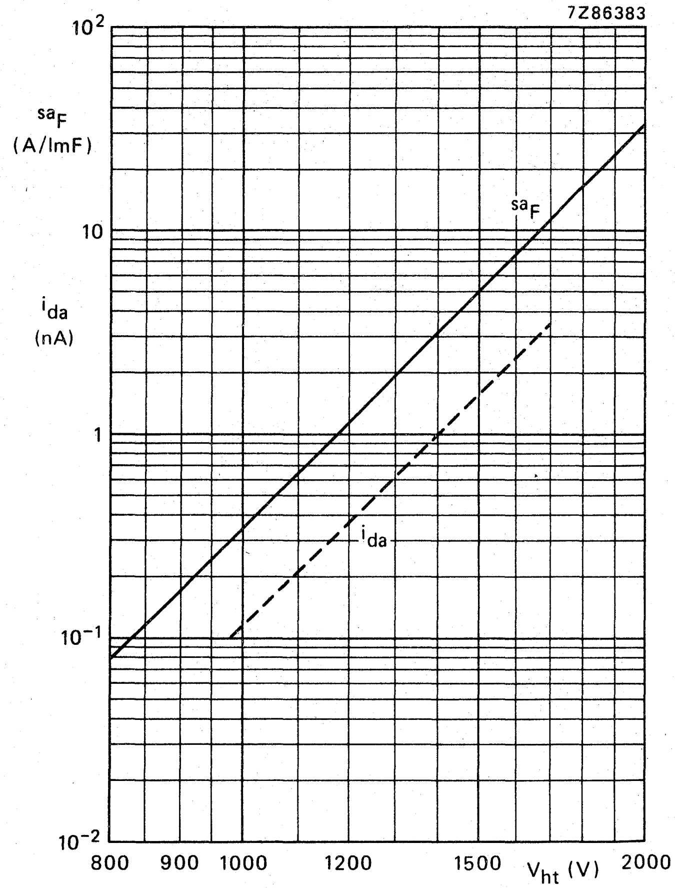


Fig. 5 Anode blue sensitivity sa_F, and anode dark current i_{da} as a function of supply voltage V_{ht}.
i_{da} is given as a dotted line to indicate its principle behaviour only.

DEVELOPMENT SAMPLE DATA

8-STAGE PHOTOMULTIPLIER TUBE

- 23 mm useful diameter head-on type
- Flat window
- Semi-transparent bi-alkaline type D photocathode
- Very good time characteristics
- For e.g. high-energy physics, scintillation counting.

QUICK REFERENCE DATA *

Spectral sensitivity characteristic	type D	
Useful diameter of the photocathode	> 23 mm	
Cathode blue sensitivity	10,8 μA/lmF	note 1
Supply voltage for anode blue sensitivity = 1 A/lmF (note 1)	1100 V	
Anode pulse rise time (with voltage divider B)	≈ 1,8 ns	
Linearity		
with voltage divider A (Fig. 2)	≈ 20 mA	
with voltage divider B (Fig. 3)	≈ 80 mA	

To be read in conjunction with *General Operational Recommendations Photomultiplier Tubes.*

GENERAL CHARACTERISTICS *

Window

Material	lime glass	
Shape	plano-concave	
Refractive index at 550 nm	1,52	

Photocathode (note 2)

Semi-transparent, head-on		
Material	Sb K Cs	
Useful diameter	> 23 mm	
Spectral sensitivity characteristic (Fig. 5)	type D	
Maximum spectral sensitivity	400 ± 30 nm	
Luminous sensitivity	≈ 65 μA/lm	note 3
Blue sensitivity	typ. 10,8 μA/lmF > 8,0 μA/lmF	note 1
Spectral sensitivity at 400 nm	≈ 75 mA/W	note 4

* Notes are given on page 5.

Multiplier system

Number of stages	8
Dynode structure	linear focused
Dynode material	Cu Be
Capacitances	
anode to final dynode	≈ 2 pF
anode to all	≈ 4 pF

Magnetic field

When the photocathode is illuminated uniformly the anode current is halved (at V_{ht} = 1200 V, voltage divider A) at a magnetic flux density of:

0,4 mT perpendicular to axis a (Fig. 1);
0,2 mT parallel to axis a.

It is recommended that the tube be screened from magnetic fields by a mu-metal shield protruding > 15 mm beyond the photocathode.

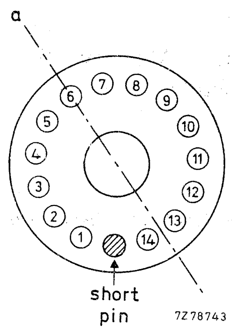


Fig. 1 Axis with respect to base pins (bottom view).

RECOMMENDED CIRCUITS

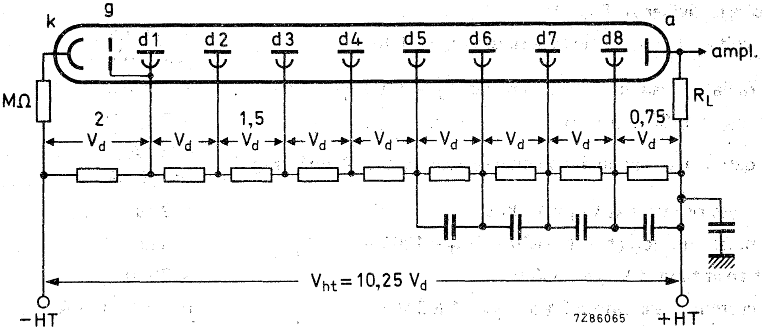


Fig. 2 Voltage divider A.

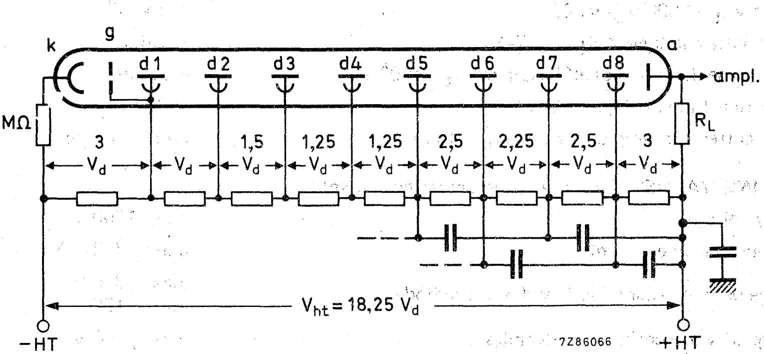


Fig. 3 Voltage divider B.

k = cathode
g = accelerating electrode
d_n = dynode no.
a = anode
R_L = load resistor

Typical value of capacitors: 1 nF

The cathode resistor of 10 MΩ limits the current should there be unintentional contact between the coating and earth when the anode is earthed.

DEVELOPMENT SAMPLE DATA

TYPICAL CHARACTERISTICS *

With voltage divider A (Fig. 2)		note 5
Supply voltage for an anode blue sensitivity of 1 A/lmF	< 1500 V typ. 1100 V	note 1
Anode radiant sensitivity at 400 nm and V_{ht} = 1100 V	≈ 7 kA/W	
Gain at V_{ht} = 1100 V (Fig. 6)	≈ $9,3 \times 10^4$	
Anode dark current at an anode blue sensitivity of 1 A/lmF (Fig. 6)	< 5 nA typ. 1 nA	notes 1,6,7
Anode pulse rise time at V_{ht} = 1300 V	≈ 2 ns	note 8
Anode pulse duration at half height at V_{ht} = 1300 V	≈ 3 ns	note 8
Signal transit time at V_{ht} = 1300 V	≈ 20 ns	note 8
Anode current linear within 2% at V_{ht} = 1300 V	up to ≈ 20 mA	
With voltage divider B (Fig. 3)		note 5
Gain at V_{ht} = 1500 V (Fig. 6)	≈ 2×10^5	
Anode pulse rise time at V_{ht} = 1500 V	≈ 1,8 ns	note 8
Anode pulse duration at half height at V_{ht} = 1500 V	≈ 2,8 ns	note 8
Signal transit time at V_{ht} = 1500 V	≈ 20 ns	note 8
Anode current linear within 2% at V_{ht} = 1500 V	up to ≈ 80 mA	

LIMITING VALUES (Absolute maximum rating system)*

Supply voltage	max. 1800 V	
Continuous anode current	max. 0,2 mA	
Voltage between first dynode and photocathode	max. 350 V min. 150 V	note 9
Voltage between consecutive dynodes	max. 250 V	
Voltage between anode and final dynode	max. 300 V min. 30 V	note 10
Ambient temperature range operational (for short periods of time)	max. +80 °C min. −30 °C	
continuous operation and storage	max. +50 °C min. −30 °C	

* Notes are given on page 5.

DEVELOPMENT SAMPLE DATA

Notes

1. Blue sensitivity, expressed in μA/lmF, is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5K. Light is transmitted through a blue filter (Corning CS no. 5-58, polished to half stock thickness).
2. The bi-alkaline photocathode has a significant resistance which increases rapidly with reducing temperature. It is therefore recommended that it should not be exposed to light of too great an intensity; the cathode current should be limited, for example, to 1 nA at room temperature or 0,1 nA at −30 °C. If too high a photocurrent is passed, the cathode can no longer be considered an equipotential surface, and the focusing of electrons onto the first dynode will be affected, resulting in departure from linearity. In applications with short pulse times the photocathode is able to deliver pulses containing 10^6 to 10^7 photoelectrons without disturbance.
3. Luminous sensitivity is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5K.
4. Spectral sensitivity is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5K. Light is transmitted through an interferential filter. Spectral sensitivity at 400 nm, expressed in A/W, can be estimated by multiplying the blue sensitivity, expressed in A/lmF, by 7×10^3 for this type of tube.
5. To obtain a peak pulse current greater than that obtainable with divider A, it is necessary to increase the inter-dynode voltage of the stages progressively. Divider circuit B is an example of a "progressive" divider, giving a compromise between gain, speed, and linearity. Other dividers can be conceived to achieve other compromises after consulting the supplier.
6. Wherever possible, the power supply should be arranged so that the cathode is earthed and the anode is at + HT, however, it is sometimes necessary to supply the tube with the anode earthed and the cathode at −HT. Under these circumstances, erratic noise and dark current are generally increased and unstable, particularly immediately after application of voltage. The envelope of the tube should be supported only by insulators with an insulation resistance of $> 10^{15}\ \Omega$.
7. Dark current is measured at ambient temperature, after the tube has been in darkness for approx. 1 min. Lower values can be obtained after a longer stabilization period in darkness (approx. 30 min).
8. Measured with a pulsed light source, with a pulse duration (FWHM) of < 1 ns; the cathode being completely illuminated. The rise time is determined between 10% and 90% of the amplitude of the anode pulse. The signal transit time is measured between the instant at which the illuminating pulse at the cathode becomes maximum, and the instant at which the anode pulse attains its maximum. Rise time, pulse duration and transit time vary as a function of high tension supply voltage V_{ht}, approximately as $V_{ht}^{-1/2}$.
9. Minimum value to obtain good collection in the input optics.
10. When calculating the anode voltage the voltage drop across the load resistor should be taken into account.

MECHANICAL DATA

Dimensions in mm

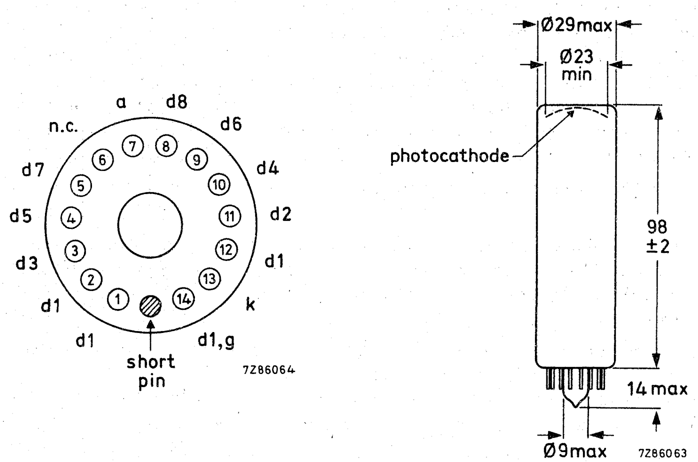


Fig. 4.

Base	14-pin all-glass
Net mass	34 g

ACCESSORIES

Socket	type FE1114

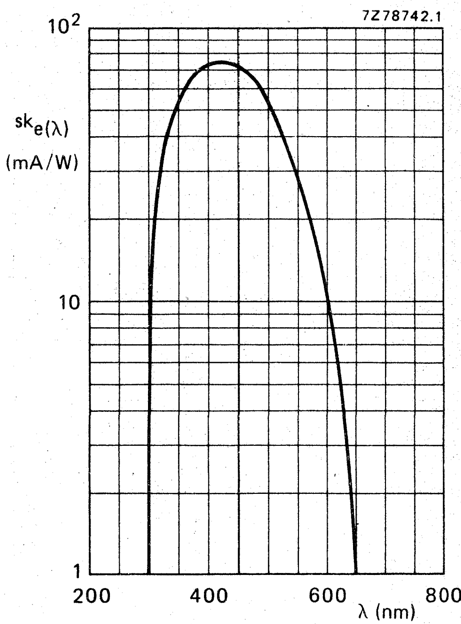


Fig. 5 Spectral sensitivity characteristic.

DEVELOPMENT SAMPLE DATA

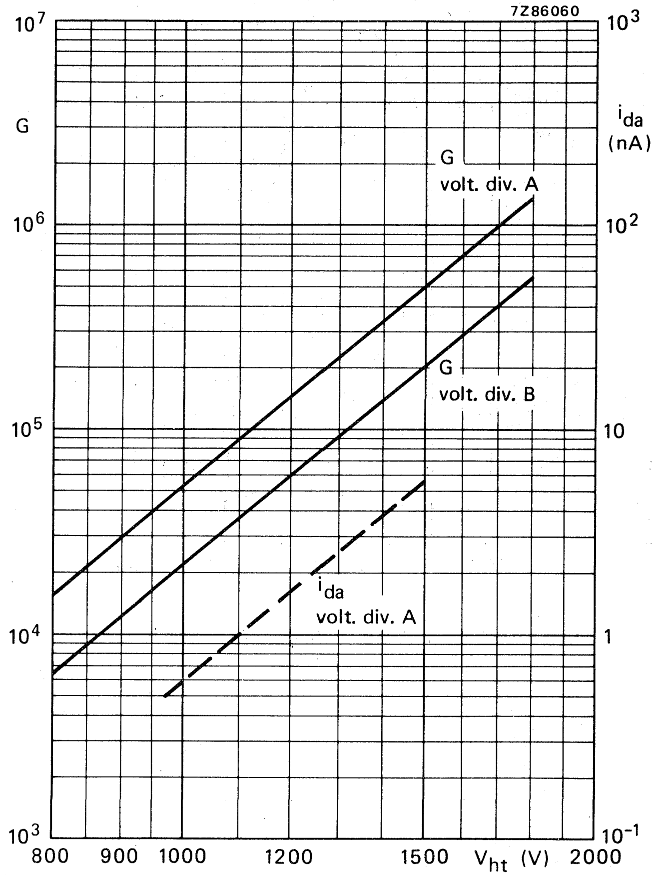


Fig. 6 Gain G and anode dark current I_{da} as a function of the supply voltage V_{ht}.

I_{da} is given as a dotted line to indicate its principle behaviour only.

11-STAGE PHOTOMULTIPLIER TUBE

- 23 mm useful diameter head-on type
- Flat window
- Semi-transparent bi-alkaline type D photocathode
- For high-energy physics and scintillation counting where good time characteristics are required, e.g. coincidence measurements and Cerenkov light detection.
- Pin-compatible with PM1982

QUICK REFERENCE DATA *

Spectral sensitivity characteristic	type D	
Useful diameter of the photocathode	> 23 mm	
Cathode blue sensitivity	10,8 μA/lmF	note 1
Supply voltage for anode blue sensitivity = 30 A/lmF (note 1)	1350 V	
Pulse amplitude resolution for ^{137}Cs	≈ 7,7%	
Anode pulse rise time (with voltage divider B)	≈ 1,9 ns	
Linearity with voltage divider A (Fig. 2) with voltage divider B (Fig. 3)	 ≈ 30 mA ≈ 80 mA	

To be read in conjunction with *General Operational Recommendations Photomultiplier Tubes.*

GENERAL CHARACTERISTICS*

Window

Material	lime glass	
Shape	plano-concave	
Refractive index at 550 nm	1,52	

Photocathode (note 2)

Semi-transparent, head-on		
Material	Sb K Cs	
Useful diameter	> 23 mm	
Spectral sensitivity characteristic (Fig. 5)	type D	
Maximum spectral sensitivity	400 ± 30 nm	
Luminous sensitivity	≈ 65 μA/lm	note 3
Blue sensitivity	typ. 10,8 μA/lmF > 8,0 μA/lmF	note 1
Spectral sensitivity at 400 nm	≈ 75 mA/W	note 4

* Notes are given on page 5.

Multiplier system

Number of stages	11
Dynode structure	linear focused
Dynode material	Cu Be
Capacitances	
anode to final dynode	≈ 2 pF
anode to all	≈ 4 pF

Magnetic field

When the photocathode is illuminated uniformly the anode current is halved (at V_{ht} = 1200 V, voltage divider A) at a magnetic flux density of:

0,4 mT perpendicular to axis a (see Fig. 1);
0,2 mT parallel to axis a.

It is recommended that the tube be screened from magnetic fields by a mu-metal shield protruding > 15 mm beyond the photocathode.

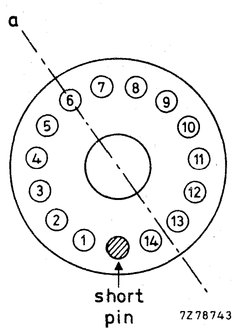


Fig. 1 Axis a with respect to base pins (bottom view).

RECOMMENDED CIRCUITS

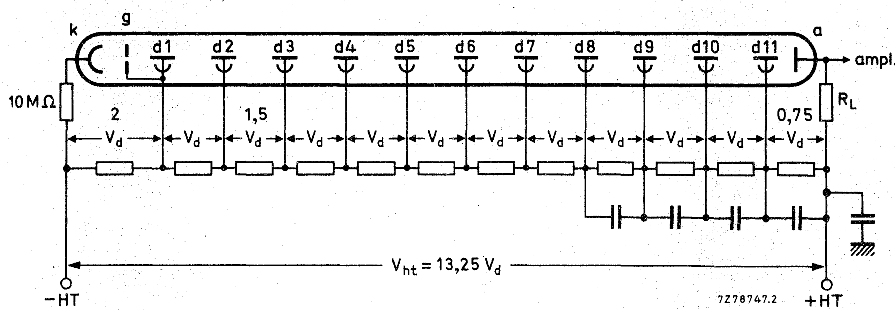


Fig. 2 Voltage divider A.

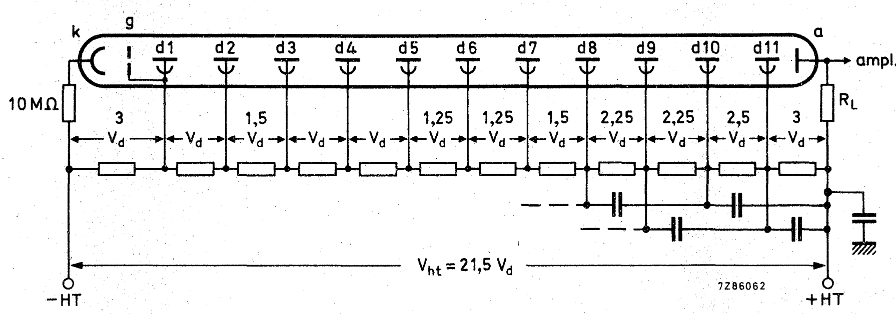


Fig. 3 Voltage divider B.

Typical value of capacitors: 1 nF

k = cathode
g = accelerating electrode
d_n = dynode no.
a = anode
R_L = load resistor

The cathode resistor of 10 MΩ limits the current should there be unintentional contact between the coating and earth when the anode is earthed.

TYPICAL CHARACTERISTICS*

With voltage divider A (Fig. 2)			note 5
Supply voltage for an anode blue sensitivity of 30 A/lmF		< 1650 V typ. 1350 V	note 1
Anode radiant sensitivity at 400 nm and V_{ht} = 1350 V		≈ 210 kA/W	
Gain at V_{ht} = 1350 V (Fig. 7)		≈ $2{,}7 \times 10^6$	
Anode dark current at an anode blue sensitivity of 30 A/lmF		< 25 nA typ. 2,5 nA	notes 1,6,7
Pulse amplitude resolution for ^{137}Cs at an anode blue sensitivity of 10 A/lmF		≈ 7,7%	notes 1,8
Anode pulse rise time at V_{ht} = 1500 V		≈ 2,2 ns	note 9
Anode pulse duration at half height at V_{ht} = 1500 V		≈ 3,7 ns	note 9
Signal transit time at V_{ht} = 1500 V		≈ 25 ns	note 9
Anode current linear within 2% at V_{ht} = 1500 V		up to ≈ 30 mA	
With voltage divider B (Fig. 3)			note 5
Gain at V_{ht} = 1800 V (Fig. 7)		≈ $6{,}5 \times 10^6$	
Anode pulse rise time at V_{ht} = 1800 V		≈ 1,9 ns	note 9
Anode pulse duration at half height at V_{ht} = 1800 V		≈ 3,3 ns	note 9
Signal transit time at V_{ht} = 1800 V		≈ 25 ns	note 9
Signal transit time difference between the centre of the photocathode and 11 mm from the centre at V_{ht} = 1800 V		≈ 0,8 ns	note 9
Signal transit time distribution at V_{ht} = 1800 V	σ	≈ 0,3 ns	notes 9,10
Anode current linear within 2% at V_{ht} = 1800 V		up to ≈ 80 mA	

LIMITING VALUES (Absolute maximum rating system)*

Supply voltage	max. 2000 V	note 11
Continuous anode current	max. 0,2 mA	
Voltage between first dynode and photocathode	max. 350 V min. 150 V	note 12
Voltage between consecutive dynodes	max. 250 V	
Voltage between anode and final dynode	max. 300 V min. 30 V	note 13
Ambient temperature range operational (for short periods of time)	max. + 80 °C min. −30 °C	
continuous operation and storage	max. + 50 °C min. −30 °C	

* Notes are given on page 5.

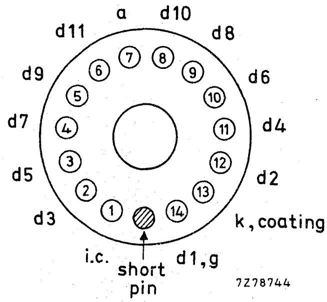
DEVELOPMENT SAMPLE DATA

Notes

1. Blue sensitivity, expressed in μA/lmF, is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5K. Light is transmitted through a blue filter (Corning CS no. 5-58, polished to half stock thickness).
2. The bi-alkaline photocathode has a significant resistance which increases rapidly with reducing temperature. It is therefore recommended that it should not be exposed to light of too great an intensity; the cathode current should be limited, for example, to 1 nA at room temperature or 0,1 nA at −30 °C. If too high a photocurrent is passed, the cathode can no longer be considered an equipotential surface, and the focusing of electrons onto the first dynode will be affected, resulting in departure from linearity. In applications with short pulse times the photocathode is able to deliver pulses containing 10^6 to 10^7 photoelectrons without disturbance.
3. Luminous sensitivity is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5K.
4. Spectral sensitivity is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5K. Light is transmitted through an interferential filter. Spectral sensitivity at 400 nm, expressed in A/W, can be estimated by multiplying the blue sensitivity, expressed in A/lmF, by 7×10^3 for this type of tube.
5. To obtain a peak pulse current greater than that obtainable with divider A, it is necessary to increase the inter-dynode voltage of the stages progressively. Divider circuit B is an example of a "progressive" divider, giving a compromise between gain, speed, and linearity. Other dividers can be conceived to achieve other compromises after consulting the supplier.
6. Wherever possible, the power supply should be arranged so that the cathode is earthed and the anode is at + HT, however, it is sometimes necessary to supply the tube with the anode earthed and the cathode at −HT. Under these circumstances, erratic noise and dark current are generally increased and unstable, particularly immediately after application of voltage. The tube is provided with a conductive coating connected to the cathode. It is recommended that, if a metal shield is used this be kept at photocathode potential. This implies safety precautions to protect the user. The envelope of the tube should be supported only by insulators with an insulation resistance of $> 10^{15}\ \Omega$.
7. Dark current is measured at ambient temperature, after the tube has been in darkness for approx. 1 min. Lower values can be obtained after a longer stabilization period in darkness (approx. 30 min).
8. Pulse amplitude resolution for ^{137}Cs is measured with an NaI (Tl) cylindrical scintillator (Quartz et Silice serial no. 1162 or equivalent) with a diameter of 22 mm and a height of 6 mm. The count rate used is $\approx 10^4$ c/s.
9. Measured with a pulsed light source, with a pulse duration (FWHM) of < 1 ns; the cathode being completely illuminated. The rise time is determined between 10% and 90% of the amplitude of the anode pulse. The signal transit time is measured between the instant at which the illuminating pulse at the cathode becomes maximum, and the instant at which the anode pulse attains its maximum. Rise time, pulse duration and transit time vary as a function of high tension supply voltage V_{ht}, approximately as $V_{ht}^{-1/2}$.
10. Transit time fluctuations of single electrons leaving the photocathode result in a transit time distribution at the anode. This distribution is characterized by its standard deviation σ.
11. Total HT supply voltage, or the voltage at which the tube has a gain of 3×10^7, whichever is lower.
12. Minimum value to obtain good collection in the input optics.
13. When calculating the anode voltage the voltage drop across the load resistor should be taken into account.

MECHANICAL DATA

Dimensions in mm



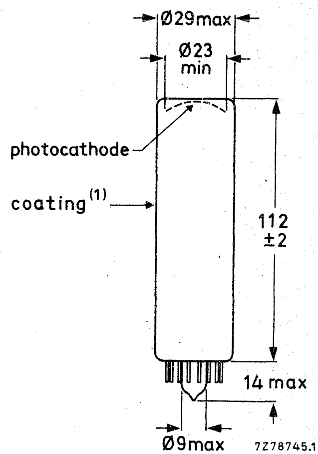


Fig. 4.

Base	14-pin all-glass
Net mass	37 g

ACCESSORIES

Socket	type FE1114

(1) **Warning:**

The envelope of the tube is covered with a conductive coating, connected to the cathode. On top of this a black paint is applied which is neither guaranteed to be light tight nor isolating.
Care should be taken to avoid hazard due to electrical shock.

DEVELOPMENT SAMPLE DATA

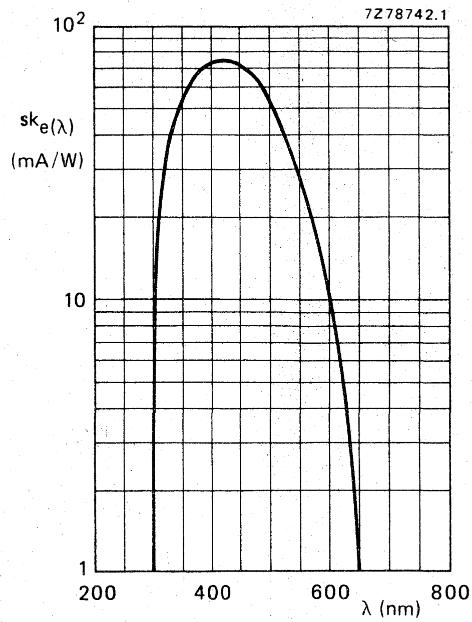


Fig. 5 Spectral sensitivity characteristic.

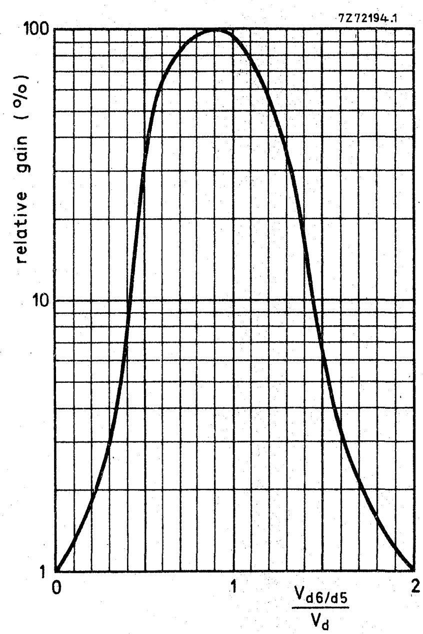


Fig. 6 Relative gain as a function of the voltage between d_6 and d_5, normalized to V_d. $V_{d7/d5}$ constant.

Note: Gain regulation by changing the voltage between d_6 and d_5 may cause a degradation of other parameters such as stability and linearity

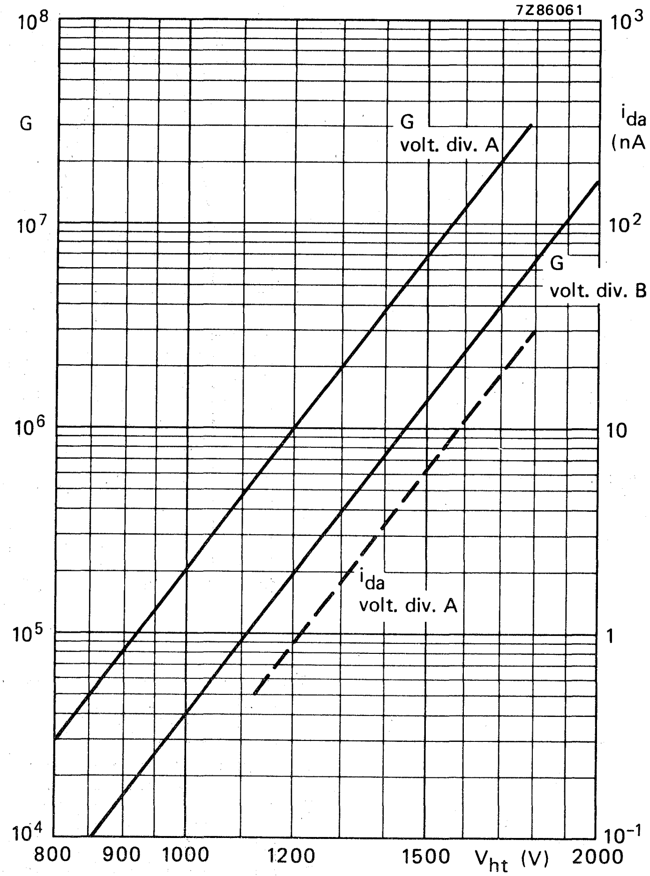


Fig. 7 Gain G and anode dark current I_{da} as a function of the supply voltage V_{ht}.

I_{da} is given as a dotted line to indicate its principle behaviour only.

10-STAGE PHOTOMULTIPLIER TUBE

The XP1017 is a 32 mm useful diameter head-on photomultiplier tube with a flat window and a semi-transparent trialkaline S20R (extended red) photocathode.
The tube is intended for use in applications where a high sensitivity in the red and near-infrared part of the spectrum is needed.

QUICK REFERENCE DATA

Spectral sensitivity characteristics			S20R	
Useful diameter of the photocathode		>	32	mm
Spectral sensitivity of the photocathode	at 550 nm	≈	35	mA/W
	at 698 nm	≈	23	mA/W
	at 858 nm		6, 5	mA/W
Supply voltage for anode luminous sensitivity = 60 A/lm			1470	V
Anode pulse rise time (with voltage divider B)		≈	3, 5	ns
Linearity				
with voltage divider A		up to ≈	30	mA
with voltage divider B		up to ≈	100	mA

To be read in conjunction with "General Operational Recommendations Photomultiplier Tubes".

GENERAL CHARACTERISTICS

Window

Material	borosilicate
Shape	plano-plano
Refractive index at 550 nm	1, 48

Photocathode

Semi-transparent, head-on

Material		Sb-Na-K-Cs	
Useful diameter	>	32	mm
Spectral sensitivity characteristic (Fig. 3)		S20R	
Maximum sensitivity at		550 ± 50	nm
Luminous sensitivity	typ.	210	μA/lm
	>	150	μA/lm
Spectral sensitivity at 858 ± 8 nm	typ.	6,5	mA/W
	>	1,5	mA/W
at 550 nm	≈	35	mA/W
at 698 nm	≈	23	mA/W
at 903 nm	≈	1,2	mA/W

Electron optical input system

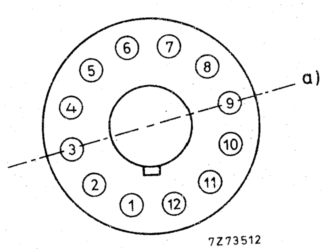
This system consists of: the photocathode, k; a metallized part of the glass envelope, internally connected to the photocathode; an accelerating electrode, acc, internally connected to S1.

Multiplier system

Number of stages			10	
Dynode structure			linear focused	
Dynode material			Cu-Be	
Capacitances				
Anode to all	C_a	≈	5	pF
Anode to final dynode	$C_{a/S10}$	≈	3	pF

Magnetic field See fig. 4.

It is recommended that the tube be screened against the influence of magnetic fields by a mu-metal shield protruding > 15 mm beyond the photocathode.



Axis a) with respect to base pins (bottom view).

RECOMMENDED CIRCUITS

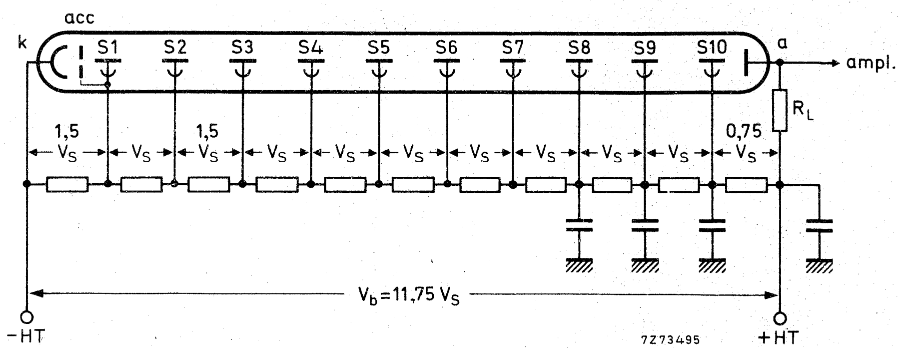


Fig. 1 Voltage divider A

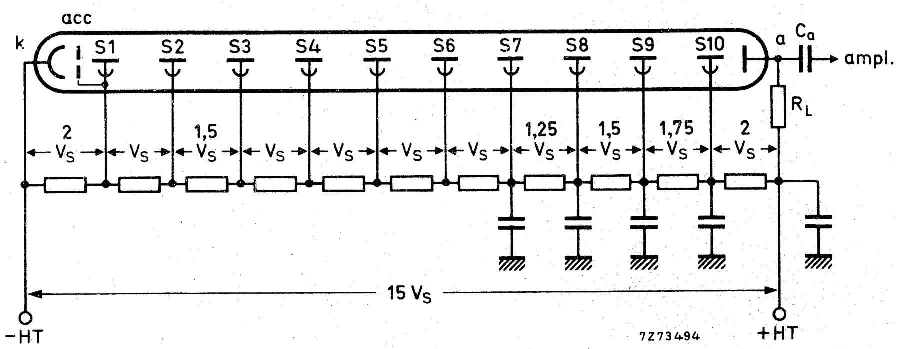


Fig. 2 Voltage divider B

k = cathode

acc = accelerating electrode

S_n = dynode no. n

a = anode

R_L = load resistor

Typical values of capacitors; 10 nF

TYPICAL CHARACTERISTICS

With voltage divider A (Fig. 1) [1]

Supply voltage for an anode luminous sensitivity N_a = 60 A/lm (Fig. 5)	<	1650	V
	typ.	1470	V
Supply voltage for a gain G = 10^6	≈	1800	V
Anode dark current at N_a = 60 A/lm (Fig. 5) [2] [3]	<	50	nA
	typ.	2	nA
Anode current linear within 2% at V_b = 1700 V up to	≈	30	mA

With voltage divider B (Fig. 2) [1]

Supply voltage for an anode luminous sensitivity N_a = 60 A/lm (Fig. 5)	≈	1730	V
Anode pulse rise time at V_b = 1700 V [4]	≈	3,5	ns
Anode pulse duration at half height at V_b = 1700 V [4]	≈	6	ns
Signal transit time at V_b = 1700 V [4]	≈	34	ns
Anode current linear within 2% at V_b = 1700 V up to	≈	100	mA

LIMITING VALUES (Absolute max. rating system)

Supply voltage [5]	max.	1900	V
Continuous anode current [9]	max.	0, 2	mA
Voltage between first dynode and photocathode [6]	max.	500	V
	min.	120	V
Voltage between consecutive dynodes	max.	300	V
Voltage between anode and final dynode [7]	max.	300	V
	min.	30	V
Ambient temperature range			
Operational (for short periods of time) [8]	max.	+80	°C
	min.	−30	°C
Continuous operation and storage	max.	+50	°C
	min.	−30	°C

Notes see page 5.

Notes to page 4

1) To obtain a peak pulse current greater than that obtainable with divider A, it is necessary to increase the inter-dynode voltage of the stages progressively. Divider circuit B is an example of a "progressive" divider, giving a compromise between gain, speed, and linearity. Other dividers can be conceived to achieve other compromises. It is generally recommended that the increase in voltage between one stage and the next be kept less than a factor of 2.

2) Wherever possible, the photomultiplier power supply should be arranged so that the cathode is earthed and the anode is at +HT, however, it is sometimes necessary to supply the tube with the anode earthed and the cathode at −HT. Under these circumstances, erratic noise and dark current are generally increased and unstable, particularly immediately after application of voltage. The glass envelope of the tube should be supported only by isolators having an insulation resistance of $> 10^{15}\ \Omega$.

3) Dark current is measured at ambient temperature, after a stabilization period of the tube in darkness ($\approx 1/4$ h).

4) Measured with a pulsed-light source, with a pulse duration (FWHM) of <1 ns, the cathode being completely illuminated.
The rise time is determined between 10% and 90% of the amplitude of the anode pulse. The signal transit time is measured between the instant at which the illuminating pulse at the cathode becomes maximum, and the instant at which the anode pulse attains its maximum. Rise time, pulse duration and transit time vary as a function of high tension supply voltage V_b, approximately as $V_b^{-1/2}$.

5) Total HT supply voltage or the voltage at which the tube has an anode luminous sensitivity of 600 A/lm, whichever is lower.

6) Minimum value to obtain good collection in the input optics.

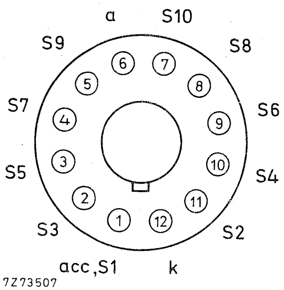
7) When calculating the anode voltage the voltage drop across the load resistor should be taken into account.

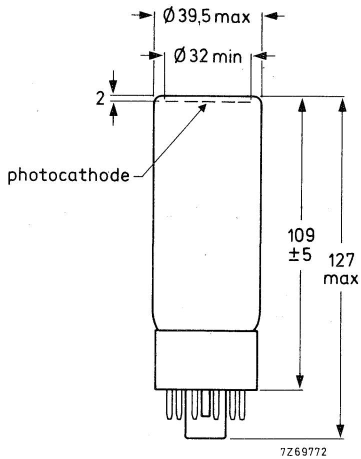
8) This range of temperatures is limited principally by stresses in the sealing layer of the base to the glass bulb.
Where low temperature operation is contemplated, the supplier should be consulted.

9) A value of $< 10\ \mu A$ is recommended for applications requiring good stability.

MECHANICAL DATA

Dimensions in mm





Net mass : 80 g

Base : 12-pin (JEDEC B12-43)

ACCESSORIES

Socket : type FE1012

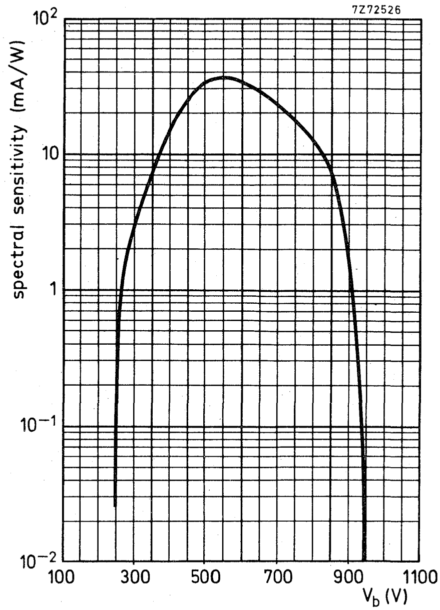


Fig. 3
Spectral sensitivity characteristic

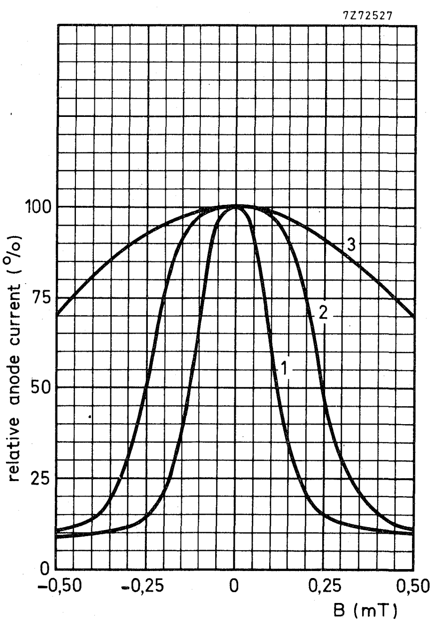


Fig. 4
Relative anode current as a function of the magnetic flux density B

1. B ⊥ tube axis, // axis a
2. B ⊥ tube axis, ⊥ axis a
3. B // tube axis

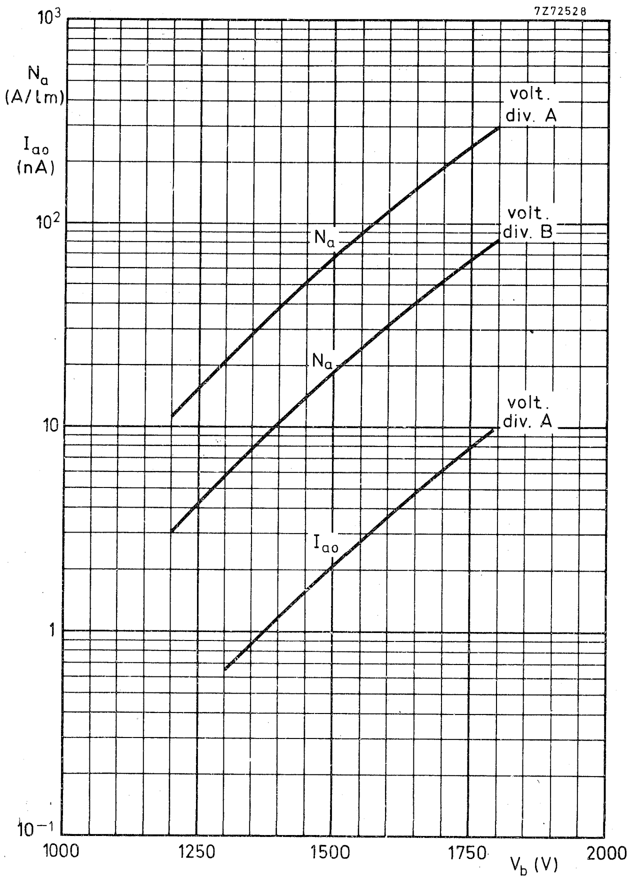


Fig. 5
Anode luminous sensitivity, Na, and anode dark current, I_{ao}, as a function of supply voltage V_b

9-STAGE PHOTOMULTIPLIER TUBE

The XP1117 is a 14 mm useful diameter head-on photomultiplier tube with a flat window and a semi-transparent S20 (type T) photocathode.
The tube is intended for use in optical measurements where a good sensitivity in the entire visible spectrum is needed.
Its rugged construction makes it particularly suitable for industrial applications under limited dimensional conditions.

QUICK REFERENCE DATA

Spectral sensitivity characteristic			S20 (type T)	
Useful diameter of the photocathode		>	14	mm
Spectral sensitivity of the photocathode at 698 nm			13	mA/W
Supply voltage for an anode luminous sensitivity N_a = 30 A/lm			1520	V
Anode pulse rise time (with voltage divider B)		≈	3,5	ns
Linearity				
with voltage divider A	up to	≈	10	mA
with voltage divider B	up to	≈	30	mA

To be read in conjunction with "General Operational Recommendations Photomultiplier Tubes"

GENERAL CHARACTERISTICS

Window

Material			borosilicate	
Shape			plano-plano	
Refractive index at 550 nm			1,48	

Photocathode

Semi-transparent, head-on				
Material			SbNaKCs	
Useful diameter		>	14	mm
Spectral sensitivity characteristic (Fig. 3)			S20 (type T)	
Maximum spectral sensitivity at			420 ± 30	nm
Luminous sensitivity	[1]) (see page 2)	typ.	140	µA/lm
		>	100	µA/lm
Spectral sensitivity at 698 ± 7 nm	[2]) (see page 2)		13	mA/W

Electron optical input system

This consists of: the photocathode, k; a metallized part of the envelope internally connected to the photocathode; an accelerating electrode, acc, internally connected to S1.

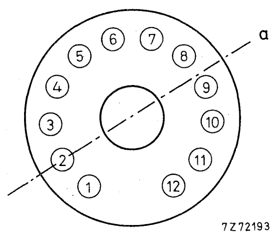
Multiplier system

Number of stages		9	
Dynode structure		linear focused	
Dynode material		CuBe	
Capacitances			
Anode to all	≈	3	pF
Anode to final dynode	≈	1,9	pF

Magnetic field

When the photocathode is illuminated uniformly the anode current is halved (at V_b = 1200 V, voltage divider A):
- at a magnetic flux density of 0,3 mT perpendicular to axis a;
- at a magnetic flux density of 0,2 mT parallel to axis a (see Fig. below.)

It is recommended that the tube be screened against the influence of magnetic fields by a mu-metal shield protruding > 15 mm beyond the photocathode.



Axis a with respect to base pins (bottom view).

RECOMMENDED CIRCUITS

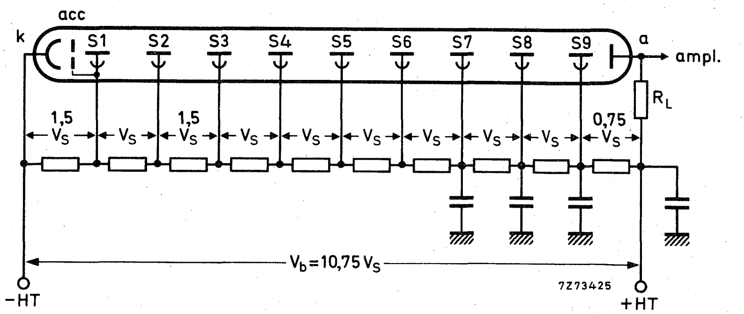


Fig. 1 Voltage divider A

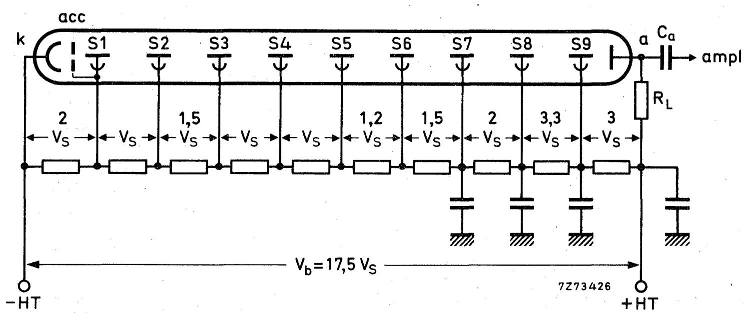


Fig. 2 Voltage divider B

k = cathode

acc = accelerating electrode

S_n = dynode no. n

a = anode

R_L = load resistor

Typical value of capacitors: 10 nF

TYPICAL CHARACTERISTICS

With voltage divider A (Fig. 1) [1]

Supply voltage for an anode luminous sensitivity N_a = 30 A/lm (Fig. 5)	typ. < 	1520 1800	V V
Anode dark current at N_a = 30 A/lm (Fig. 5) [2][3]	typ. <	10 100	nA nA
Anode current linear within 2% at V_b = 1800 V up to	≈	10	mA

With voltage divider B (Fig. 2) [1]

Anode luminous sensitivity at V_b = 1800 V (Fig. 5)	≈	15	A/lm
Anode pulse rise time at V_b = 1800 V [4]	≈	3, 5	ns
Anode pulse duration at half height at V_b = 1800 V [4]	≈	6	ns
Signal transit time at V_b = 1800 V [4]	≈	28	ns
Anode current linear within 2% at V_b = 1800 V up to	≈	30	mA

LIMITING VALUES (Absolute max. rating system)

Supply voltage [5]	max.	1900	V
Continuous anode current [8]	max.	0, 2	mA
Voltage between first dynode and photocathode [6]	max. min.	350 100	V V
Voltage between consecutive dynodes	max.	200	V
Voltage between anode and final dynode [7]	max. min.	300 30	V V
Ambient temperature range			
Operational (for short periods of time)	max. min.	+70 −50	°C °C
Continuous operation and storage	max. min.	+50 −50	°C °C

Notes see page 5.

Notes to page 4

1) To obtain a peak pulse current greater than that obtainable with divider A, it is necessary to increase the inter-dynode voltage of the stages progressively. Divider circuit B is an example of a "progressive" divider, giving a compromise between gain, speed, and linearity. Other dividers can be conceived to achieve other compromises. It is generally recommended that the increase in voltage between one stage and the next be kept less than a factor of 2.

2) Wherever possible, the power supply should be arranged so that the cathode is earthed and the anode is at +HT, however, it is sometimes necessary to supply the tube with the anode earthed and the cathode at −HT. Under these circumstances, erratic noise and dark current are generally increased and unstable, particularly immediately after application of voltage. The shrink sleeve or the mu-metal shield around the tube should be supported only by isolators having an insulation resistance of $> 10^{15}\ \Omega$.

3) Dark current is measured at ambient temperature, after a stabilization period of the tube in darkness ($\approx 1/4$ h).

4) Measured with a pulsed-light source, with a pulse duration (FWHM) of < 1 ns, the cathode being completely illuminated.
The rise time is determined between 10% and 90% of the amplitude of the anode pulse. The signal transit time is measured between the instant at which the illuminating pulse at the cathode becomes maximum, and the instant at which the anode pulse attains its maximum. Rise time, pulse duration and transit time vary as a function of high tension supply voltage V_b, approximately as $V_b^{-1/2}$.

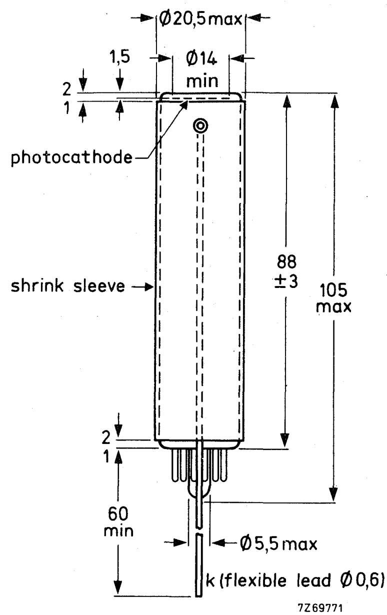
5) Total HT supply voltage, or the voltage at which the tube has an anode sensitivity of 500 A/lm, whichever is lower.

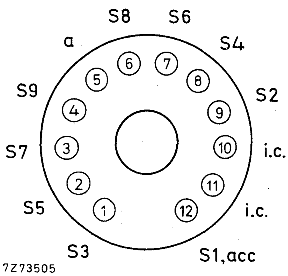
6) Minimum value to obtain good collection in the input optics.

7) When calculating the anode voltage the voltage drop across the load resistor should be taken into account.

8) A value of < 10 μA is recommended for applications requiring good stability.

MECHANICAL DATA Dimensions in mm





Net mass : 25 g

Base : 12-pin all glass

ACCESSORIES

Socket : type FE1004

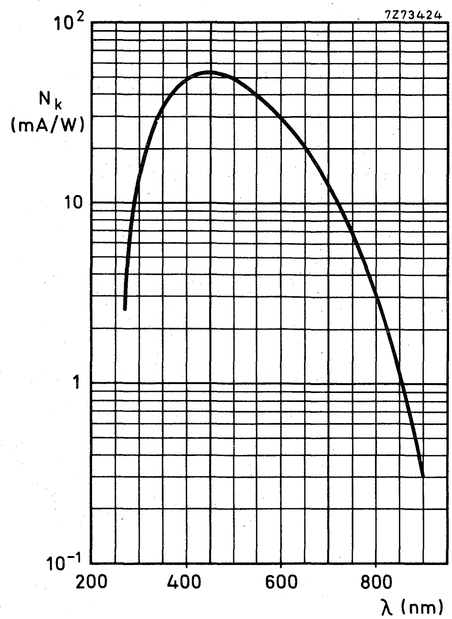


Fig. 3

Spectral sensitivity characteristic

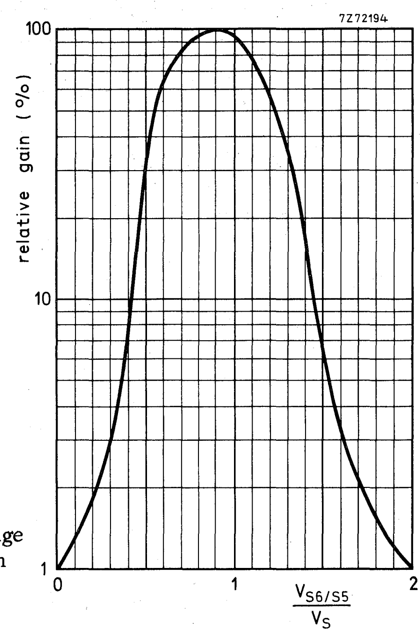


Fig. 4 Relative gain as a function of the voltage between S_6 and S_5, normalized to V_S. $V_{S7/S5}$ constant.

Note: Gain regulation by changing the voltage between S6 and S5 may cause a degradation of other parameters such as stability and linearity.

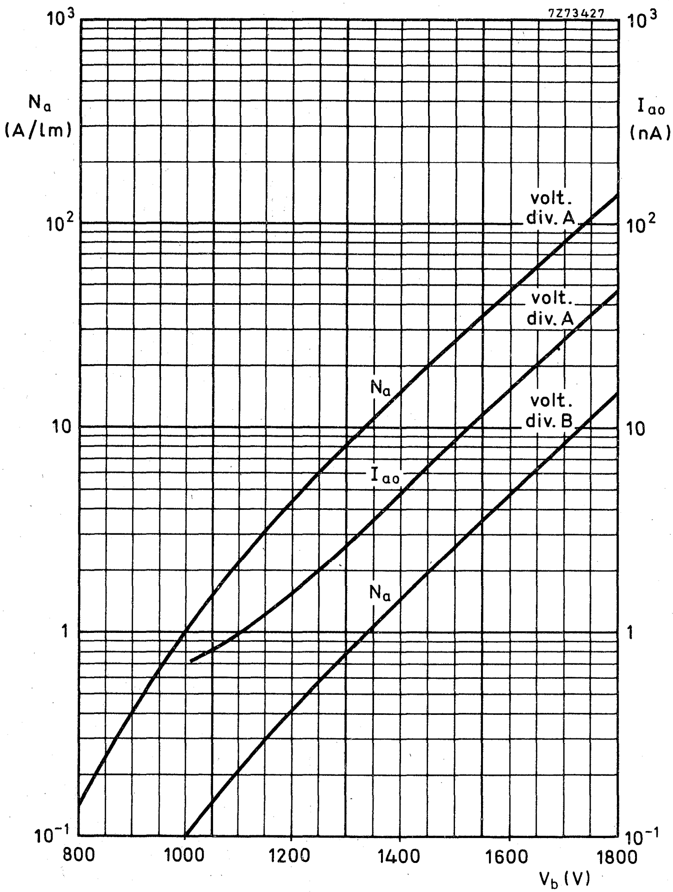


Fig. 5

Anode luminous sensitivity, N_a, and anode dark current, I_{ao}, as a function of supply voltage V_b

6-STAGE PHOTOMULTIPLIER TUBE

The XP1920 is a 14 mm useful diameter head-on photomultiplier tube with a flat window and a semi-transparent S11 (type A) photocathode. The tube is intended for use in optical measurements with relatively high luminous fluxes where it offers a good sensitivity combined with a wide bandwidth and a good signal to noise ratio. Its construction makes it particularly suitable for industrial applications under limited dimensional conditions.

QUICK REFERENCE DATA

Spectral sensitivity characteristic		S11 (type A)
Useful diameter of the photocathode	>	14 mm
Cathode spectral sensitivity at 437 nm		60 mA/W
Supply voltage for an anode spectral sensitivity = 0,2 kA/W		700 V
Anode pulse rise time (with voltage divider B)	≈	2 ns
Linearity		
with voltage divider A	up to ≈	30 mA
with voltage divider B	up to ≈	80 mA

To be read in conjunction with *General Operational Recommendations Photomultiplier Tubes.*

GENERAL CHARACTERISTICS

Window

Material		lime glass
Shape		plano-concave
Refractive index at 550 nm		1,52

Photocathode

Semi-transparent, head-on		
Material		SbCs
Useful diameter	>	14 mm
Spectral sensitivity characteristic (Fig. 5)		S11 (type A)
Maximum spectral sensitivity at		420 ± 30 nm
Luminous sensitivity	≈	60 μA/lm
Spectral sensitivity at 437 ± 5 nm	typ.	60 mA/W
	>	40 mA/W

Multiplier system

Number of stages		6
Dynode structure		linear focused
Dynode material		CuBe
Capacitances		
anode to final dynode	≈	2 pF
anode to all	≈	4 pF

Magnetic field

When the photocathode is illuminated uniformly the anode current is halved (at V_b = 800 V, voltage divider A) at a magnetic flux of:

0,3 mT perpendicular to axis a,

0,2 mT parallel to axis a; see Fig. 1.

It is recommended that the tube be screened against the influence of magnetic fields by a mu-metal shield protruding 15 mm beyond the photocathode.

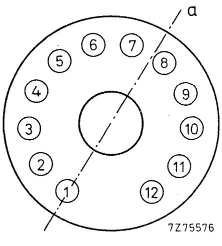


Fig. 1 Axis a with respect to base pins (bottom view).

RECOMMENDED CIRCUITS

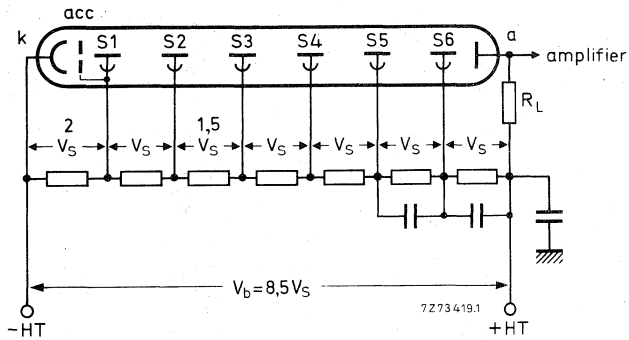


Fig. 2 Voltage divider A. Typical values of capacitors: 10 nF; k = cathode; acc = accelerating electrode; S_n = dynode no.; a = anode; R_L = load resistor.

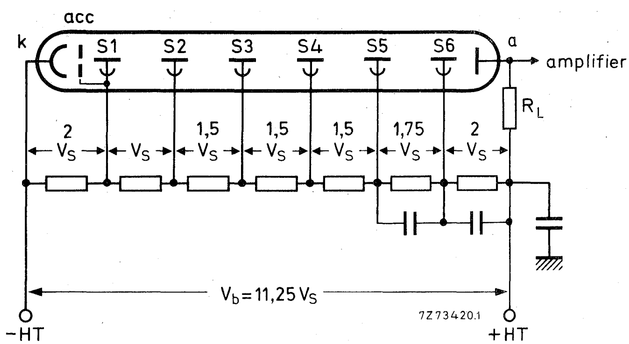


Fig. 3 Voltage divider B. Typical value of capacitors: 10 nF; k = cathode; acc = accelerating electrode; S_n = dynode no.; a = anode; R_L = load resistor.

TYPICAL CHARACTERISTICS *

	note		
With voltage divider A (Fig. 2)	1		
Supply voltage for anode spectral sensitivity N_{ar} = 0,2 kA/W (Fig. 6)		<	1200 V
		typ.	700 V
Anode dark current at N_{ar} = 0,2 kA/W (Fig. 6)	2,3	<	5 nA
		typ.	0,5 nA
Anode current linear within 2% at V_b = 1100 V		up to ≈	30 mA
With voltage divider B (Fig. 3)	1		
Anode spectral sensitivity at V_b = 1200 V (Fig. 6)		≈	0,5 kA/W
Anode pulse rise time at V_b = 1200 V	4	≈	2 ns
Anode pulse duration at half height at V_b = 1200 V	4	≈	3,2 ns
Signal transit time at V_b = 1200 V	4	≈	16 ns
Anode current linear within 2% at V_b = 1200 V		up to ≈	80 mA

LIMITING VALUES (absolute maximum rating system)

	note		
Supply voltage		max.	1300 V
Continuous anode current	7	max.	0,2 mA
Voltage between first dynode and photocathode	5	max.	350 V
		min.	100 V
Voltage between anode and final dynode	6	max.	300 V
		min.	30 V
Voltage between consecutive dynodes		max.	250 V
Ambient temperature range			
operational (for short periods of time)		max.	+80 °C
		min.	−30 °C
continuous operation and storage		max.	+50 °C
		min.	−30 °C.

* All spectral sensitivities refer to a wavelength of 437 nm.

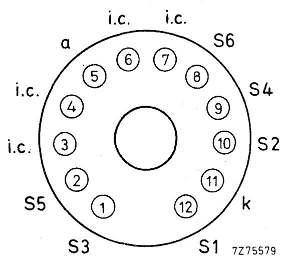
Notes see page 5.

Notes

1. To obtain a peak pulse current greater than that obtainable with divider A, it is necessary to increase the inter-dynode voltage of the stages progressively. Divider circuit B is an example of a "progressive" divider, giving a compromise between gain, speed, and linearity. Other dividers can be conceived to achieve other compromises. It is generally recommended that the increase in voltage between one stage and the next be kept less than a factor of 2.
2. Wherever possible, the power supply should be arranged so that the cathode is earthed and the anode is at +HT, however, it is sometimes necessary to supply the tube with the anode earthed and the cathode at −HT. Under these circumstances, erratic noise and dark current are generally increased and unstable, particularly after application of voltage. The glass envelope of the tube should be supported only by isolators having an insulation resistance of $>10^{15}$ ohm.
3. Dark current is measured at ambient temperature, after a stabilization period of the tube in darkness (≈¼ h).
4. Measured with a pulsed light source, with a pulse duration (FWHM) of < 1 ns: the cathode being completely illuminated. The rise time is determined between 10% and 90% of the amplitude of the anode pulse. The signal transit time is measured between the instant at which the illuminating pulse at the cathode becomes maximum, and the instant at which the anode pulse attains its maximum. Rise time, pulse duration and transit time vary as a function of high tension supply voltage V_b, approximately as $V_b^{-1/2}$.
5. Minimum value to obtain good collection in the input optics.
6. When calculating the anode voltage the voltage drop across the load resistor should be taken into account.
7. A value of < 10 μA is recommended for applications requiring good stability.

MECHANICAL DATA

Dimensions in mm



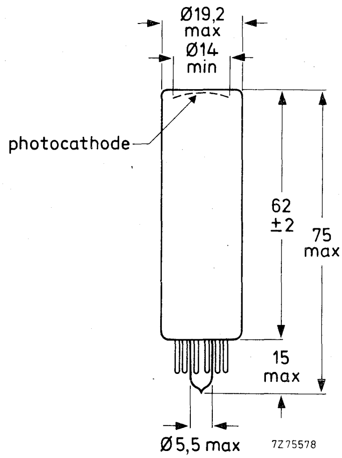


Fig. 4.

Base	12-pin all glass
Net mass	16 g

ACCESSORIES

Socket	FE 1004

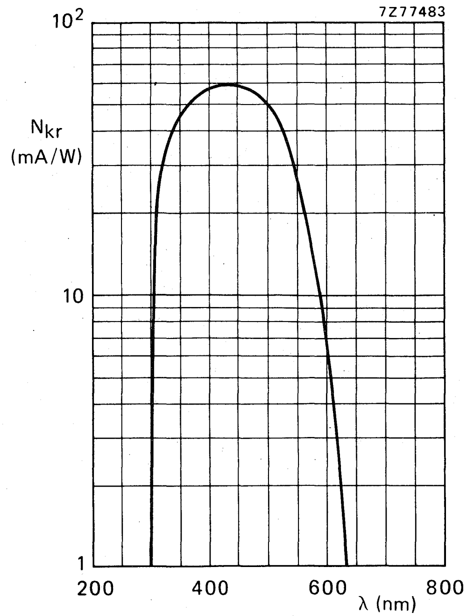


Fig. 5 Spectral sensitivity characteristic.

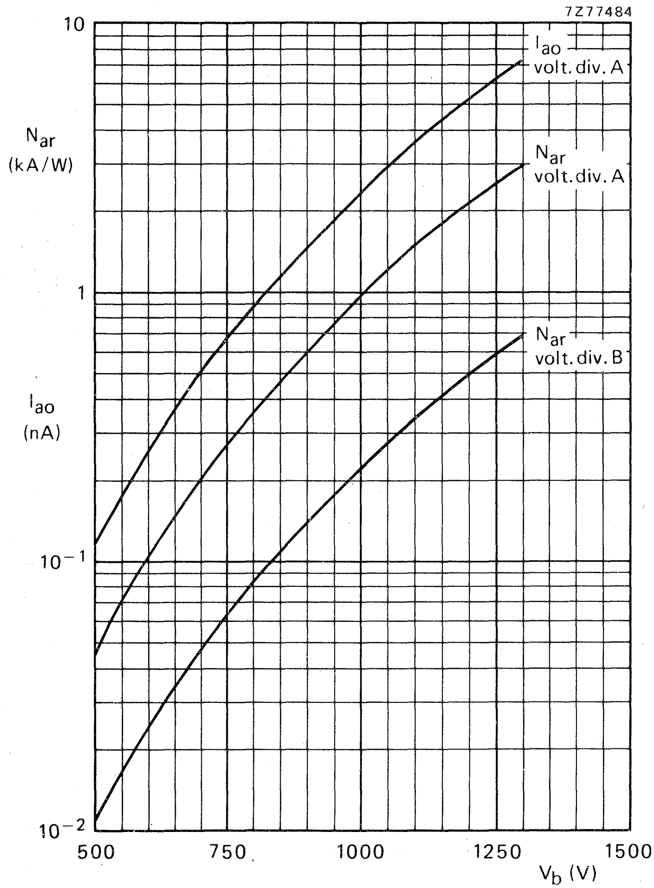


Fig. 6 Anode spectral sensitivity N_{ar}, and anode dark current I_{ao} as a function of the supply voltage V_b.

10-STAGE PHOTOMULTIPLIER TUBES

The XP2008 and XP2008UB are 32 mm useful diameter head-on photomultiplier tubes with a flat window and a semi-transparent Super A photocathode. The tubes are intended for use in applications such as scintillation counting, laboratory and industrial photometry and large volume calorimeter experiments. Their CuBe dynode system offers a high stability. The XP2008 is provided with a 12-pin plastic base; the XP2008UB has a 14-pin all-glass base.

QUICK REFERENCE DATA

Spectral sensitivity characteristic		Super A	
Useful diameter of the photocathode	>	32	mm
Spectral sensitivity of the photocathode at 437 nm	≈	70	mA/W
Supply voltage for luminous sensitivity N_a = 60 A/lm		1180	V
Pulse amplitude resolution for ^{137}Cs	≈	8	%
Mean anode sensitivity deviation	≈	1	%
Anode pulse rise time (with voltage divider B)	≈	2,5	ns
Linearity			
with voltage divider A	up to ≈	100	mA
with voltage divider B	up to ≈	200	mA

To be read in conjunction with "General Operational Recommendations Photomultiplier Tubes".

GENERAL CHARACTERISTICS

Window

Shape	plano-plano		
Material	lime glass		
Refractive index at 550 nm		1,52	

Photocathode

Semi-transparent, head-on			
Material	Sb-Cs		
Useful diameter	>	32	mm
Spectral sensitivity characteristic (Fig. 3)	type Super A		
Maximum sensitivity at		420 ± 30	nm
Luminous sensitivity	typ.	80	µA/lm
	>	40	µA/lm
Spectral sensitivity at 437 ± 5 nm	≈	70	mA/W

For BBQ light the typical integral quantum efficiency is 13% and can be measured on request.

Electron optical input system

This system consists of: the photocathode, k; a metallized part of the glass envelope, internally connected to the photocathode; an accelerating electrode, acc, internally connected to S 1.

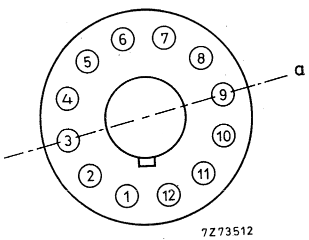
Multiplier system

Number of stages	10
Dynode structure	linear focused
Dynode material	Cu-Be
Capacitances	
Anode to all	≈ 5 pF
Anode to final dynode	≈ 3 pF

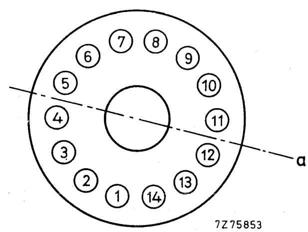
Magnetic field

When the photocathode is illuminated uniformly the anode current is halved (at V_b = 1200 V, voltage divider A):
— at a magnetic flux density of 0,6 mT in the direction of the longitudinal axis;
— at a magnetic flux density of 0,35 mT perpendicular to axis a (see Fig. below);
— at a magnetic flux density of 0,15 mT parallel to axis a.

It is recommended that the tube be screened against the influence of magnetic fields by a mu-metal shield protruding > 15 mm beyond the photocathode.



XP2008



XP2008UB

Fig. 1 Axis a with respect to base pins (bottom view).

RECOMMENDED CIRCUITS

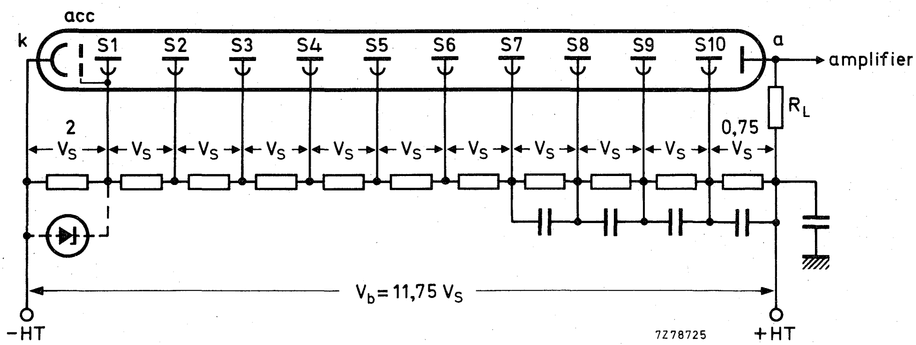


Fig. 1 Voltage divider A.

Note: For optimum peak amplitude resolution it is recommended that the voltage between first dynode and photocathode be maintained at ≈ 200 V, e.g. by means of a voltage regulator diode.

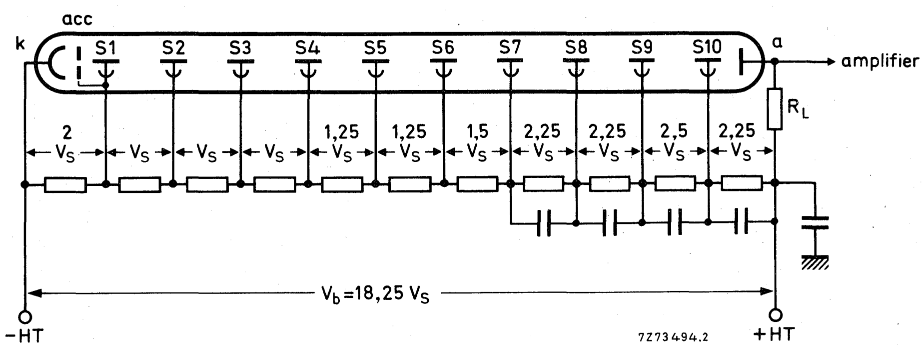


Fig. 2 Voltage divider B.

k = cathode
acc = accelerating electrode
S_n = dynode no. n
a = anode
R_L = load resistor

Typical values of capacitors: 10 nF

TYPICAL CHARACTERISTICS

	note		
With voltage divider A (Fig. 1)	1		
Supply voltage for an anode luminous sensitivity N_a = 60 A/lm (Fig. 5)		$<$ typ.	1500 V 1180 V
Anode dark current at an anode luminous sensitivity N_a = 60 A/lm (Fig. 5)	2,3	$<$ typ.	50 nA 5 nA
Pulse amplitude resolution for ^{137}Cs at N_a = 10 A/lm	4	≈	8 %
Mean anode sensitivity deviation at V_b = 1200 V	5		
long term		≈	1 %
after change of count rate		≈	1 %
Anode current linear within 2% at V_b = 1700 V		up to ≈	100 mA
With voltage divider B (Fig. 2)			
Anode luminous sensitivity at V_b = 1700 V (Fig. 5)		≈	150 A/lm
Anode pulse rise time at V_b = 1700 V	6	≈	2,5 ns
Anode pulse duration at half height at V_b = 1700 V	6	≈	6 ns
Signal transit time at V_b = 1700 V	6	≈	26 ns
Anode current linear within 2% at V_b = 1700 V		up to ≈	200 mA

LIMITING VALUES (Absolute maximum rating system)

	note		
Supply voltage	7	max.	1800 V
Continuous anode current	11	max.	0,2 mA
Voltage between first dynode and photocathode	8	max. min.	500 V 150 V
Voltage between consecutive dynodes		max.	300 V
Voltage between anode and final dynode	9	max. min.	300 V 30 V
Ambient temperature range			
Operational (for short periods of time)	10	max. min.	+80 °C −30 °C
Continuous operating and storage		max. min.	+50 °C −30 °C

Notes see page 5.

Notes

1. To obtain a peak pulse current greater than that obtainable with divider A, it is necessary to increase the inter-dynode voltage of the stages progressively. Divider circuit B is an example of a "progressive" divider, giving a compromise between gain, speed, and linearity. Other dividers can be conceived to achieve other compromises after consulting the supplier.

2. Wherever possible, the photomultiplier power supply should be arranged so that the cathode is earthed and the anode is at +HT, however, it is sometimes necessary to supply the tube with the anode earthed and the cathode at −HT. Under these circumstances, erratic noise and dark current are generally increased and unstable, particularly immediately after application of voltage. The glass envelope of the tube should be supported only by isolators having an insulation resistance of $> 10^{15}\ \Omega$.

3. Dark current is measured at ambient temperature, after a stabilization period of the tube in darkness ($\approx$ 1/4 h).

4. Pulse amplitude resolution for ^{137}Cs is measured with an NaI (Tl) cylindrical scintillator with a diameter of 32 mm and a height of 32 mm. The count rate used is $\approx 10^4$ c/s.

5. The mean anode sensitivity deviation is measured by coupling an NaI (Tl) scintillator to the window of the tube. Long term (16 h) deviation is measured by placing a ^{137}Cs source at a distance from the scintillator such that the scintillator count rate is $\approx 10^4$ c/s corresponding to an average anode current of $\approx$ 300 nA.
   Mean pulse amplitude deviation after change of count rate is measured with a ^{137}Cs source at a distance of the scintillator such that the count rate can be changed from 10^4 c/s to 10^3 c/s corresponding to an average anode current of $\approx 1\ \mu$A and $\approx 0{,}1\ \mu$A respectively.
   Both tests are carried out according to ANSI–N42–9–1972 of IEEE recommendations.

6. Measured with a pulsed-light source, with a pulse duration (FWHM) of < 1 ns, the cathode being completely illuminated. The rise time is determined between 10% and 90% of the amplitude of the anode pulse. The signal transit time is measured between the instant at which the illuminating pulse at the cathode becomes maximum, and the instant at which the anode pulse attains its maximum. Rise time, pulse duration and transit time vary as a function of high tension supply voltage V_b, approximately as $V_b^{-1/2}$.

7. Total HT supply voltage or the voltage at which the tube has an anode luminous sensitivity of 600 A/lm, whichever is lower.

8. Minimum value to obtain good collection in the input optics.

9. When calculating the anode voltage the voltage drop across the load resistor should be taken into account.

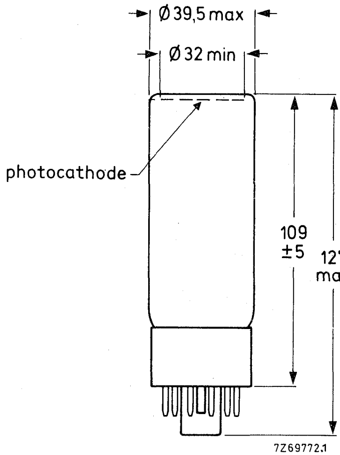
10. For type XP2008 this range of temperatures is limited principally by stresses in the sealing layer of the base to the glass bulb. Where low temperature operation is contemplated, the supplier should be consulted.

11. A value of $< 10\ \mu$A is recommended for applications requiring good stability.

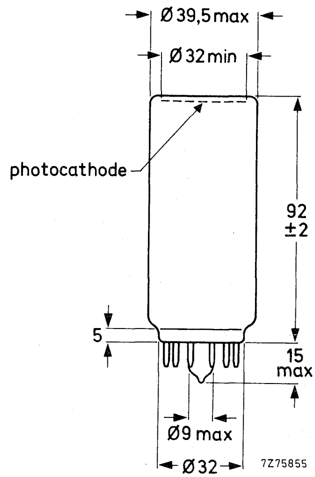
MECHANICAL DATA

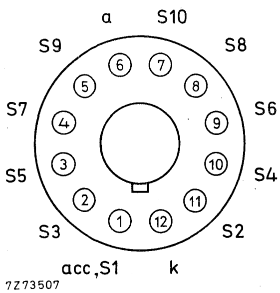
Dimensions in mm

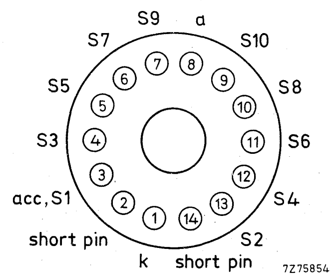
XP2008



XP2008UB







Base: 12-pin (JEDEC B12-43)
Net mass: 72 g

Base: 14-pin all-glass
Net mass: 54 g

ACCESSORIES

Socket:
for XP2008 type FE1012
for XP2008UB type FE1112

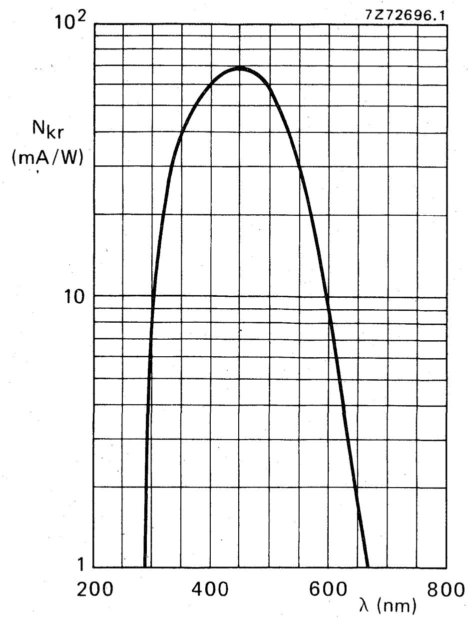


Fig. 3 Spectral sensitivity characteristic.

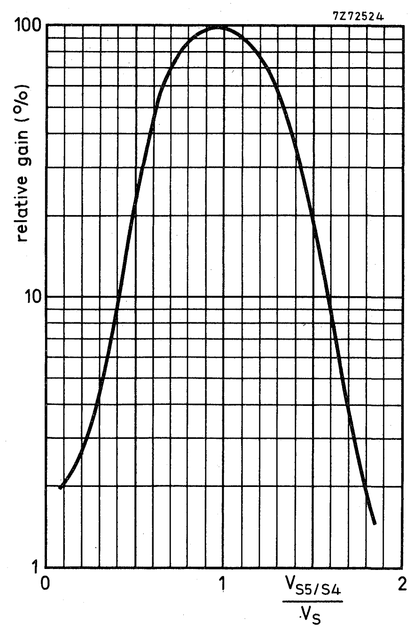


Fig. 4 Relative gain as a function of the voltage between S5 and S4, normalized to V_S. $V_{S6/S4}$ constant.

Note: Gain regulation by changing the voltage between S5 and S4 may cause a degradation of other parameters such as stability and linearity.

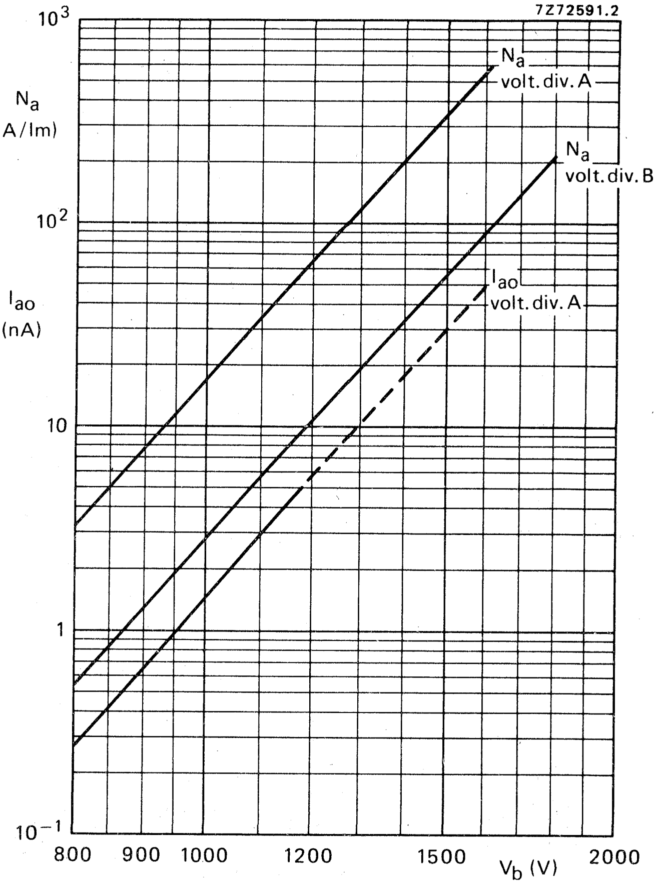


Fig. 5 Anode luminous sensitivity, N_a, and anode dark current, I_{ao}, as a function of supply voltage V_b.

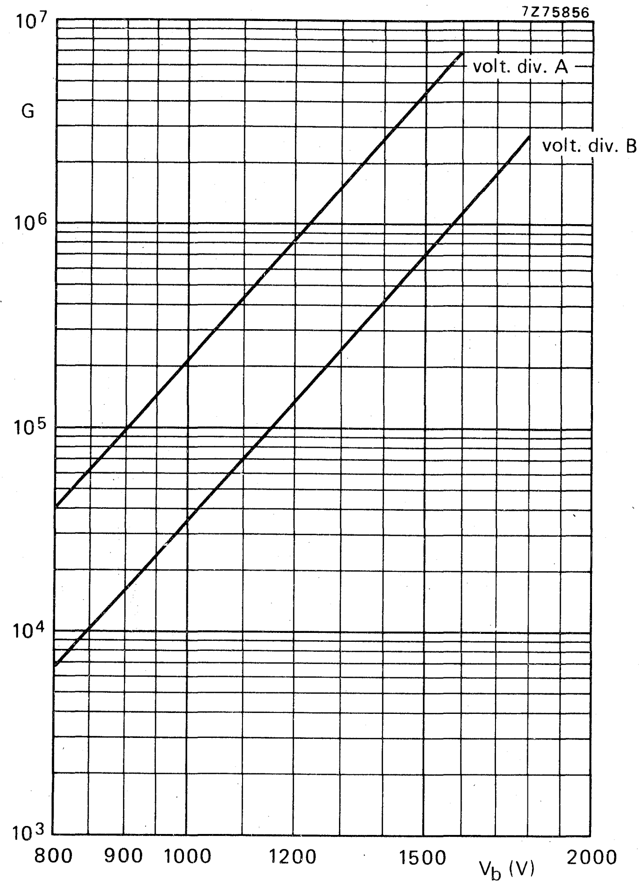


Fig. 6 Gain G as a function of supply voltage V_b.

10-STAGE PHOTOMULTIPLIER TUBE

The XP2010 is a 32 mm useful diameter head-on photomultiplier tube with a flat window and a semi-transparent Super A photocathode. The tube is intended for use in X-ray and γ-spectrometry.
Its CuBe dynode system offers a high stability.

QUICK REFERENCE DATA

Spectral sensitivity characteristic		Super A		
Useful diameter of the photocathode		>	32	mm
Spectral sensitivity of the photocathode at 437 nm		≈	80	mA/W
Supply voltage for anode luminous sensitivity N_a = 60 A/lm			1180	V
Pulse amplitude resolution for ^{55}Fe at N_a = 60 A/lm		≈	45	%
Mean anode sensitivity deviation		≈	1	%
Anode pulse rise time (with voltage divider B)		≈	2,5	ns
Linearity				
with voltage divider A	up to	≈	100	mA
with voltage divider B	up to	≈	200	mA

To be read in conjunction with "General Operational Recommendations Photomultiplier Tubes".

GENERAL CHARACTERISTICS

Window

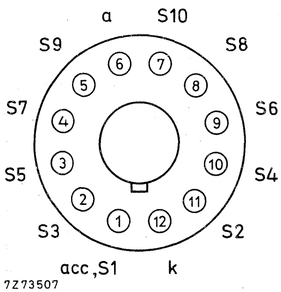
Shape	plano-plano		
Material	lime glass		
Refractive index at 550 nm		1,52	

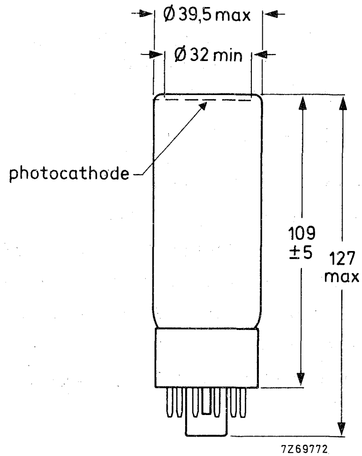
Photocathode

Semi-transparent, head-on			
Material	SbCs		
Useful diameter	>	32	mm
Spectral sensitivity characteristic (Fig.3)	type Super A		
Maximum sensitivity at		420 ± 30	nm
Luminous sensitivity	typ	90	μA/lm
	>	70	μA/lm
Spectral sensitivity at 437 ± 5 nm	≈	80	mA/W

MECHANICAL DATA

Dimensions in mm





Net mass:	72 g
Base:	12-pin (JEDEC B12–43)

ACCESSORIES

Socket:	type FE1012

10-STAGE PHOTOMULTIPLIER TUBES

The XP2012 and XP2012B are 32 mm useful diameter head-on photomultiplier tubes with a flat window and a semitransparant bialkaline type D photocathode. The tubes are intended for use in X-ray and γ-spectrometry and for all applications requiring a low background noise and/or dark current. Their Cu-Be dynode system offers a high stability. The XP2012B is provided with a 12-pin plastic base, the XP2012 has a 14-pin all-glass base.

QUICK REFERENCE DATA

Spectral sensitivity characteristic		type D		
Useful diameter of the photocathode		>	32	mm
Spectral sensitivity of the photocathode at 401 nm			77	mA/W
Supply voltage for an anode spectral sensitivity = 60 kA/W			1350	V
Pulse amplitude resolution				
for ^{57}Co at N_a = 10 kA/W		≈	11,2	%
for ^{55}Fe at Na = 60 kA/W		≈	42	%
Peak-to-valley ratio for ^{55}Fe at Na = 60 kA/W		≈	34	
Anode pulse rise time (with voltage divider B)		≈	2,5	ns
Mean anode sensitivity deviation		≈	1	%
Linearity				
with voltage divider A	up to	≈	100	mA
with voltage divider B	up to	≈	200	mA

To be read in conjunction with "General Operational Recommendations Photomultiplier Tubes".

GENERAL CHARACTERISTICS

Window

Shape	plano-plano		
Material	lime glass		
Refractive index at 550 nm		1,52	

Photocathode (note 1)

Semi-transparent, head-on	SbKCs		
Useful diameter	>	32	mm
Spectral sensitivity characteristic (Fig. 6)	type D		
Maximum sensitivity at		400 ± 30	nm
Spectral sensitivity at 401 ± 3 nm	typ.	77	mA/W
	>	60	mA/W

Electron optical input system

This system consists of: the photocathode, k; a metallized part of the glass envelope, internally connected to the photocathode; an accelerating electrode, acc, internally connected to S1.

Multiplier system

Number of stages		10
Dynode structure	linear focused	
Dynode material	Cu Be	
Capacitances		
Anode to all	≈	5 pF
Anode to final dynode	≈	3 pF

Magnetic field

When the photocathode is illuminated uniformly the anode current is halved (at V_b = 1200 V, voltage divider A):
— at a magnetic flux density of 0,6 mT in the direction of the longitudinal axis;
— at a magnetic flux density of 0,35 mT perpendicular to axis a (see Fig. below);
— at a magnetic flux density of 0,15 mT parallel to axis a.

It is recommended that the tube be screened against the influence of magnetic fields by a mu-metal shield protruding > 15 mm beyond the photocathode.

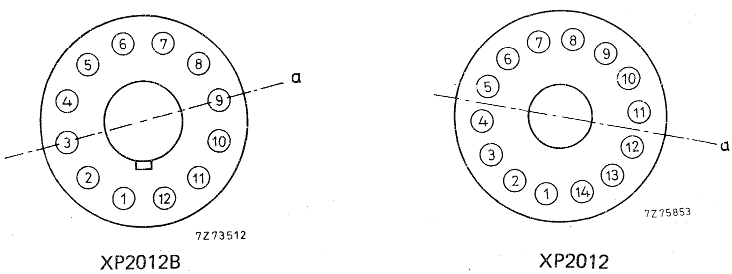


Fig. 1 Axis a with respect to base pins (bottom view).

RECOMMENDED CIRCUITS

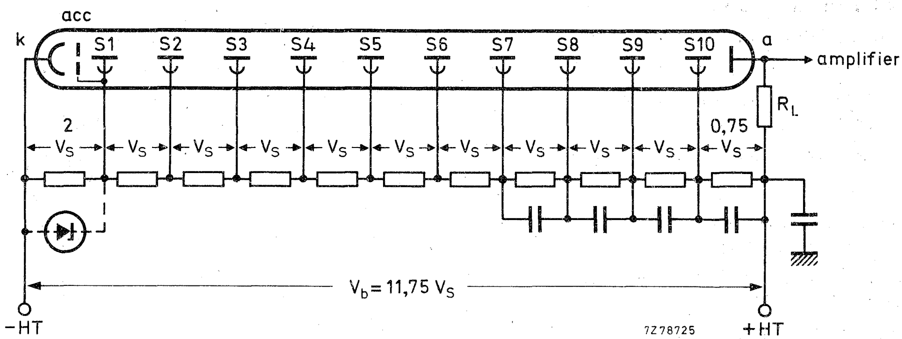


Fig. 2 Voltage divider A.

For optimum peak amplitude resolution it is recommended that the voltage between the first dynode and the photocathode be maintained at ≈ 200 V, e.g. by means of a voltage regulator diode.

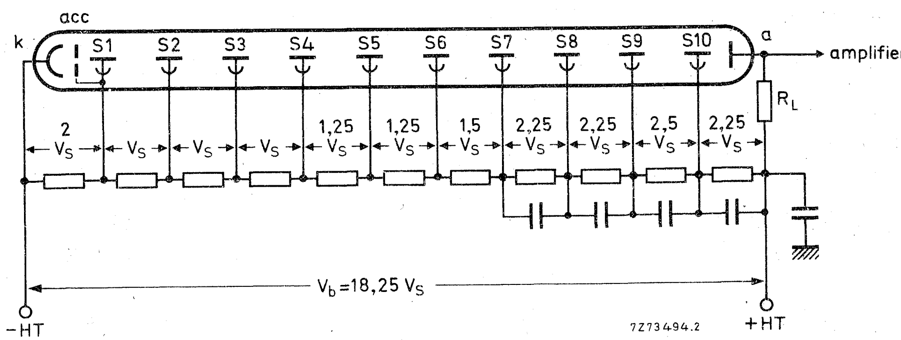


Fig. 3 Voltage divider B.

k = cathode
acc = accelerating electrode
S_n = dynode no.n
a = anode
R_L = load resistor

Typical values of capacitors: 10 nF

TYPICAL CHARACTERISTICS*

	note			
With voltage divider A (Fig. 2)	2			
Supply voltage for an anode spectral sensitivity of 60 kA/W (Fig. 8)			<	1600 V
			typ.	1350 V
for an anode spectral sensitivity of 300 kA/W (Fig. 8)			≈	1650 V
Anode dark current at an anode spectral sensitivity of 60 kA/W (Fig. 8)	3,4		<	20 nA ←
			typ.	1 nA
Pulse amplitude resolution for ^{137}Cs at N_{ar} = 10 kA/W	5		≈	7,2 %
Pulse amplitude resolution for ^{57}Co at N_{ar} = 10 kA/W	5		≈	11,2 %
Pulse amplitude resolution for ^{55}Fe at N_{ar} = 60 kA/W	6		≈	42 %
Peak-to-valley ratio for ^{55}Fe at N_{ar} = 60 kA/W	6		≈	34
Anode current linear within 2% at V_b = 1700 V		up to	≈	100 mA
Mean anode sensitivity deviation	13			
long term (16 h)			≈	1 %
after change of count rate			≈	1 %
versus temperature between 0 and + 40 °C at 450 nm			≈	0,2 %/°C
With voltage divider B (Fig. 2)	2			
Anode spectral sensitivity at V_b = 1700 V (Fig. 8)			≈	50 kA/W
Anode pulse rise time at V_b = 1700 V	7		≈	2,5 ns
Anode pulse duration at half-height at V_b = 1700 V	7		≈	6 ns
Signal transit time at V_b = 1700 V	7		≈	26 ns
Anode current linear within 2% at V_b = 1700 V		up to	≈	200 mA

LIMITING VALUES (Absolute maximum rating system)

	note		
Supply voltage	8	max.	1800 V
Continuous anode current	9	max.	0,2 mA
Voltage between first dynode and photocathode	10	max.	500 V
		min.	150 V
Voltage between consecutive dynodes		max.	300 V
Voltage between anode and final dynode	11	max.	300 V
		min.	30 V
Ambient temperature range			
Operational (for short periods of time)	12	max.	+ 80 °C
		min.	−30 °C
Continuous operation and storage		max.	+ 50 °C
		min.	−30 °C

* All spectral sensitivities refer to a wavelength of 401 nm.

Notes see page 5.

Notes

1. The bialkaline photocathode has a significant resistance which increases rapidly with reducing temperature. It is thus recommended that it should not be subjected to light of too great an intensity; the cathode current should be limited, for example, to 1 nA at room temperature or 0,1 nA at −30 °C. If too high a photocurrent is passed, the cathode can no longer be considered to be an equipotential surface, and the focusing of electrons onto the first dynode will be affected, resulting in departures of linearity.
2. To obtain a peak pulse current greater than that obtainable with divider A, it is necessary to increase the inter-dynode voltage of the stages progressively. Divider circuit B is an example of a "progressive" divider, giving a compromise between gain, speed, and linearity. Other dividers can be conceived to achieve other compromises. It is generally recommended that the increase in voltage between one stage and the next be kept less than a factor of 2.
3. Wherever possible, the photomultiplier power supply should be arranged so that the cathode is earthed and the anode is at +HT, however, it is sometimes necessary to supply the tube with the anode earthed and the cathode at −HT. Under these circumstances, erratic noise and dark current are generally increased and unstable, particularly immediately after application of voltage. The glass envelope of the tube should be supported only by isolators having an insulation resistance of $> 10^{15}\ \Omega$.
4. Dark current is measured at ambient temperature, after a stabilization period of the tube in darkness (≈ 1/4 h).
5. Pulse amplitude resolution for ^{137}Cs and ^{57}Co is measured with an NaI (Tl) cylindrical scintillator with a diameter of 32 mm and a height of 32 mm. The count rate used is ≈ 10^3 c/s.
6. Pulse amplitude resolution for ^{55}Fe is measured with an NaI (Tl) cylindrical scintillator with a diameter of 25 mm and a height of 1 mm provided with a beryllium window. The count rate used is ≈ 2 x 10^3 c/s.
7. Measured with a pulsed-light source, with a pulse duration (FWHM) of < 1 ns, the cathode being completely illuminated. The rise time is determined between 10% and 90% of the amplitude of the anode pulse. The signal transit time is measured between the instant at which the illuminating pulse at the cathode becomes maximum, and the instant at which the anode pulse attains its maximum. Rise time, pulse duration and transit time vary as a function of high tension supply voltage V_b, approximately as $V_b^{-1/2}$.
8. Total HT supply voltage or the voltage at which the tube has an anode spectral sensitivity of 600 kA/W, whichever is lower.
9. A value of < 10 μA is recommended for applications requiring high stability.
10. Minimum value to obtain good collection in the input optics.
11. When calculating the anode voltage the voltage drop across the load resistor should be taken into account.
12. For type XP2012B this range of temperatures is limited principally by stresses in the sealing layer of the base to the glass bulb.
13. The mean pulse amplitude deviation is measured by coupling an NaI (Tl) scintillator to the window of the tube. Long term (16 h) deviation is measured by placing a ^{137}Cs source at a distance from the scintillator such that the count rate is ≈ 10^4 c/s corresponding to an anode current of ≈ 300 nA.
    Mean pulse amplitude deviation after change of count rate is measured with a ^{137}Cs source at a distance of the scintillator such that the count rate can be changed from 10^4 c/s to 10^3 c/s corresponding to an anode current of ≈ 1 μA and ≈ 0,1 μA respectively.
    Both tests are carried out according to ANSI—N42—9—1972 of IEEE recommendations.

MECHANICAL DATA

Dimensions in mm

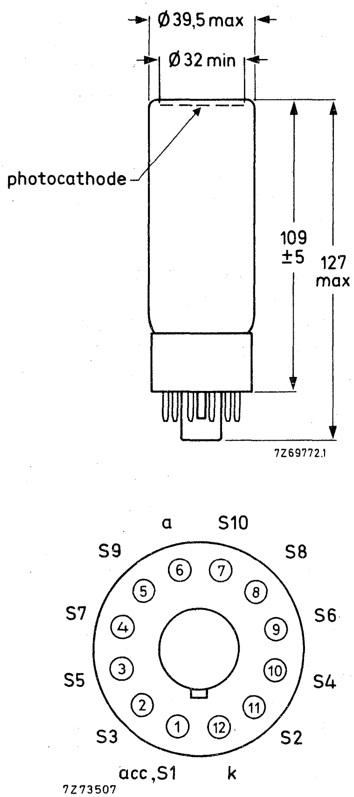


Fig. 4 XP2012B.

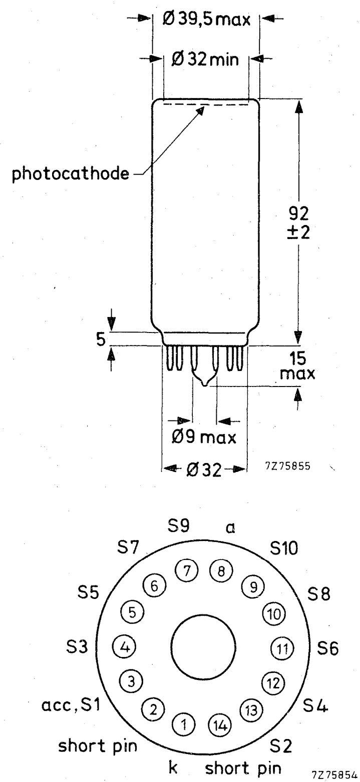


Fig. 5 XP2012.

Base: 12-pin (JEDEC B12-43)
Net mass: 72 g

Base: 14-pin all-glass
Net mass: 54 g

ACCESSORIES

Socket:
for XP2012B type FE1012
for XP2012 type FE1112

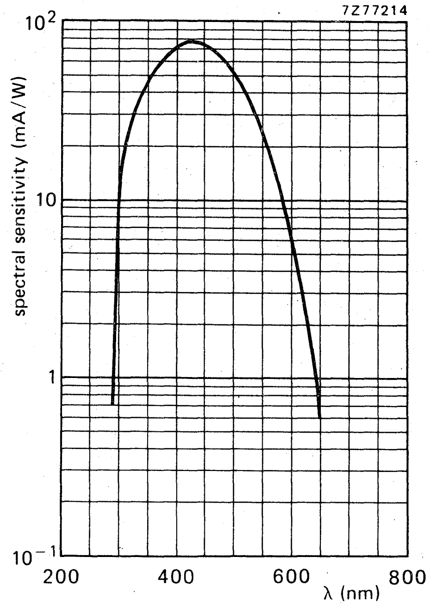


Fig. 6
Spectral sensitivity characteristic.

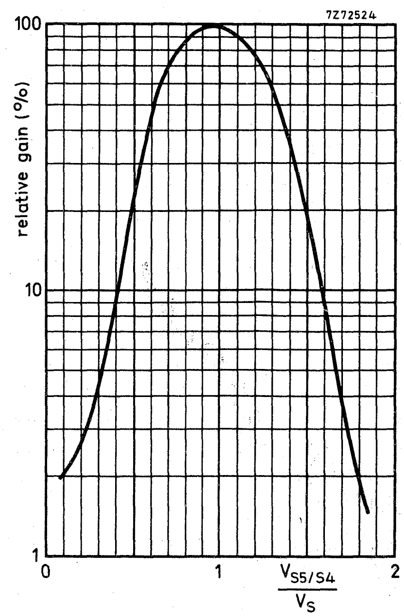


Fig. 7 Relative gain as a function of the voltage between S5 and S4, normalized to V_S. $V_{S6/S4}$ constant.

Note: Gain regulation by changing the voltage between S5 and S4 may cause a degradation of other parameters such as stability and linearity.

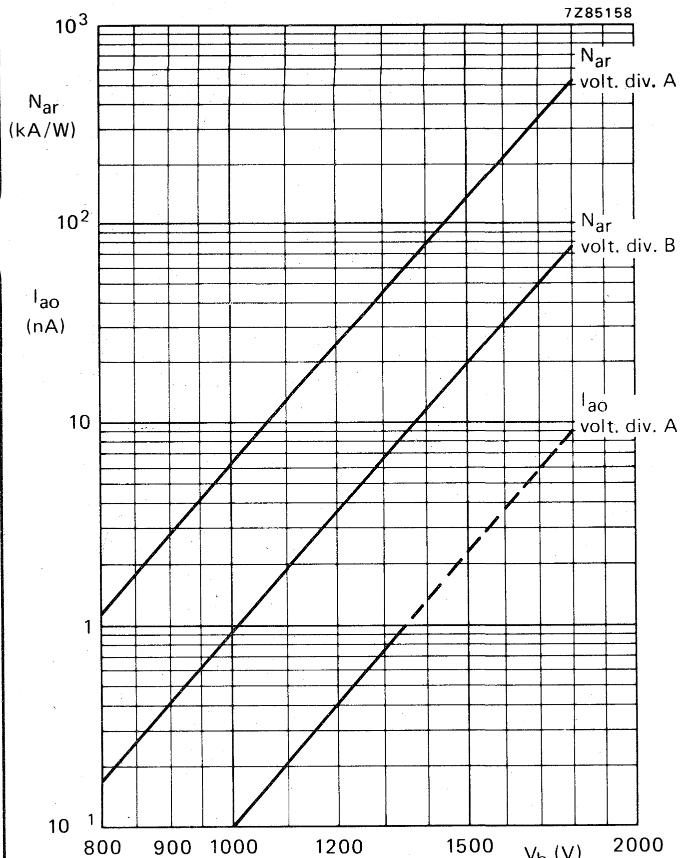


Fig. 8 Anode spectral sensitivity, N_{ar}, and anode dark current, I_{ao}, as a function of supply voltage V_b

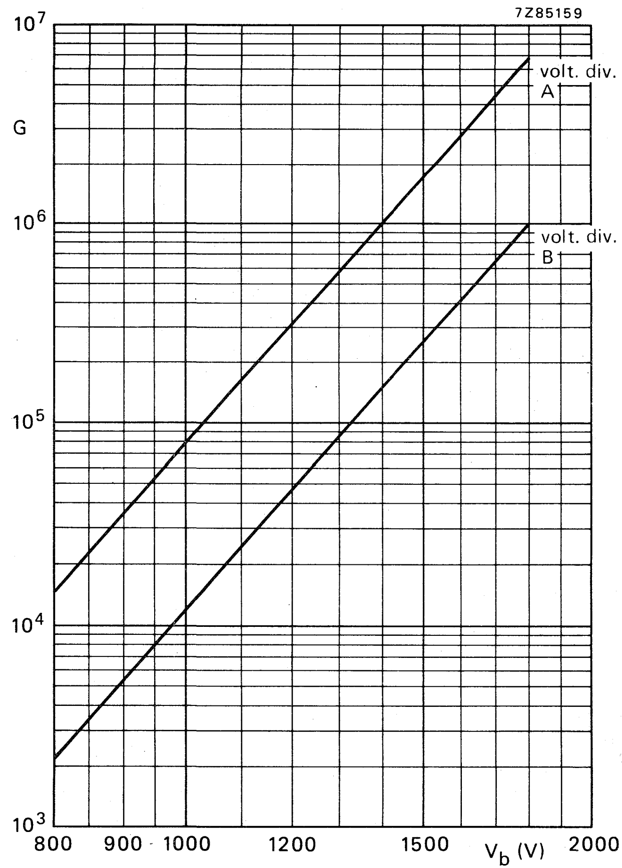


Fig. 9 Gain G as a function of supply voltage V_b.

10-STAGE PHOTOMULTIPLIER TUBE

The XP2013B is a 32 mm useful diameter head-on photomultiplier tube with a flat window and a semi-transparent trialkaline S20 (type T) photocathode. The tube is intended for use in low light level measurements in the entire part of the visible spectrum. Its CuBe dynode multiplier system offers a high stability which makes it especially suitable for industrial applications, such as laser reading.

QUICK REFERENCE DATA

Spectral sensitivity characteristic			S20 (type T)
Useful diameter of the photocathode		>	32 mm
Cathode spectral sensitivity at 698 nm			20 mA/W
Supply voltage for an anode luminous sensitivity of 60 A/lm			1250 V
Anode pulse rise time (with voltage divider B)		≈	2,5 ns
Linearity with voltage divider A	up to	≈	100 mA
with voltage divider B	up to	≈	200 mA

To be read in conjunction with *General Operational Recommendations Photomultiplier Tubes.*

GENERAL CHARACTERISTICS

Window (frosted)

Material	borosilicate
Shape	plano-plano
Refractive index at 550 nm	1,48

Photocathode

Semi-transparent, head-on

Material	SbNaKCs
Useful diameter	> 32 mm
Spectral sensitivity characteristic (Fig. 5)	S20 (type T)
Maximum spectral sensitivity at	420 ± 30 nm

Photocathode (continued)

Luminous sensitivity	≈ 200 μA/lm
Spectral sensitivity	
at 698 ± 7 nm	typ. 20 mA/W
	> 10 mA/W
at 629 ± 3 nm	≈ 40 mA/W

Multiplier system

Number of stages	10
Dynode structure	linear focused
Dynode material	CuBe
Capacitances	
anode to final dynode	≈ 3 pF
anode to all	≈ 5 pF

Magnetic field

When the photocathode is illuminated uniformly the anode current is halved (at V_b = 1200 V, voltage divider A) at a magnetic flux density of:
0,6 mT in the direction of the longitudinal axis;
0,35 mT perpendicular to axis a (see Fig. 1);
0,15 mT parallel to axis a.

It is recommended that the tube be screened against the influence of magnetic fields by a mu-metal shield protruding > 15 mm beyond the photocathode.

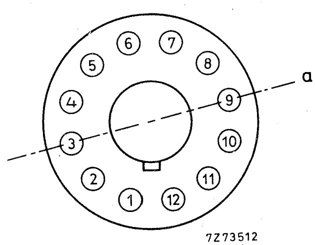


Fig. 1 Axis a with respect to base pins (bottom view).

RECOMMENDED CIRCUITS

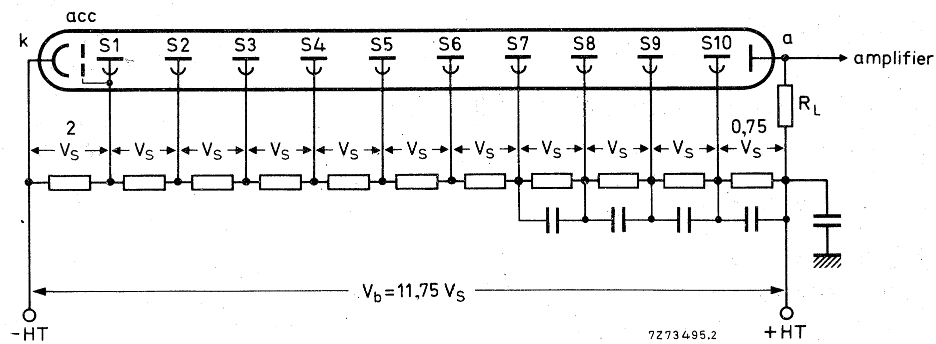


Fig. 2 Voltage divider A. Typical values of capacitors: 10 nF; k = cathode; acc = accelerating electrode; S_n = dynode no.; a = anode; R_L = load resistor.

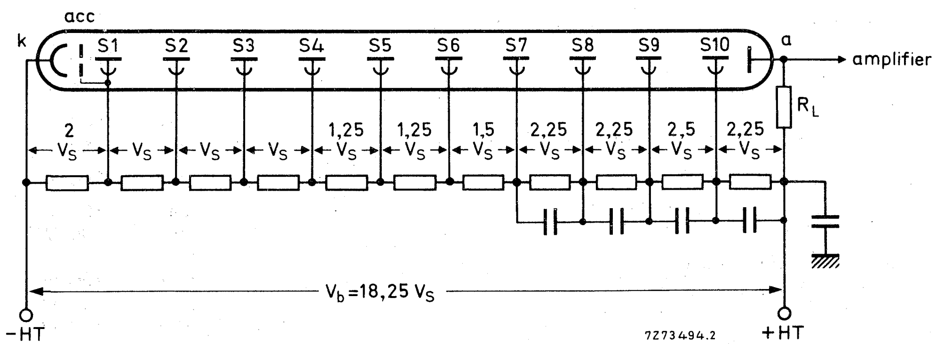


Fig. 3 Voltage divider B. Typical values of capacitors: 10 nF; k = cathode; acc = accelerating electrode; S_n = dynode no.; a = anode; R_L = load resistor.

TYPICAL CHARACTERISTICS

	note			
With voltage divider A (Fig. 2)	1			
Supply voltage for an anode luminous sensitivity N_a = 60 A/lm (Fig. 7)		typ.	1250	V
		<	1600	V
Anode dark current at N_a = 60 A/lm (Fig. 7)	2,3	typ.	2	nA
		<	50	nA
Anode current linear within 2% at V_b = 1700 V up to		≈	100	mA
Mean anode sensitivity deviation at V_b = 1000 V long term (16 h)	4	≈	1	%
With voltage divider B (Fig. 3)	1			
Anode luminous sensitivity at V_b = 1700 V (Fig. 7)		≈	90	A/lm
Anode pulse rise time at V_b = 1700 V	5	≈	2,5	ns
Anode pulse duration at half height at V_b = 1700 V	5	≈	6	ns
Signal transit time at V_b = 1700 V	5	≈	26	ns
Anode current linear within 2% at V_b = 1700 V up to		≈	200	mA

LIMITING VALUES (absolute maximum rating system)

	note			
Supply voltage	6	max.	1800	V
Continuous anode current	10	max.	0,2	mA
Voltage between first dynode and photocathode	7	max.	500	V
		min.	150	V
Voltage between consecutive dynodes		max.	300	V
Voltage between anode and final dynode	8	max.	300	V
		min.	30	V
Ambient temperature range	9			
operational (for short periods of time)		max.	+80	°C
		min.	−30	°C
continuous operation and storage		max.	+50	°C
		min.	−30	°C

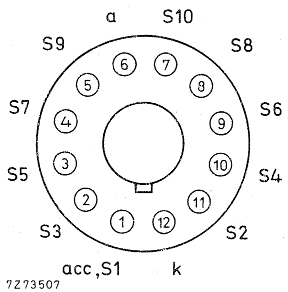
Notes see page 5.

Notes

1. To obtain a peak pulse current greater than that obtainable with divider A, it is necessary to increase the inter-dynode voltage of the stages progressively. Divider circuit B is an example of a "progressive" divider, giving a compromise between gain, speed, and linearity. Other dividers can be conceived to achieve other compromises. It is generally recommended that the increase in voltage between one stage and the next be kept less than a factor of 2.
2. Wherever possible, the power supply should be arranged so that the cathode is earthed and the anode is at +HT, however, it is sometimes necessary to supply the tube with the anode earthed and the cathode at −HT. Under these circumstances, erratic noise and dark current are generally increased and unstable, particularly after application of voltage. The glass envelope of the tube should be supported only by isolators having an insulation resistance of $> 10^{15}$ ohm.
3. Dark current is measured at ambient temperature, after a stabilization period of the tube in darkness (≈¼ h).
4. The mean anode sensitivity deviation measurement is carried out with light pulses at a count rate of $\approx 10^4$ c/s, resulting in an average anode current of 0,3 μA. See also *General Operational Recommendations Photomultiplier Tubes.*
5. Measured with a pulsed light source, with a pulse duration (FWHM) of < 1 ns: the cathode being completely illuminated. The rise time is determined between 10% and 90% of the amplitude of the anode pulse. The signal transit time is measured between the instant at which the illuminating pulse at the cathode becomes maximum, and the instant at which the anode pulse attains its maximum. Rise time, pulse duration and transit time vary as a function of high tension supply voltage V_b, approximately as $V_b^{-1/2}$.
6. Total HT supply voltage, or the voltage at which the tube has an anode luminous sensitivity of ≈ 600 A/lm, whichever is lower.
7. Minimum value to obtain good collection in the input optics.
8. When calculating the anode voltage the voltage drop across the load resistor should be taken into account.
9. This range of temperatures is limited by stresses in the sealing layer of the base to the glass bulb.
10. A value of < 10 μA is recommended for applications requiring good stability.

MECHANICAL DATA

Dimensions in mm



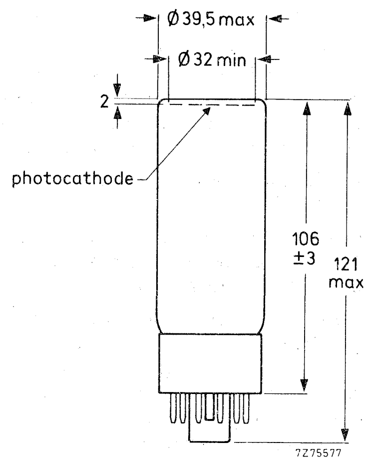


Fig. 4.

Remark

In order to improve the anode sensitivity over the entire cathode area the external surface of the window has been frosted.

Base	12-pin (JEDEC B12-43)
Net mass	81 g

ACCESSORIES

Socket	type FE1012

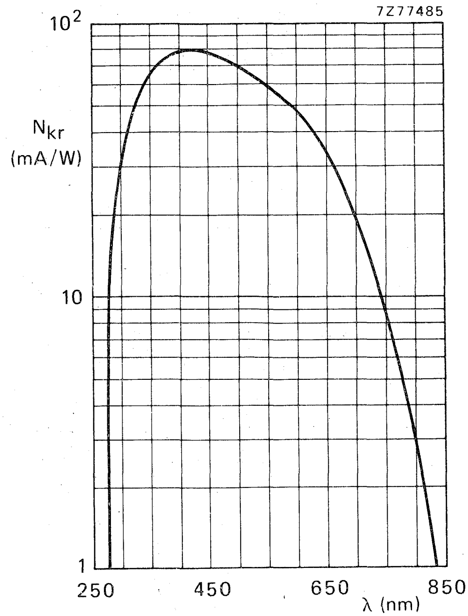


Fig. 5 Spectral sensitivity characteristic.

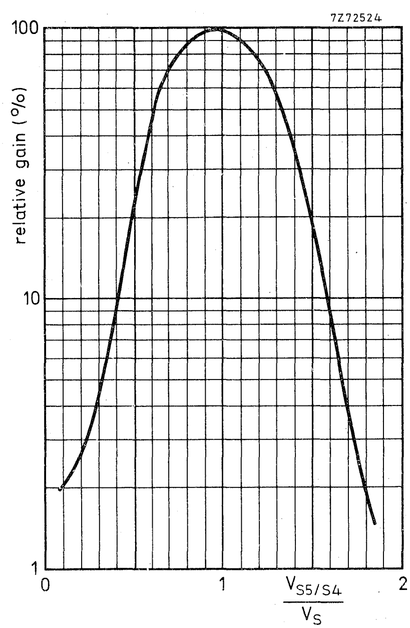


Fig. 6 Relative gain as a function of the voltage between S5 and S4, normalized to V_S. $V_{S6/S4}$ constant.

Note: Gain regulation by changing the voltage between S5 and S4 may cause a degradation of other parameters such as stability and linearity.

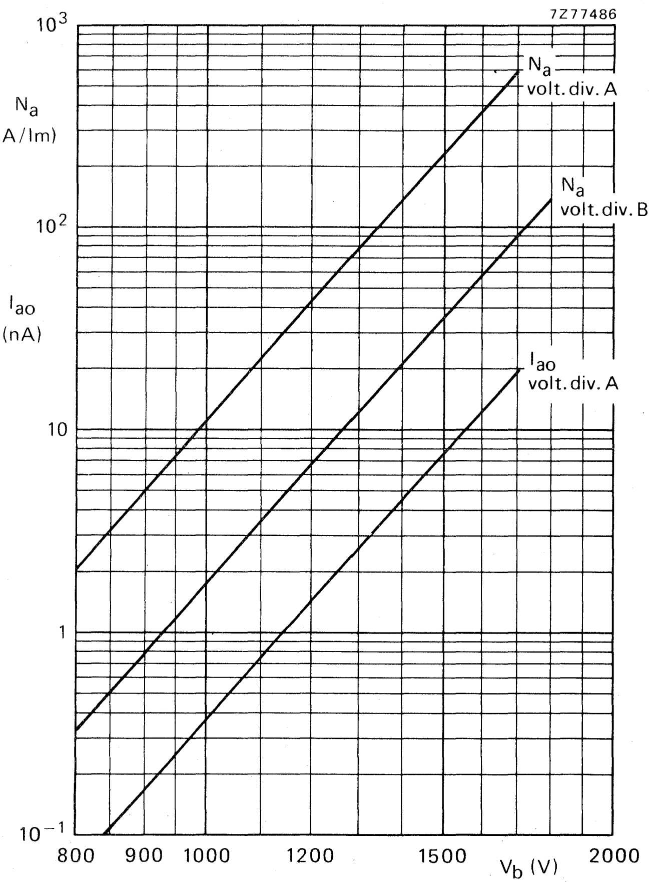


Fig. 7 Anode luminous sensitivity N_a, and anode dark current I_{ao} as a function of the supply voltage V_b.

12-STAGE PHOTOMULTIPLIER TUBE

The XP2020 and XP2020Q are 44 mm useful diameter head-on photomultiplier tubes with a plano-concave window and a semi-transparent type D photocathode. The tubes are intended for use in nuclear physics where the number of photons to be detected is very low. The tubes feature a high cathode sensitivity and a good linearity combined with very low background noise and extremely good time characteristics. They are especially useful in high-energy physics experiments where ultimate time characteristics are needed, such as coincidence measurements, Cerenkov detection, etc. The XP2020Q has a fused silica window enabling transmission at a wavelength of 160 nm and higher.

QUICK REFERENCE DATA

Spectral sensitivity characteristic	XP2020 XP2020Q	type D type DU			
Useful diameter of the photocathode			>	44	mm
Quantum efficiency at 401 nm					
XP2020				26	%
XP2020Q				25	%
Spectral sensitivity of the photocathode at 401 nm					
XP2020				85	mA/W
XP2020Q				80	mA/W
Supply voltage for a gain of 3×10^7				2200	V
Pulse amplitude resolution for ^{137}Cs			≈	7,5	%
Anode pulse rise time (with voltage divider B′)			≈	1,5	ns
Linearity, with voltage divider B	up to		≈	280	mA
Signal transit time distribution	σ		≈	0,25	ns

To be read in conjunction with *General Operational Recommendations Photomultiplier Tubes.*

GENERAL CHARACTERISTICS

Window

Material	
XP2020	borosilicate
XP2020Q	fused silica
Shape	plano-concave
Refractive index	
XP2020, at 550 nm	1,48
XP2020Q, at 400 nm	1,47
XP2020Q, at 250 nm	1,50

Photocathode (note 1)

Semi-transparent, head-on	
Material	SbKCs
Useful diameter	> 44 mm

Note, see page 6.

	XP2020	XP2020Q	
Spectral sensitivity characteristic	type D (Fig. 6)	type DU (Fig. 7)	
Maximum spectral sensitivity at	400 ± 30	400 ± 30	nm
Quantum efficiency at 401 nm	26	25	%
Spectral sensitivity at 401 ± 3 nm	typ. 85	typ. 80	mA/W
	> 60	> 60	mA/W

Multiplier system

Number of stages	12	
Dynode structure	linear focused	
Dynode material	CuBe	
Capacitances		
Grid 1 to k + S_1 + acc + g_2 + S_5	≈ 20	pF
Anode to final dynode	≈ 4	pF
Anode to all	≈ 7	pF

Magnetic field

See Fig. 13.

It is recommended that the tube be screened against the influence of magnetic fields by a mu-metal shield protruding > 15 mm beyond the photocathode.

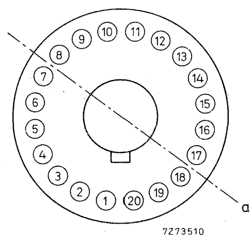


Fig. 1 Axis a with respect to base pins (bottom view).

RECOMMENDED CIRCUITS

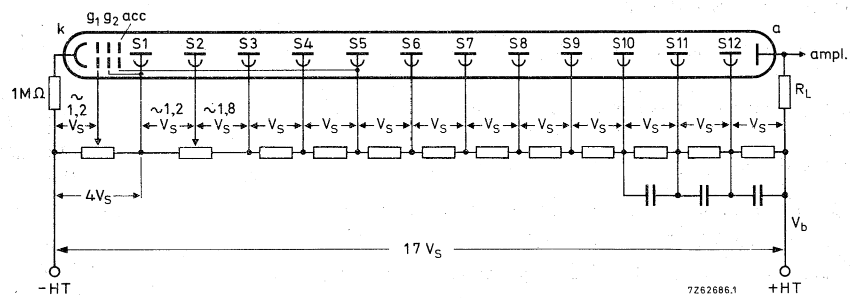


Fig. 2 Voltage divider type A.

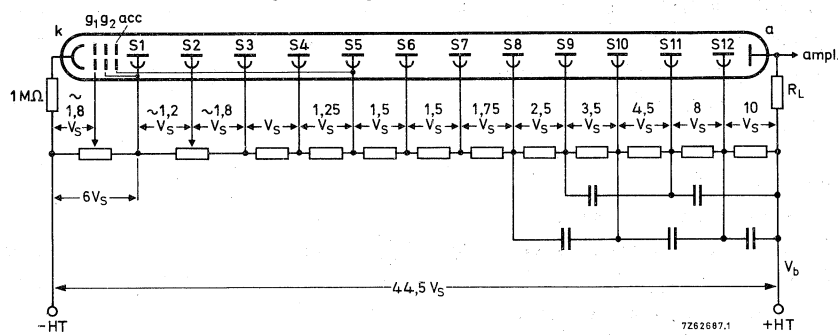


Fig. 3 Voltage divider type B.

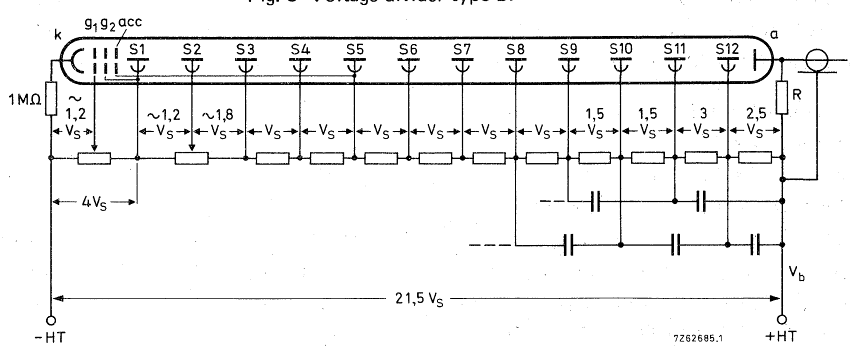


Fig. 4 Voltage divider type B'.

k	= cathode
g_1, g_2	= focusing electrodes
acc	= accelerating electrode
S_n	= dynode no. n
a	= anode
R_L	= load resistor

R = This resistor connects the anode when the output cable is not terminated. Recommended value: 10 kΩ.

The cathode resistor of 1 MΩ limits the current in case of unintentional contact between the conductive coating and earth when the anode is earthed.
Typical value of capacitors: 1 nF.

TYPICAL CHARACTERISTICS

	note			
With voltage divider A (Fig. 2)	2			
Supply voltage for a gain of 3×10^7 (Fig. 8)			typ. <	2200 V 2600 V
Anode dark current at a gain of 3×10^7 (Fig. 8)	3,4		typ. <	7 nA 100 nA
Background noise at a gain of 3×10^7 (Fig. 11)	5		typ. <	900 c/s 2500 c/s
→ Pulse amplitude resolution for ^{55}Fe at a gain of 3×10^7	6		≈	43 %
Peak to valley ratio for ^{55}Fe at a gain of 3×10^7			≈	34
Pulse amplitude resolution for ^{137}Cs at V_b = 1500 V	6		≈	7,5 %
Anode pulse rise time at V_b = 2000 V	7,13		≈	1,6 ns
Anode pulse duration at half height at V_b = 2000 V	7,13		≈	3,7 ns
Signal transit time at V_b = 2000 V	7,13		≈	28 ns
Anode current linear within 2% at V_b = 2000 V		up to	≈	25 mA
Obtainable peak anode current			≈	100 mA
With voltage divider B (Fig. 3)	2			
Gain at V_b = 2800 V			≈	2×10^6
Anode pulse rise time at V_b = 2800 V	7,13		≈	1,7 ns
Anode pulse duration at half height at V_b = 2800 V	7,13		≈	2,7 ns
Signal transit time at V_b = 2800 V	7,13		≈	31 ns
Signal transit time difference between the centre of the photocathode and 18 mm from the centre at V_b = 2800 V			≈	0,25 ns
Anode current linear within 2% at V_b = 2800 V		up to	≈	280 mA
Obtainable peak anode current			≈	0,5 to 1 A
With voltage divider B′ (Fig. 4)	2			
Gain at V_b = 2500 V			≈	2×10^7
Anode pulse rise time at V_b = 2500 V	7,13		≈	1,5 ns
Anode pulse duration at half height at V_b = 2500 V	7,13		≈	2,4 ns
Signal transit time at V_b = 2500 V	7,13		≈	30 ns
Signal transit time distribution at V_b = 2500 V	12,13	σ	≈	0,25 ns
Signal transit time difference between the centre of the photocathode and 18 mm from the centre at V_b = 2500 V			≈	0,25 ns
Anode current linear within 2% at V_b = 2500 V		up to	≈	70 mA
Obtainable peak anode current			≈	250 mA

Notes see page 6.

LIMITING VALUES (Absolute maximum rating system)	note		
Supply voltage	8	max.	3000 V
Continuous anode current	14	max.	0,2 mA
Voltage between focusing electrode, g_1 and photocathode		max.	300 V
Voltage between first dynode and photocathode	9	max.	800 V
		min.	300 V
Voltage between consecutive dynodes (except S_{11} and S_{12})		max.	400 V
Voltage between dynodes S_{11} and S_{12}	13	max.	600 V
Voltage between anode and final dynode	10	max.	700 V
		min.	80 V
Ambient temperature range	11		
operational (for short periods of time)		max.	+80 °C
		min.	−30 °C
continuous operation and storage		max.	+50 °C
		min.	−30 °C

Notes see page 6.

Notes to pages 1, 4 and 5

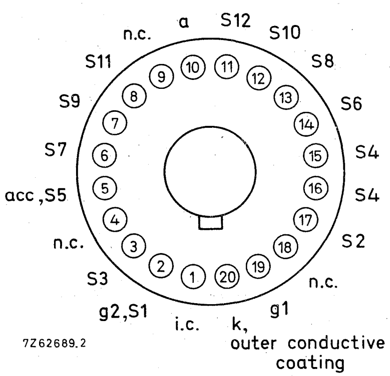
1. The bialkaline photocathode has a significant resistance which increases rapidly with reducing temperature. It is thus recommended that it should not be subjected to light of too great an intensity; the cathode current should be limited to, for example, 1 nA at room temperature or 0,1 nA at −30 °C. If too high a photocurrent is passed, the cathode can no longer be considered to be an equipotential surface, and the focusing of electrons onto the first dynode will be affected, resulting in departure of linearity.
2. To obtain a peak pulse current greater than that obtainable with divider A, it is necessary to increase the inter-dynode voltages of the stages progressively. Dividers B and B′ are examples of "progressive" dividers, each giving a compromise between gain, speed, and linearity. Other dividers can be conceived to achieve other compromises. It is generally recommended that the increase in voltage between one stage and the next be kept less than a factor of 2.
3. Wherever possible, the power supply should be arranged so that the cathode is earthed and the anode is at + HT, however, it is sometimes necessary to supply the tube with the anode earthed and the cathode at −HT. Under these circumstances, erratic noise and dark current are generally increased and unstable, particularly immediately after application of voltage. The tube is provided with a conductive coating connected to the cathode. It is recommended that, if a metal shield is used, this should be kept at cathode potential. This implies safety precautions to protect the user. The envelope of the tube should be supported only by isolators having an insulation resistance of $> 10^{15}\ \Omega$.
4. Dark current is measured at ambient temperature, after a stabilization period of the tube in darkness (≈ ¼ h).
5. After having been stored with its protective hood, the tube is placed in darkness with V_b set to a value to give a gain of 3×10^7. After a 30 min. stabilization period noise pulses with a threshold of $4{,}25 \times 10^{-13}$ C (corresponding to 0,1 photoelectron) are recorded (Fig. 9).
6. Pulse amplitude resolution for ^{55}Fe is measured with a NaI (Tl) cylindrical scintillator with a diameter of 19 mm and a height of 3 mm. The count rate is $\approx 10^3$ c/s. Pulse amplitude resolution for ^{137}Cs is measured with a NaI (Tl) cylindrical scintillator with a diameter of 44 mm and a height of 50 mm. The count rate is $\approx 10^4$c/s.
7. Measured with a pulsed light source, with a pulse duration (FWHM) of < 1 ns, the cathode being completely illuminated. The rise time is determined between 10% and 90% of the amplitude of the anode pulse. The signal transit time is measured between the instant at which the illuminating pulse at the cathode becomes maximum, and the instant at which the anode pulse attains its maximum. Rise time, pulse duration and transit time vary as a function of high tension supply voltage V_b, approximately as $V_b^{-1/2}$.
8. Total HT supply voltage, or the voltage at which the tube has a gain of 2×10^8, whichever is lower.
9. Minimum value to obtain good collection in the input optics.
10. When calculating the anode voltage the voltage drop across the load resistor should be taken into account.
11. This range of temperatures is limited principally by stresses in the sealing layer of the base to the glass bulb. Where low temperature operation is contemplated, the supplier should be consulted.
12. Transit time fluctuations of single electrons leaving the photocathode result in a transit time distribution at the anode. This distribution is characterized by its standard deviation σ.
13. Non-inductive resistors of 51 Ω are incorporated in the base connected to S_{11} and S_{12}. See also *General Operational Recommendations Photomultiplier Tubes.*
14. A value of $< 10\ \mu$A is recommended for applications requiring good stability.

MECHANICAL DATA

Dimensions in mm

(1) **Warning:**

The envelope of the tube is covered with a conductive coating, connected to the cathode.
Care should be taken to avoid hazard due to electric shock.



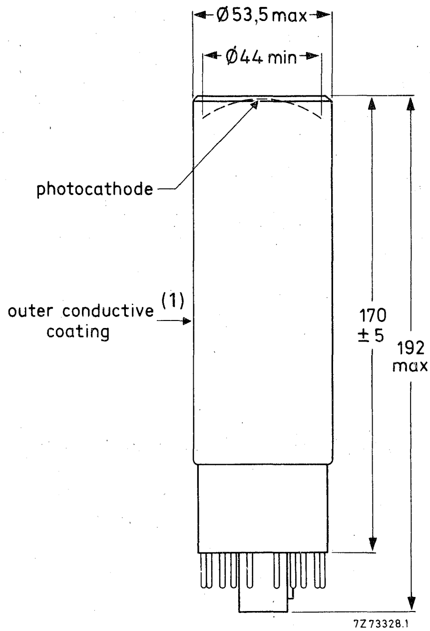


Fig. 5.

The base connections of the XP2020 are such that the tube is unilaterally interchangeable with the 56AVP-family tubes.

Base	20-pin (JEDEC B20-102)
Net mass	240 g

ACCESSORIES

Socket	type FE1020

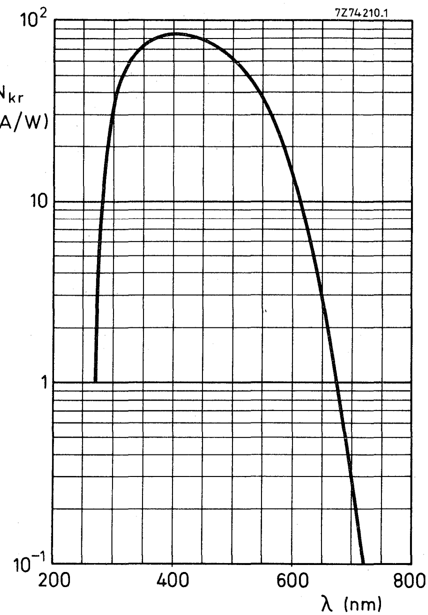


Fig. 6 Spectral sensitivity characteristic XP2020.

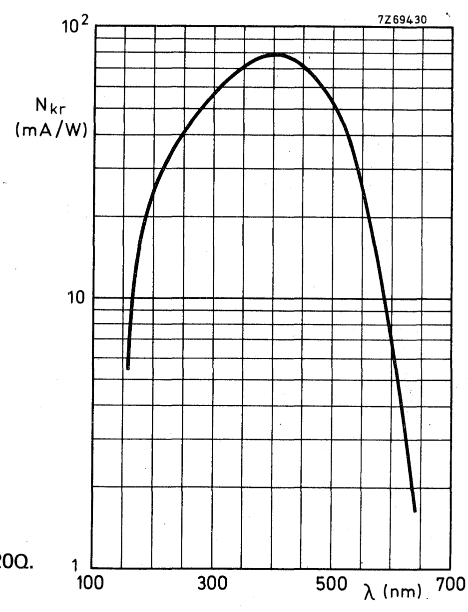


Fig. 7 Spectral sensitivity characteristic XP2020Q.

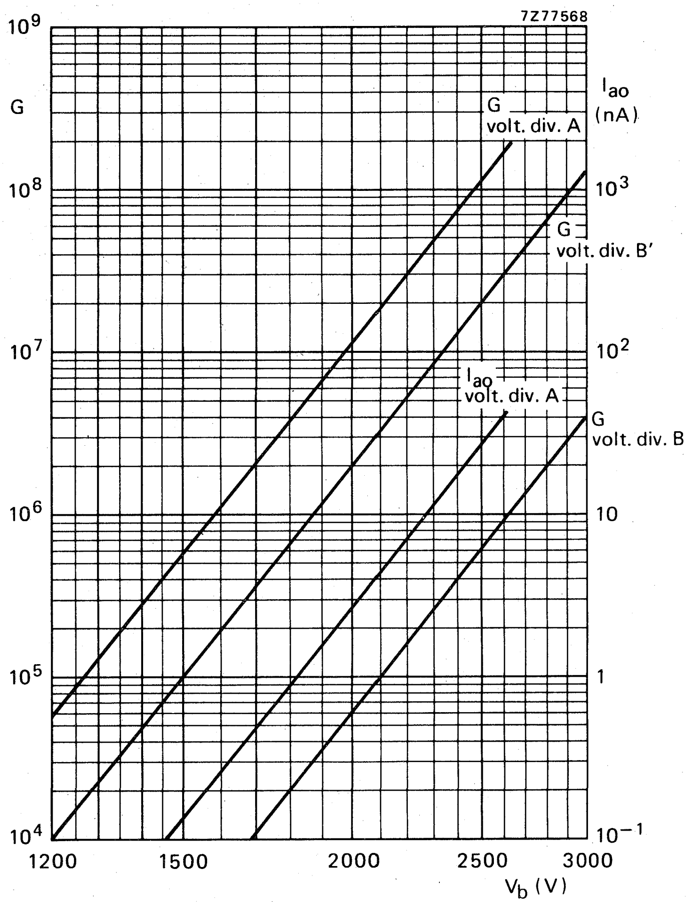


Fig. 8 Gain, G, and anode dark current, I_{ao}, as a function of supply voltage V_b.

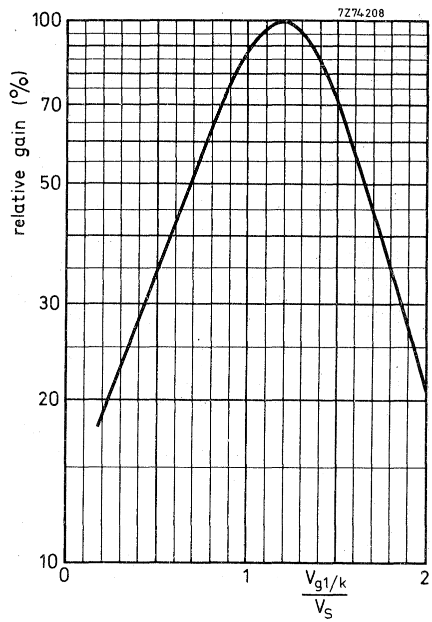


Fig. 9 Relative gain as a function of the voltage between grid 1 and cathode, normalized to V_S. $V_{S1/k}$ constant.

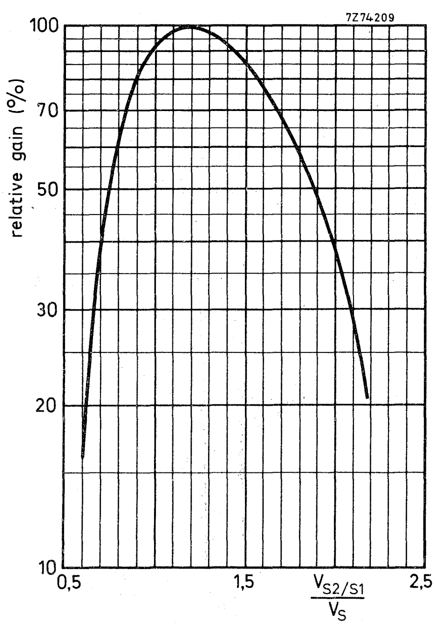


Fig. 10 Relative gain as a function of the voltage between S_2 and S_1, normalized to V_S. $V_{S3/S1}$ constant.

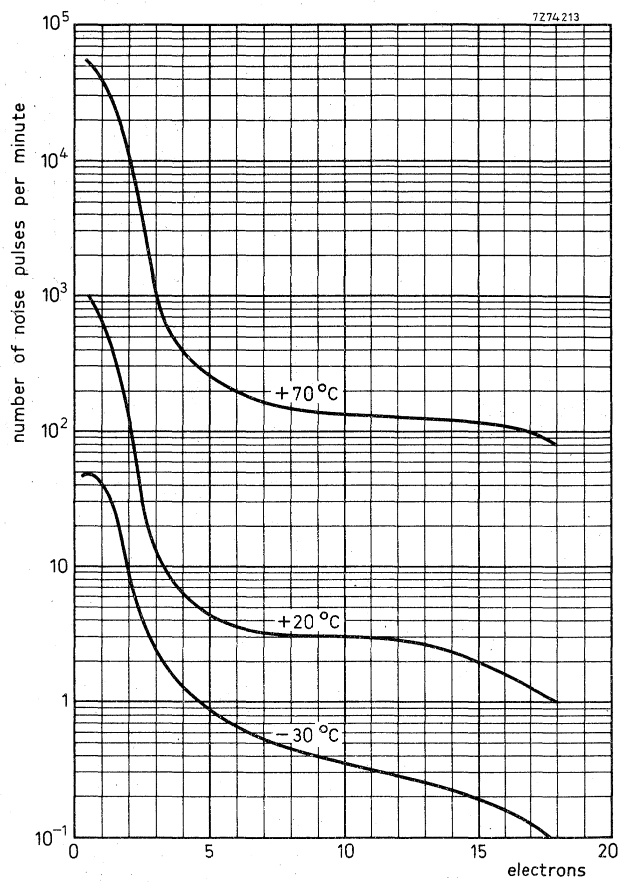


Fig. 11 Typical background spectrum from 0,1 to 18 equivalent photoelectrons, at a gain of 3×10^7 with voltage divider A.

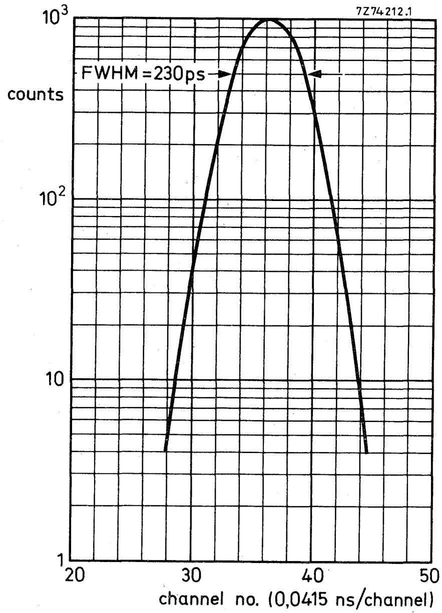


Fig. 12 Time resolution for 2 tubes XP2020 in coincidence. Measuring conditions:
Number of photoelectrons ≈ 1500
Supply voltage 2500 V
Constant fraction operation
Dynamic energy region 20%.

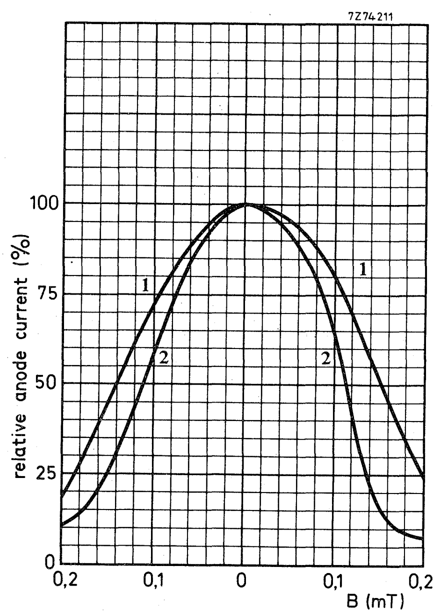


Fig. 13 Relative anode current as a function of the magnetic flux density B.
1. ⊥ axis a
2. // axis a

14-STAGE PHOTOMULTIPLIER TUBE

The XP2040 (XP2040Q) is a 110 mm useful diameter head-on photomultiplier tube with a concave-convex window and a semi-transparent S11 (type A) photocathode.
The tube is intended for use in nuclear physics where the number of photons to be detected is very low or where good time characteristics are required (coincidence measurements, Cerenkov counters).
A plano-concave plastic adapter supplied with tube type XP2040 enables transmission from 300 nm. The XP2040Q is supplied with a plano-concave fused silica adapter enabling transmission at a wavelength of 200 nm and higher.

QUICK REFERENCE DATA

Spectral sensitivity characteristic			S11 (type A) extended ultraviolet	
Useful diameter of the photocathode		>	110	mm
Supply voltage for a gain of 3 x 10^7			2000	V
Cathode spectral sensitivity at 437 nm			70	mA/W
Anode pulse rise time (with voltage divider B')		≈	2	ns
Linearity,				
with voltage divider A	up to	≈	30	mA
with voltage divider B	up to	≈	280	mA
with voltage divider B'	up to	≈	80	mA

To be read in conjunction with "General Operational Recommendations Photomultiplier Tubes".

GENERAL CHARACTERISTICS

Window

Glass: Ultraviolet transmitting (type Schott 8337 or equivalent) [1]		
Shape	concave-convex	
Radius of curvature	183 ± 5	mm
Refractive index at 550 nm	1,48	

[1] This glass window must be protected from humidity.

Photocathode

Semi-transparent, head on			
Useful diameter	>	110	mm
Spectral sensitivity characteristic (Fig. 4)		S11 (type A) extended ultraviolet	
Material		Sb-Cs	
Maximum spectral sensitivity at		420 ± 30	nm
Luminous sensitivity	typ.	70	µA/lm
	>	45	µA/lm
Spectral sensitivity at 437 ± 5 nm	≈	70	mA/W

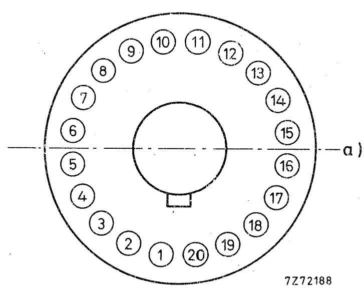
Multiplier system

Number of stages			14	
Dynode structure			linear focused	
Dynode material			Cu-Be	
Capacitances				
Grid no. 1 to k+g2+acc+S1	$C_{g1/k, g2, acc, S1}$	≈	70	pF
Anode to final dynode	$C_{a/S14}$	≈	5	pF
Anode to all	C_a	≈	7	pF

Magnetic field

When the photocathode is illuminated uniformly the anode current is halved (at V_b = 1900 V, voltage divider A):
- at a magnetic flux density of 0, 15 mT in the direction of the longitudinal axis ;
- at a magnetic flux density of 0, 13 mT perpendicular to axis a) (see Fig. below).
- at a magnetic flux density of 0, 05 mT parallel to axis a)

It is recommended that the tube be screened against the influence of magnetic fields by a mu-metal shield protruding > 15 mm beyond the photocathode.



Axis a) with respect to base pins (bottom view).

RECOMMENDED CIRCUITS

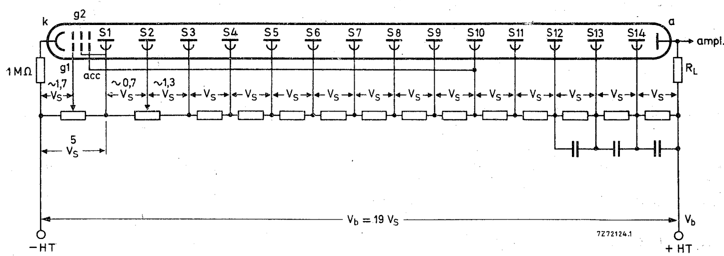


Fig. 1 Voltage divider A

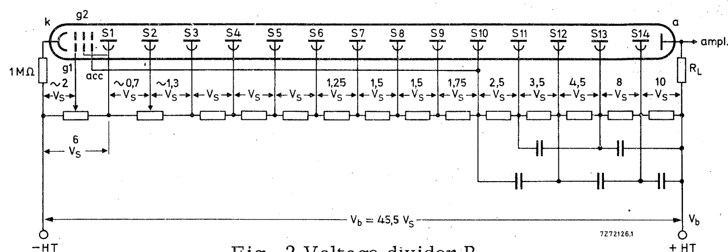


Fig. 2 Voltage divider B

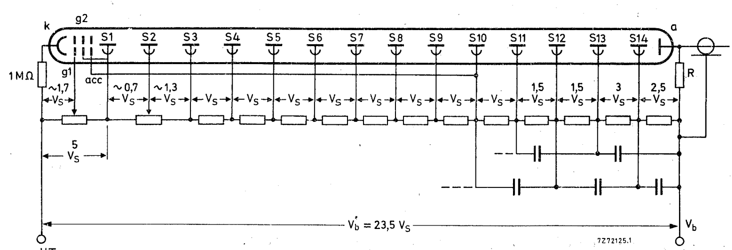


Fig. 3 Voltage divider B'

k = cathode
g_1, g_2 = focusing electrodes
acc = accelerating electrode
S_n = dynode no. n
a = anode
R_L = load resistor

R = This resistor serves to connect the anode when the output cable is not terminated. Recommended value 10 kΩ.

The cathode resistor of 1 MΩ limits the current in case of unintentional contact between the conductive coating and earth when the anode is earthed.

The voltage between k and g1 should be adjusted at about 1,7 V_S for voltage dividers A and B' or at about 2 V_S for voltage divider B.

The voltage between S_1 and S_2 should be adjusted at about 0,7 V_S.
Typical value of capacitors: 1 nF.

TYPICAL CHARACTERISTICS

With voltage divider A (Fig. 1)

Supply voltage for a gain G of 3×10^7, Fig. 6	1)	<	2700	V
		typ.	2000	V
Anode dark current at $G = 3 \times 10^7$, Fig. 6	1) 2)	<	4	µA
		typ.	0,2	µA
Anode pulse rise time at V_b = 2200 V	3) 4)	≈	2,5	ns
Anode pulse width at half height at V_b = 2200 V	3)	≈	5	ns
Signal transit time at V_b = 2200 V	3)	≈	46	ns
Anode current linear within 2%, at V_b = 2200 V up to		≈	30	mA
Obtainable peak anode current		≈	200	mA

With voltage divider B (Fig. 2) 5)

Gain at V_b = 2800 V, Fig. 6		≈	1×10^7	
Anode pulse rise time at V_b = 2800 V	3) 4)	≈	2,1	ns
Anode pulse width at half height at V_b = 2800 V	3)	≈	3	ns
Signal transit time at V_b = 2800 V	3)	≈	49	ns
Signal transit time difference between the centre of the photocathode and 50 mm from the centre, at V_b = 2800 V		≈	1	ns
Anode current linear within 2%, at V_b = 2800 V up to		≈	280	mA
Obtainable peak anode current		≈	0,5 to 1,0	A

With voltage divider B' (Fig. 3) 5)

Gain at V_b = 2500 V, Fig. 6		≈	5×10^7	
Anode pulse rise time at V_b = 2500 V	3) 4)	≈	2	ns
Anode pulse width at half height at V_b = 2500 V	3)	≈	3	ns
Signal transit time at V_b = 2500 V	3)	≈	46	ns
Signal transit time difference between the centre of the photocathode and 50 mm from the centre, at V_b = 2500 V		≈	1	ns
Anode current linear within 2%, at V_b = 2500 V up to		≈	80	mA
Obtainable peak anode current		≈	500	mA

Notes see page 5.

Notes to page 4

1) Wherever possible, the photomultiplier power supply should be arranged so that the cathode is earthed and the anode is at +HT, however, it is sometimes necessary to supply the tube with the anode earthed and the cathode at -HT. Under these circumstances, erratic noise and dark current are generally increased and unstable, particularly immediately after application of voltage. The tube is provided with a conductive coating connected to the cathode. It is recommended to keep the metal envelope at cathode potential. This implies safety precautions to protect the user.

2) Dark current is measured at ambient temperature, after a stabilization period of the tube in darkness (≈1/4 h).

3) Measured with a pulsed light source with a pulse duration of < 1 ns ; the cathode being completely illuminated.
The rise time is determined between 10% and 90% of the amplitude of the anode pulse. The signal transit time is measured between the instant at which the illuminating pulse at the cathode becomes maximum, and the instant at which the anode pulse attains its maximum. Rise time, pulse width, and transit time vary as a function of the HT supply voltage V_b, approximately as $V_b^{-1/2}$.

4) A non-inductive resistor of 50 Ω is incorporated in the base, connected to S14. See also "General Operational Recommendations Photomultiplier tubes".

5) Divider circuits B and B' are examples of "progressive dividers", each giving a compromise between gain, speed, and linearity. Other dividers can be conceived to achieve other compromises. It is generally advisable to keep the increase in voltage between one stage and the next to less than a factor 2.

LIMITING VALUES (Absolute max. rating system)

Supply voltage	1)	max.	3000	V
Continuous anode current	5)	max.	0,2	mA
Voltage between first dynode and photocathode	2)	max.	800	V
		min.	400	V
Voltage between focusing electrode g_1 and photocathode		max.	300	V
Voltage between accelerating electrode and photocathode		max.	18	V_S
		min.	14	V_S
Voltage between consecutive dynodes		max.	500	V
Voltage between anode and final dynode	3)	max.	500	V
		min.	80	V
Ambient temperature range	4)			
Operational (for short periods of time)		max.	+80	°C
		min.	-30	°C
Continuous operation and storage		max.	+50	°C
		min.	-30	°C

---

1) Total HT supply voltage, or the voltage at which the tube circuited in voltage divider "A" has a gain of 3×10^8, whichever is lower.

2) Minimum value to obtain good collection in the input optics.

3) When calculating the anode voltage the voltage drop across the load resistor should be taken into account.

4) This range of temperatures is limited principally by stresses in the sealing layer of the base to the glass bulb.
Where low temperature operation is contemplated, the supplier should be consulted.

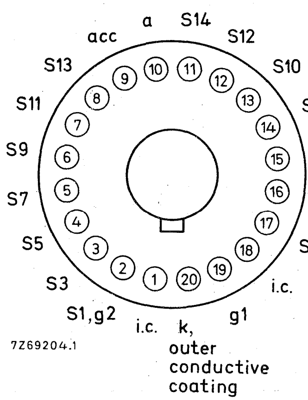
5) For applications requiring a high stability a value of < 10 µA is recommended.

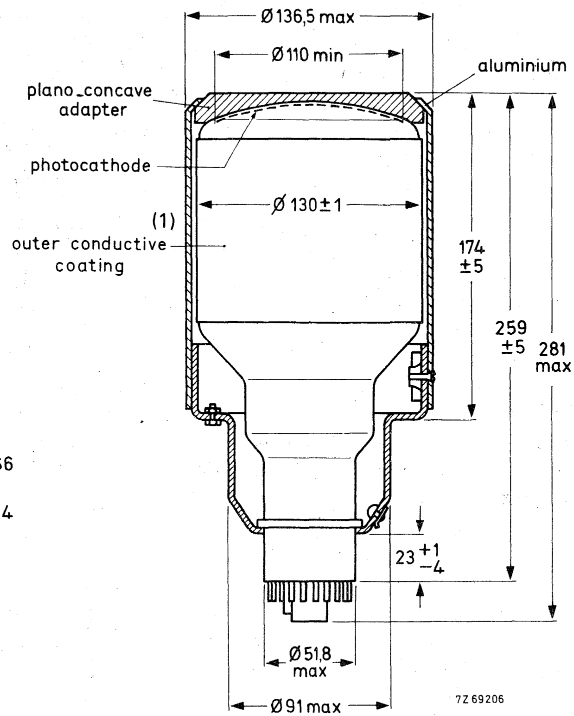
MECHANICAL DATA

Dimensions in mm

(1) **Warning:**

The envelope of the tube is covered with a conductive coating connected to the cathode.
Care should be taken to avoid hazard due to electric shock. See also note 1 on page 5.





Base: 20-pin (JEDEC B20-102)

Net mass: 1340 g

CAUTION

Care should be taken in handling this larger diameter tube because of the risk of implosion.

ACCESSORIES

Socket type FE1020

The XP2040 may be used with the base assembly S5630/03, consisting of two magnetic shields, a voltage divider, a mechanical system with provisions for mounting the photomultiplier tube and a scintillator. Details available on request.

Optical coupling silicone grease is supplied with each tube. This grease should be applied to the adapter-photomultiplier interface before operation.

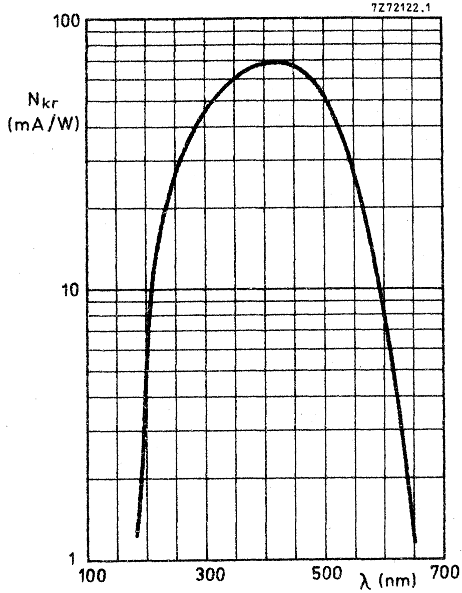


Fig. 4.

Spectral sensitivity characteristic (without adapter, or with fused silica adapter).

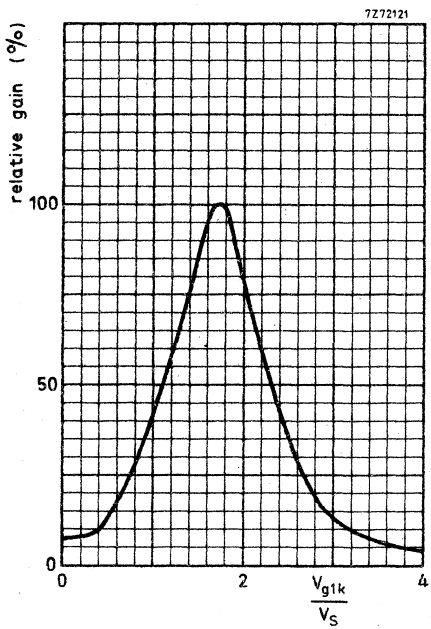


Fig. 5

Relative gain as a function of the voltage between focusing electrode g_1 and photocathode k, normalized to V_S.

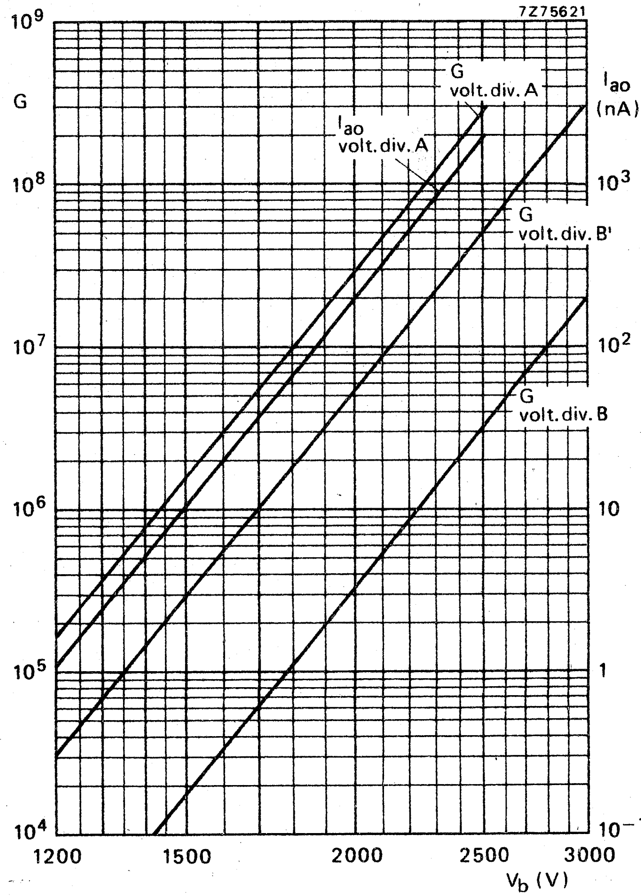


Fig. 6

Gain G, and anode dark current I_{ao}, as a function of supply voltage V_b.

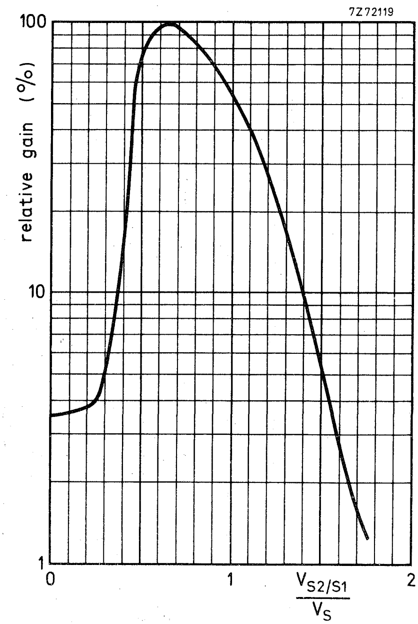


Fig. 7

Relative gain as a function of the voltage between S_2 and S_1, normalized to V_S, $V_{S3/S1}$ constant.

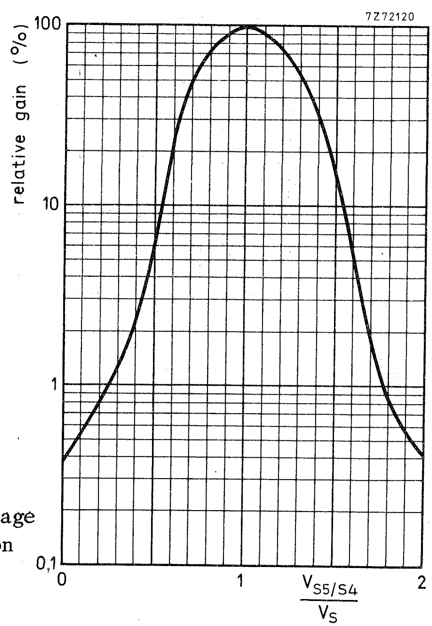


Fig. 8 Relative gain as a function of the voltage between S5 and S4, normalized to V_S. $V_{S6/S4}$ constant.

Note: Gain regulation by changing the voltage between S5 and S4 may cause a degradation of other parameters such as stability and linearity.

14-STAGE PHOTOMULTIPLIER TUBE

The XP2041 (XP2041Q) is a 110 mm useful diameter head-on photomultiplier tube with a concave-convex window and a semi-transparent bialkaline type D photocathode.
The tube is intended for use in nuclear physics where the number of photons to be detected is very low or where good time characteristics are required (coincidence measurements, Cerenkov counters).
A plano-concave plastic adapter supplied with tube type XP2041 enables transmission from 300 nm. The XP2041Q is supplied with a plano-concave fused silica adapter enabling transmission at a wavelength of 200 nm and higher.

QUICK REFERENCE DATA

Spectral sensitivity characteristic			type D extended ultraviolet	
Useful diameter of the photocathode		>	110	mm
Supply voltage for a gain of 3×10^7			2200	V
Quantum efficiency at 401 nm			26	%
Cathode spectral sensitivity at 401 nm			85	mA/W
Anode pulse rise time (with voltage divider B')		≈	2	ns
Linearity				
with voltage divider A	up to	≈	30	mA
with voltage divider B	up to	≈	220	mA
with voltage divider B'	up to	≈	80	mA

To be read in conjunction with "General Operational Recommendations Photomultiplier tubes".

GENERAL CHARACTERISTICS

Window

Glass : Ultraviolet transmitting (type Schott 8337 or equivalent) 1)

Shape	concave-convex	
Radius of curvature	183 ± 5	mm
Refractive index at 550 nm	1,48	

1) This glass window must be protected from humidity.

Photocathode

Semi-transparent, head-on				
Useful diameter		>	110	mm
Spectral sensitivity characteristic (Fig. 4)			type D extended ultraviolet	
Material			bi-alkaline Sb-K-Cs	
Maximum spectral sensitivity at			400 ± 30	nm
Spectral sensitivity at 401 ± 3 nm		typ.	85	mA/W
		>	65	mA/W

Multiplier system

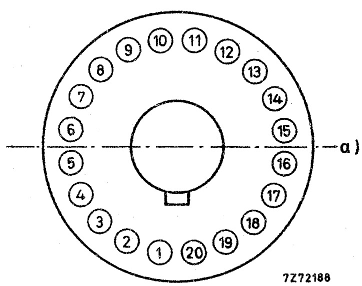
Number of stages			14	
Dynode structure			linear focused	
Dynode material			Cu-Be	
Capacitances				
Grid no. 1 to k+g_2+acc+S1	$C_{g1/k, g2, acc, S1}$	≈	70	pF
Anode to final dynode	$C_{a/S14}$	≈	5	pF
Anode to all	C_a	≈	7	pF

Magnetic field

When the photocathode is illuminated uniformly the anode current is halved (at V_b = 1900 V, voltage divider A):

- at a magnetic flux density of 0, 15 mT in the direction of the longitudinal axis;
- at a magnetic flux density of 0, 13 mT perpendicular to axis a);
- at a magnetic flux density of 0, 05 mT parallel to axis a) (see Fig. below)

It is recommended that the tube be screened against the influence of magnetic fields by a mu-metal shield protruding >15 mm beyond the photocathode.



Axis a) with respect to base pins (bottom view).

RECOMMENDED CIRCUITS

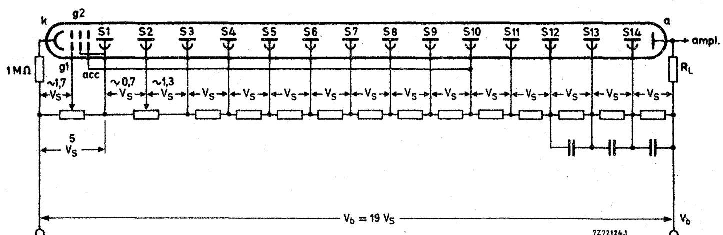


Fig. 1 Voltage divider A

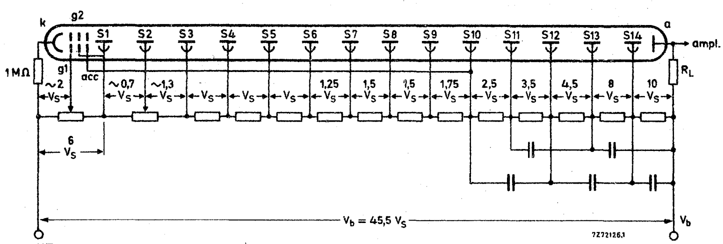


Fig. 2 Voltage divider B

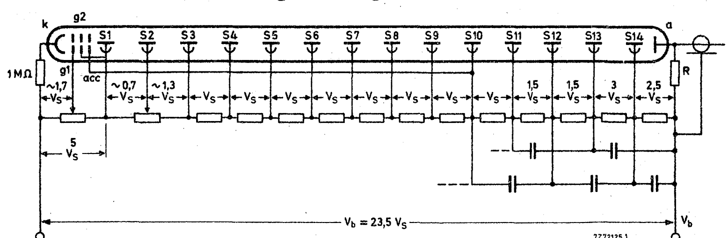


Fig. 3 Voltage divider B'

k	=	cathode
g_1, g_2	=	focusing electrodes
acc	=	accelerating electrode
S_n	=	dynode no. n
a	=	anode
R_L	=	load resistor

The voltage between k and g_1 should be adjusted at about 1, 7 V_S for voltage dividers A and B' or at about $2V_S$ for voltage divider B.

R = This resistor serves to connect the anode when the output cable is not terminated. Recommended value : 10 kΩ.

The cathode resistor of 1 MΩ limits the current in case of unintentional contact between the conductive coating and earth when the anode is earthed.

The voltage between S1 and S2 should be adjusted at about 0, 7 V_S.
Typical value of capacitors : 1 nF.

TYPICAL CHARACTERISTICS

With voltage divider A (Fig. 1)				
Supply voltage for a gain G of 3×10^7, Fig. 6	1)	<	2700	V
		typ.	2200	V
Anode dark current at $G = 3 \times 10^7$, Fig. 6	1) 2)	<	600	nA
		typ.	30	nA
Anode pulse rise time at V_b = 2200 V	3) 4)	≈	2,5	ns
Anode pulse width at half height at V_b = 2200 V	3)	≈	5	ns
Signal transit time at V_b = 2200 V	3)	≈	46	ns
Anode current linear within 2%, at V_b = 2200 V up to		≈	30	mA
Obtainable peak anode current		≈	200	mA
With voltage divider B (Fig. 2)	5)			
Gain at V_b = 2800 V. Fig. 6		≈	4×10^6	
Anode pulse rise time at V_b = 2800 V	3) 4)	≈	2,1	ns
Anode pulse width at half height at V_b = 2800 V	3)	≈	3	ns
Signal transit time at V_b = 2800 V	3)	≈	49	ns
Signal transit time difference between the centre of the photocathode and 50 mm from the centre at V_b = 2800 V		≈	1	ns
Anode current linear within 2%, at V_b = 2800 V up to		≈	280	mA
Obtainable peak anode current		≈	0,5 to 1,0	A
With voltage divider B' (Fig. 3)	5)			
Gain at V_b = 2500 V, Fig. 6		≈	2×10^7	
Anode pulse rise time at V_b = 2500 V	3) 4)	≈	2	ns
Anode pulse width at half height at Vb = 2500 V	3)	≈	3	ns
Signal transit time at V_b = 2500 V	3)	≈	46	ns
Signal transit time difference between the centre of the photocathode and 50 mm from the centre at V_b = 2500 V		≈	1	ns
Anode current linear within 2%, at V_b = 2500 V up to		≈	80	mA
Obtainable peak anode current		≈	500	mA

Notes see page 5.

Notes to page 4

1) Wherever possible, the photomultiplier power supply should be arranged so that the cathode is earthed and the anode is at +HT, however, it is sometimes necessary to supply the tube with the anode earthed and the cathode at -HT. Under these circumstances, erratic noise and dark current are generally increased and unstable, particularly immediately after application of voltage. The tube is provided with a conductive coating connected to the cathode. It is recommended to keep the metal envelope at cathode potential. This implies safety precautions to protect the user.

2) Dark current is measured at ambient temperature, after a stabilization period of the tube in darkness ($\approx$ 1/4 h).

3) Measured with a pulsed light source with a pulse duration of < 1 ns; the cathode being completely illuminated.
The rise time is determined between 10% and 90% of the amplitude of the anode pulse. The signal transit time is measured between the instant at which the illuminating pulse at the cathode becomes maximum, and the instant at which the anode pulse attains its maximum. Rise time, pulse width, and transit time vary as a function of the HT supply voltage V_b, approximately as $V_b^{-1/2}$.

4) A non-inductive resistor of 50 Ω is incorporated in the base, connected to S14. See also "General Operational Recommendations Photomultiplier tubes"

5) Divider circuits B and B' are examples of "progressive dividers", each giving a compromise between gain, speed, and linearity. Other dividers can be conceived to achieve other compromises. It is generally advisable to keep the increase in voltage between one stage and the next to less than a factor 2.

LIMITING VALUES (Absolute max. rating system)

Supply voltage	1)	max.	3000	V
Continuous anode current	5)	max.	0,2	mA
Voltage between first dynode and photocathode	2)	max.	800	V
		min.	400	V
Voltage between focusing electrode g_1 and photocathode		max.	300	V
Voltage between accelerating electrode and photocathode		max.	18	V_S
		min.	14	V_S
Voltage between consecutive dynodes		max.	500	V
Voltage between anode and final dynode	3)	max.	500	V
		min.	80	V
Ambient temperature range	4)			
Operational (for short periods of time)		max.	+80	^oC
		min.	-30	^oC
continuous operation and storage		max.	+50	^oC
		min.	-30	^oC

1) Total HT supply voltage, or the voltage at which the tube circuited in voltage divider "A" has a gain of 3×10^8, whichever is lower.

2) Minimum value to obtain good collection in the input optics.

3) When calculating the anode voltage the voltage drop across the load resistor should be taken into account.

4) This range of temperatures is limited principally by stresses in the sealing layer of the base to the glass bulb.
Where low temperature operation is contemplated, the supplier should be consulted.

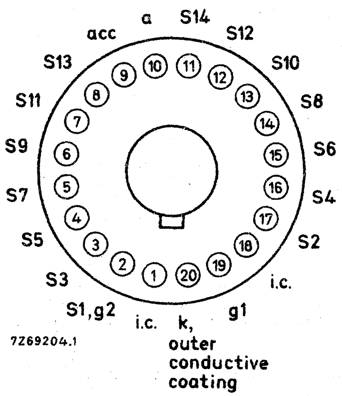
5) For applications requiring a high stability a value of $< 10\,\mu A$ is recommended.

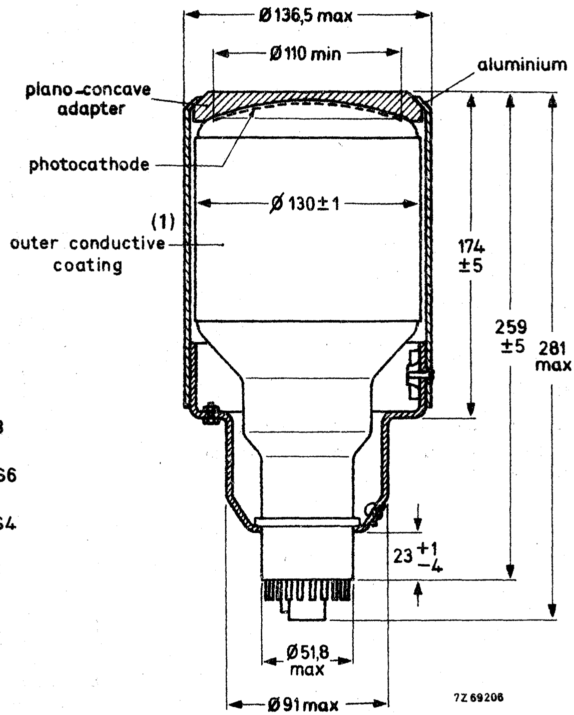
MECHANICAL DATA

Dimensions in mm

(1) **Warning:**

The envelope of the tube is covered with a conductive coating connected to the cathode.
Care should be taken to avoid hazard due to electric shock. See also note 1 on page 5.





CAUTION

Care should be taken in handling this larger diameter tube because of the risk of implosion.

Base: 20-pin (JEDEC B20-102)

Net mass: 1340 g

ACCESSORIES

Socket type FE1020

The XP2041 may be used with the base assembly S5630/03, consisting of two magnetic shields, a voltage divider, a mechanical system with provisions for mounting the photomultiplier tube and a scintillator. Details are available on request.

Optical coupling silicone grease is supplied with each tube. The grease should be applied to the adapter-photomultiplier interface before operation.

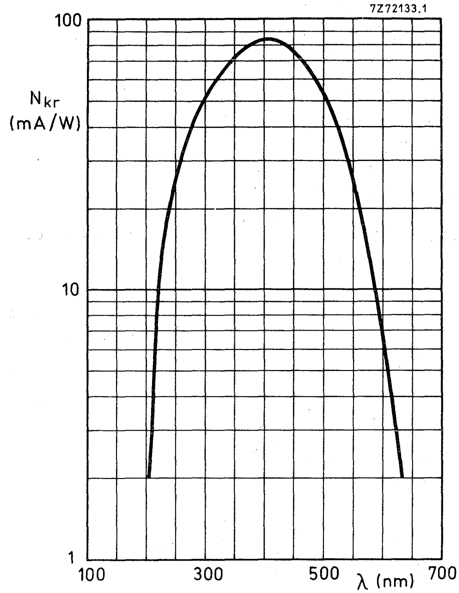


Fig. 4

Spectral sensitivity characteristic (without adapter or with fused silica adapter).

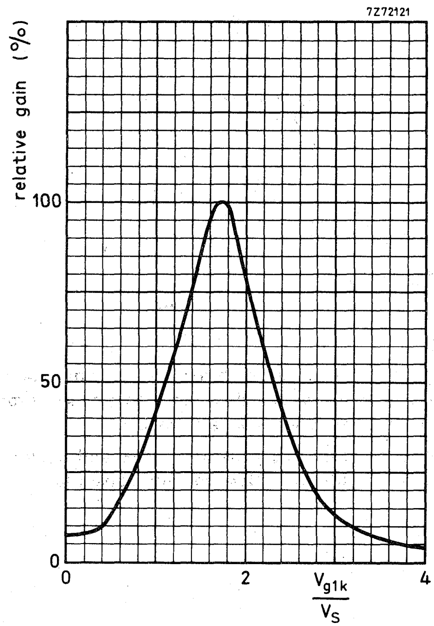


Fig. 5

Relative gain as a function of the voltage between focusing electrode g_1 and photocathode, normalized to V_S.

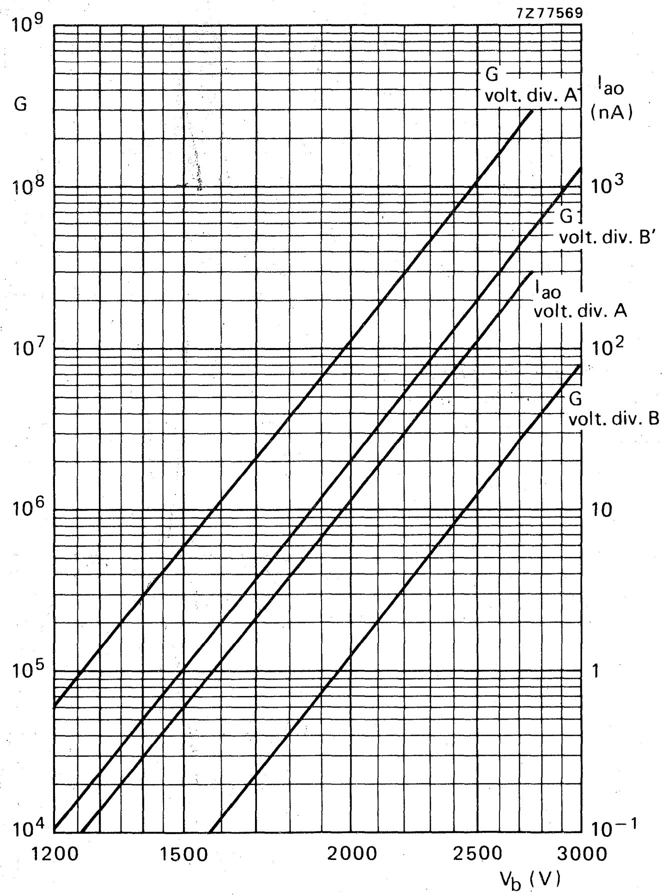


Fig. 6

Gain, G, and anode dark current, I_{ao}, as a function of supply voltage V_b.

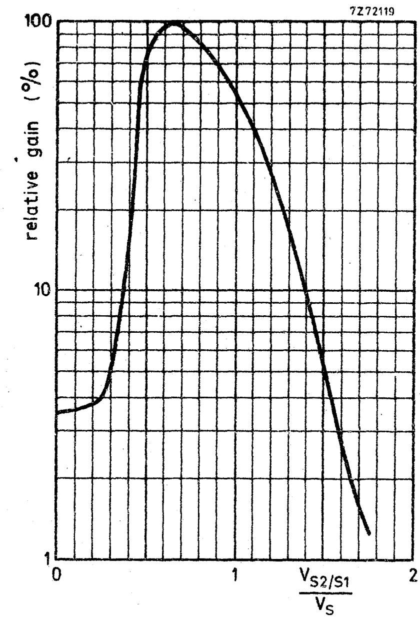


Fig. 7

Relative gain as a function of the voltage between S_2 and S_1, normalized to V_S.

$V_{S3/S1}$ constant.

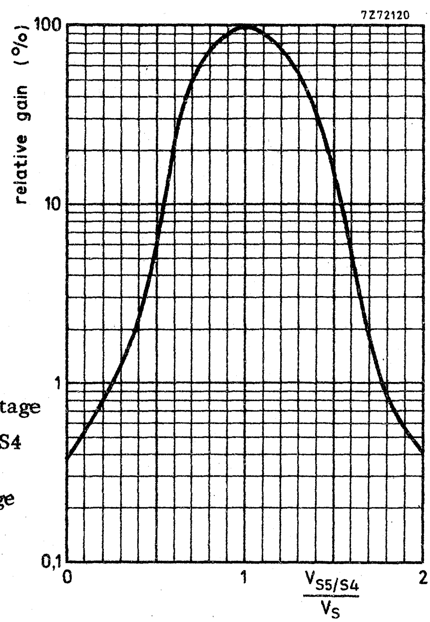


Fig. 8 Relative gain as a function of the voltage between S5 and S4, normalized to V_S. $V_{S6/S4}$ constant.

Note: Gain regulation by changing the voltage between S5 and S4 may cause a degradation of other parameters such as stability and linearity.

10-STAGE VENETIAN BLIND PHOTOMULTIPLIER TUBE

The XP2050 is a 110 mm useful diameter head-on photomultiplier tube with a flat window and a semi-transparent bialkaline type D photocathode. The tube is intended especially for scintillation counting in different fields, such as gamma spectrometry or high energy physics (large dimensional Cerenkov counters).

QUICK REFERENCE DATA

Spectral sensitivity characteristic		type D	
Useful diameter of the photocathode	>	110	mm
Quantum efficiency at 401 nm		95	mA/W
Supply voltage for an anode spectral sensitivity of 12 kA/W at 401 nm		1270	V
Pulse amplitude resolution (^{137}Cs)	≈	7,5	%
Mean anode sensitivity deviation	≈	1	%

To be read in conjunction with *General Operational Recommendations Photomultiplier tubes.*

GENERAL CHARACTERISTICS

Window

Material	borosilicate
Shape	plano-plano
Refractive index at 550 nm	1,48

Photocathode *

Semi-transparent, head-on

Material	Sb K Cs
Useful diameter	> 110 mm
Spectral sensitivity characteristic (Fig. 4)	type D

* The bialkaline photocathode has a significant resistance which increases rapidly with reducing temperature. It is thus recommended that it should not be subjected to light of too great an intensity; the cathode current should be limited, for example, to 1 nA at room temperature or 0,1 nA at −30 °C. If too high a photocurrent is passed, the cathode can no longer be considered to be an equipotential surface, and the focusing of electrons onto the first dynode will be affected, resulting in departure of linearity.

Photocathode (continued)

Maximum spectral sensitivity at			400 ± 30 nm
Quantum efficiency at 401 ± 3 nm			29 %
Spectral sensitivity at 401 ± 3 nm	N_{kr}	typ.	95 mA/W
		>	65 mA/W

Multiplier system

Number of stages		10
Dynode structure		venetian blind
Dynode material		Cu-Be
Capacitances		
anode to final dynode	≈	7 pF
anode to all	≈	8,5 pF

Magnetic field

When the cathode is illuminated uniformly the anode current is halved (at V_b = 1500 V) at a magnetic flux density of 0,2 mT perpendicular to the tube axis.

It is recommended that the tube be screened against the influence of magnetic fields by a mu-metal shield protruding > 15 mm beyond the photocathode.

RECOMMENDED CIRCUITS

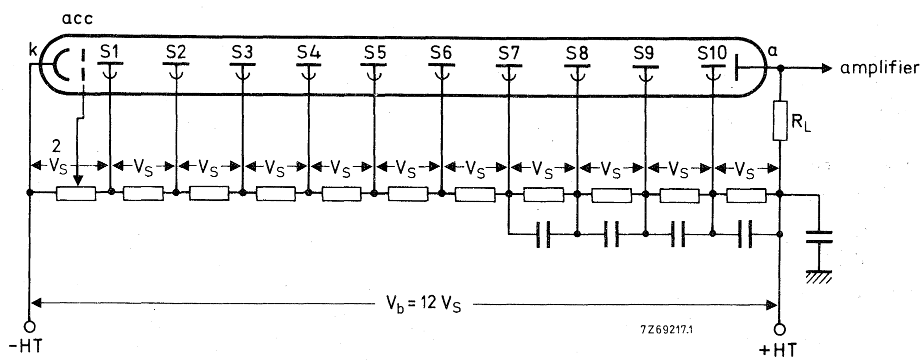


Fig. 1 Voltage divider A. Typical values of capacitors: 10 nF; k = cathode; acc = accelerating electrode; S_n = dynode no.; a = anode; R_L = load resistor.

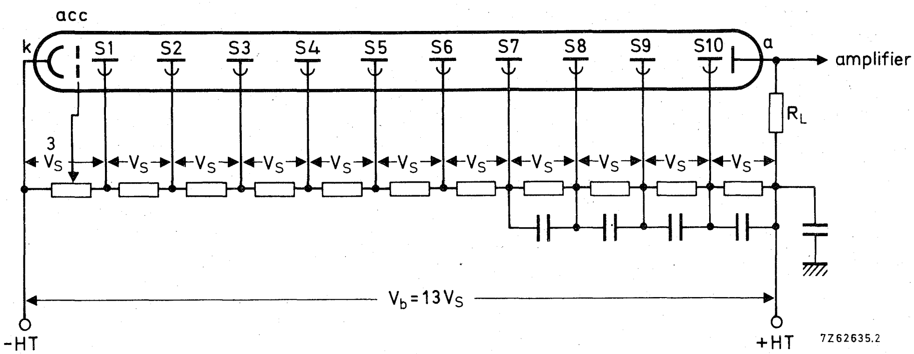


Fig. 2 Voltage divider A_1. Typical values of capacitors: 10 nF; k = cathode; acc = accelerating electrode; S_n = dynode no.; a = anode; R_L = load resistor.

The accelerating electrode potential should be adjusted for optimum pulse amplitude resolution.

TYPICAL CHARACTERISTICS

	note				
With voltage divider A (Fig. 1)	1				
Supply voltage for an anode spectral sensitivity N_{ar} = 12 kA/W at 401 nm (Fig. 5)			<	1500	V
			typ.	1270	V
Anode spectral sensitivity at V_b = 1500 V			≈	35	kA/W
Anode dark current at N_{ar} = 12 kA/W at 401 nm	2		<	5	nA
			typ.	0,5	nA
Anode current linear within 2% at V_b = 1500 V		up to	≈	10	mA
With voltage divider A_1 (Fig. 2)					
Anode spectral sensitivity at V_b = 1500 V and 401 nm (Fig. 5)			≈	25	kA/W
Pulse amplitude resolution for ^{137}Cs at N_{ar} = 12 kA/W	3		≈	7,5	%
Anode current linear within 2% at V_b = 1500 V		up to	≈	10	mA
Mean anode sensitivity deviation	4				
long term (16 h)			≈	1	%
after change of count rate			≈	1	%
Anode pulse rise time at V_b = 1500 V	5		≈	16	ns
Anode pulse width at half height at V_b = 1500 V	5		≈	40	ns
Signal transit time at V_b = 1500 V	5		≈	90	ns

Notes see page 4.

LIMITING VALUES (absolute maximum rating system)	note		
Supply voltage	6	max.	2000 V
Continuous anode current	10	max.	0,2 mA
Voltage between first dynode and photocathode	7	max. min.	500 V 150 V
Voltage between accelerating electrode and photocathode		max.	500 V
Voltage between consecutive dynodes		max.	300 V
Voltage between anode and final dynode	8	max.	300 V
Ambient temperature range	9		
operational (for short periods of time)		max. min.	+80 °C −30 °C
continuous operation and storage		max. min.	+50 °C −30 °C

Notes

1. Wherever possible, the power supply should be arranged so that the cathode is earthed and the anode is at + HT, however, it is sometimes necessary to supply the tube with the anode earthed and the cathode at −HT. Under these circumstances, erratic noise and dark current are generally increased and unstable, particularly after application of voltage. The glass envelope of the tube should be supported only by isolators having an insulation resistance of $> 10^{15}$ ohm.
2. Dark current is measured at ambient temperature, after a stabilization period of the tube in darkness (≈ ¼ h).
3. Pulse amplitude resolution for ^{137}Cs and ^{57}Co is measured with an NaI (Tl) cylindrical scintillator (Quartz et Silice serial no. 4170 or equivalent) with a diameter of 75 mm and a height of 75 mm. The count rate used is $\approx 10^4$ c/s.
4. The mean anode sensitivity deviation is measured by coupling an NaI (Tl) scintillator to the window of the tube. Long-term (16 h) deviation is measured by placing a ^{137}Cs source at a distance from the scintillator such that the count rate is $\approx 10^4$ c/s, corresponding to an anode current of ≈ 300 nA. Mean anode sensitivity deviation after change of count rate is measured with a ^{137}Cs source at a distance from the scintillator such that the count rate can be changed from $\approx 10^4$ c/s to $\approx 10^3$ c/s, corresponding to anode currents of ≈ 1 μA and ≈ 0,1 μA respectively. Both tests are carried out according to ANSI-N42-9-1972 of IEEE recommendations.
5. Measured with a pulsed light source, with a pulse duration (FWHM) of < 1 ns: the cathode being completely illuminated. The rise time is determined between 10% and 90% of the amplitude of the anode pulse. The signal transit time is measured between the instant at which the illuminating pulse at the cathode becomes maximum, and the instant at which the anode pulse attains its maximum. Rise time, pulse duration and transit time vary as a function of high tension supply voltage V_b, approximately as $V_b^{-1/2}$.
6. Total HT supply voltage, or the voltage at which the tube has an anode spectral sensitivity of ≈ 300 kA/W, whichever is lower.
7. Minimum value to obtain good collection in the input optics.
8. When calculating the anode voltage the voltage drop across the load resistor should be taken into account.
9. This range of temperatures is limited by stresses in the sealing layer of the base to the glass bulb. Where low temperature operation is contemplated, the supplier should be consulted.
10. A value of < 10 μA is recommended for applications requiring good stability.

MECHANICAL DATA

Dimensions in mm

Warning

Care should be taken in handling this larger diameter tube because of the risk of implosion.

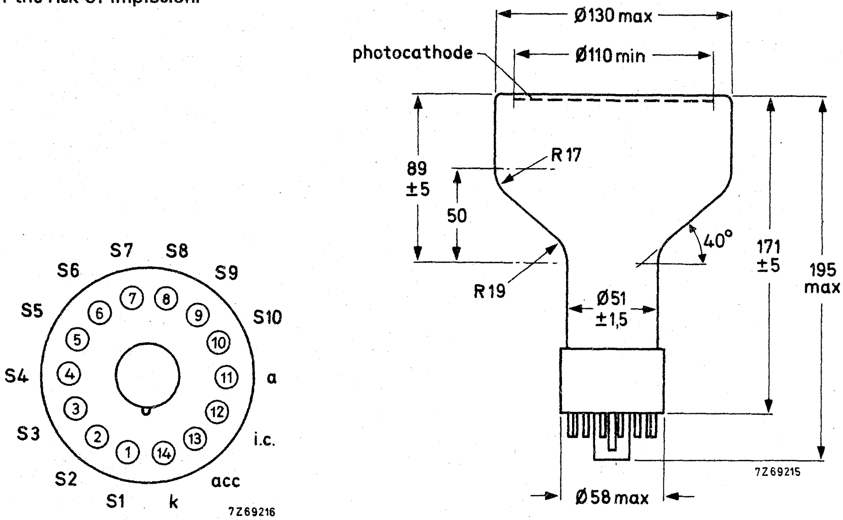


Fig. 3.

Base: IEC 67–I–16a (Jedec B14–38)

Net mass: 460 g

ACCESSORIES

Socket type FE1014

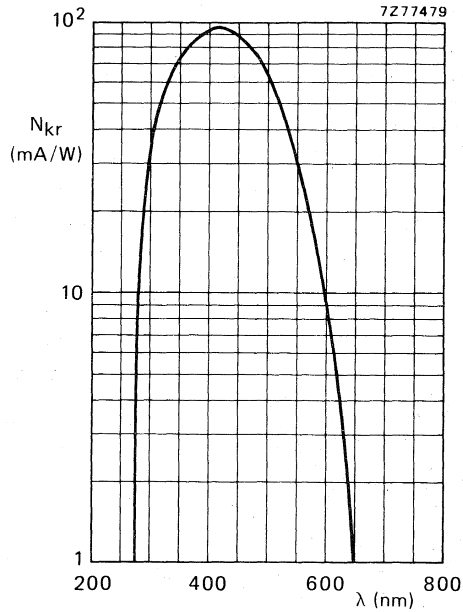


Fig. 4 Spectral sensitivity characteristic.

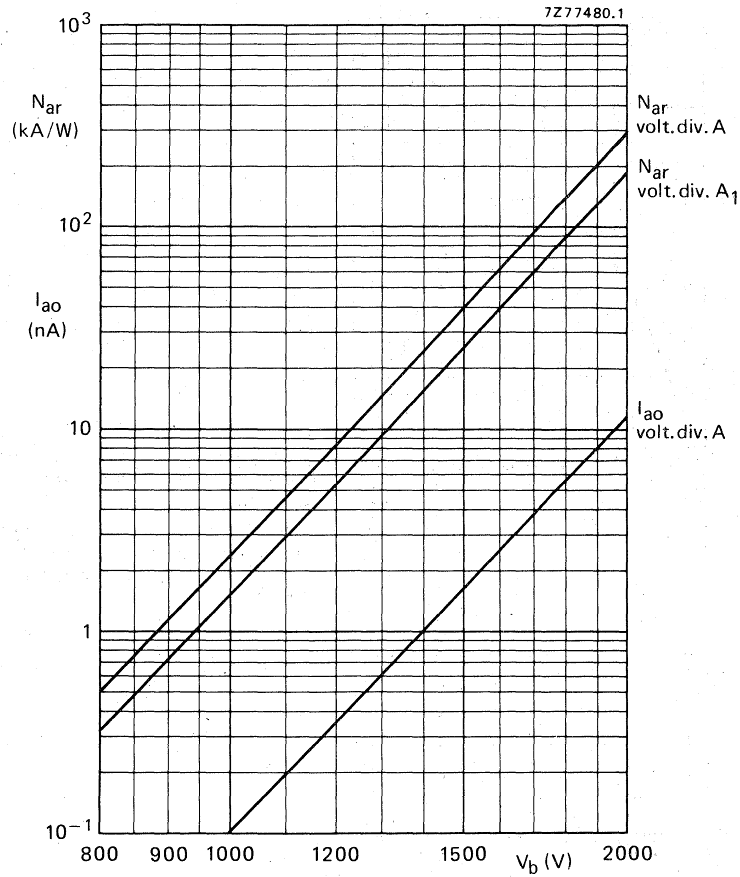


Fig. 5 Anode spectral sensitivity N_{ar}, and anode dark current I_{ao} as a function of the supply voltage V_b.

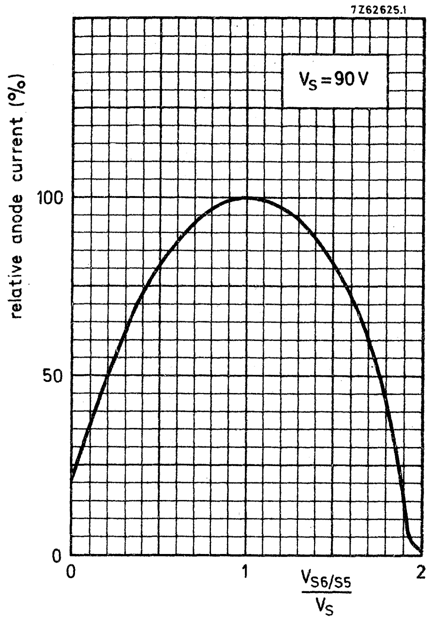


Fig. 6 Relative gain as a function of the voltage between S_6 and S_5, normalized to V_S. $V_{S7/S5}$ constant.

Note: Gain regulation by changing the voltage between S6 and S5 may cause a degradation of other parameters such as stability and linearity.

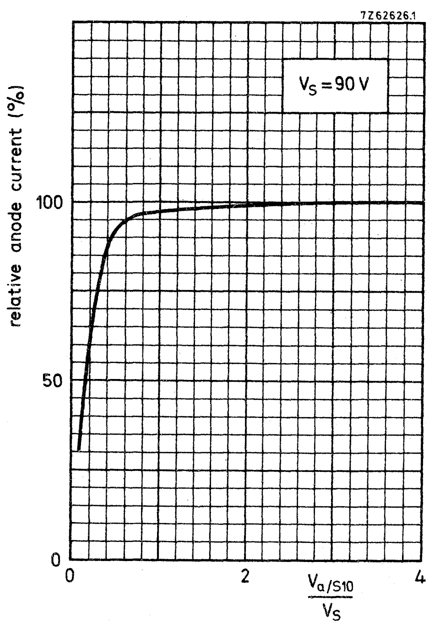


Fig. 7 Relative anode current as a function of the voltage between anode and final dynode.

10-STAGE PHOTOMULTIPLIER TUBE

The XP2060 and XP2060B are 32 mm useful diameter head-on photomultiplier tubes with a flat window and a semitransparent Super A photocathode. The tubes are intended for use in applications such as scintillation counting, laboratory and industrial photometry. Its Cu Be dynode system offers a high stability.
The XP2060B is provided with a 12-pin plastic base; the XP2060 has a 14-pin all-glass base.

QUICK REFERENCE DATA

Spectral sensitivity characteristic		Super A
Useful diameter of the photocathode		> 32 mm
Spectral sensitivity of the photocathode at 437 nm		≈ 70 mA/W
Supply voltage for luminous sensitivity N_a = 60 A/lm		1180 V
Pulse amplitude resolution for ^{137}Cs		≈ 8 %
Mean anode sensitivity deviation		≈ 1 %
Anode pulse rise time (with voltage divider B)		≈ 2,5 ns
Linearity		
with voltage divider A	up to	≈ 100 mA
with voltage divider B	up to	≈ 200 mA

To be read in conjunction with "General Operational Recommendations Photomultiplier Tubes".

GENERAL CHARACTERISTICS

Window

Shape	plano-plano
Material	lime glass
Refractive index at 550 nm	1,52

Photocathode

Semi-transparent, head-on	
Material	Sb Cs
Useful diameter	> 32 mm
Spectral sensitivity characteristic (Fig. 3)	type Super A
Maximum sensitivity at	420 ± 30 nm
Luminous sensitivity	typ 80 μA/lm
	> 40 μA/lm
Spectral sensitivity at 437 ± 5 nm	≈ 70 mA/W

Electron optical input system

This system consists of: the photocathode, k; a metallized part of the glass envelope, internally connected to the photocathode; an accelerating electrode, acc, internally connected to **S1**.

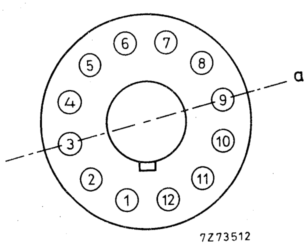
Multiplier system

Number of stages		10
Dynode structure		linear focused
Dynode material		Cu Be
Capacitances		
Anode to all	≈	5 pF
Anode to final dynode	≈	3 pF

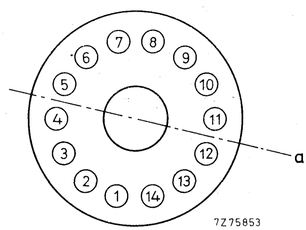
Magnetic field

When the photocathode is illuminated uniformly the anode current is halved (at V_b = 1200 V, voltage divider A):
— at a magnetic flux density of 0,6 mT in the direction of the longitudinal axis;
— at a magnetic flux density of 0,35 mT perpendicular to axis a (see Fig. below);
— at a magnetic flux density of 0,15 mT parallel to axis a.

It is recommended that the tube be screened against the influence of magnetic fields by a mu-metal shield protruding > 15 mm beyond the photocathode.



XP2060B



XP2060

Axis a with respect to base pins (bottom view).

RECOMMENDED CIRCUITS

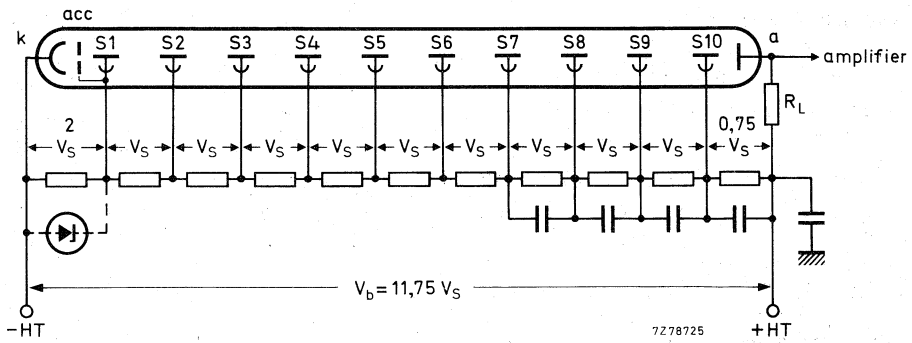


Fig. 1 Voltage divider A*.

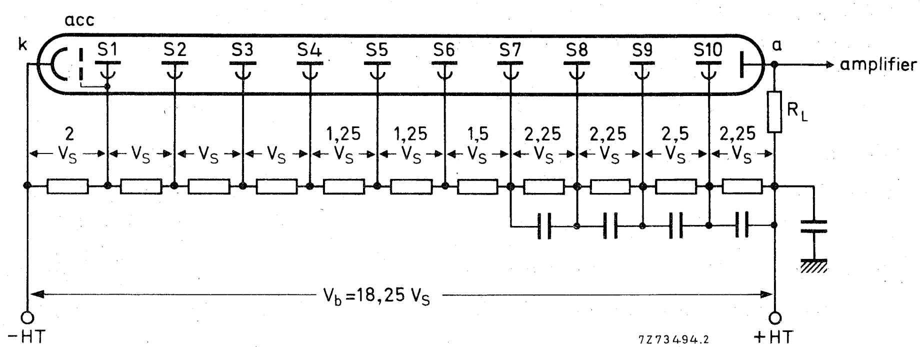


Fig. 2 Voltage divider B.

k = cathode
acc = accelerating electrode
S_n = dynode no. n
a = anode
R_L = load resistor

Typical values of capacitors: 10 nF

* For optimum peak amplitude resolution it is recommended that the voltage between first dynode and photocathode be maintained at ≈ 200 V e.g. by means of a voltage regulator diode.

TYPICAL CHARACTERISTICS

	notes (see page 5)			
With voltage divider A (Fig. 1)	1			
Supply voltage for an anode luminous sensitivity N_a = 60 A/lm (Fig. 5)		$<$ typ	1500 1180	V V
Anode dark current at an anode luminous sensitivity N_a = 60 A/lm (Fig. 5)	2,3	$<$ typ	50 5	nA nA
Pulse amplitude resolution for ^{137}Cs at N_a = 10 A/lm	4	≈	8	%
Mean anode sensitivity deviation at V_b = 1200 V	5			
long term		≈	1	%
after change of count rate		≈	1	%
Anode current linear within 2% at V_b = 1700 V		up to ≈	100	mA
With voltage divider B (Fig. 2)				
Anode luminous sensitivity at V_b = 1700 V (Fig. 5)		≈	150	A/lm
Anode pulse rise time at V_b = 1700 V	6	≈	2,5	ns
Anode pulse duration at half height at V_b = 1700 V	6	≈	6	ns
Signal transit time at V_b = 1700 V	6	≈	26	ns
Anode current linear within 2% at V_b = 1700 V		up to ≈	200	mA

LIMITING VALUES (Absolute maximum rating system)

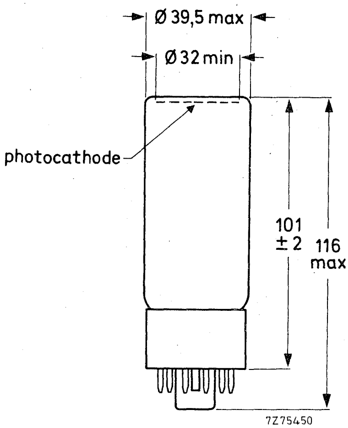
Supply voltage	7	max	1800	V
Continuous anode current	11	max	0,2	mA
Voltage between first dynode and photocathode	8	max min	500 150	V V
Voltage between consecutive dynodes		max	300	V
Voltage between anode and final dynode	9	max min	300 30	V V
Ambient temperature range				
Operational (for short periods of time)	10	max min	+80 −30	°C °C
Continuous operating and storage		max min	+50 −30	°C °C

Notes

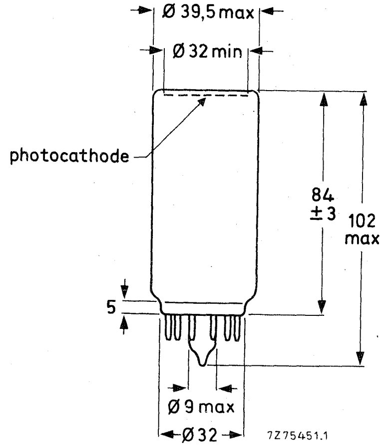
1. To obtain a peak pulse current greater than that obtainable with divider A, it is necessary to increase the inter-dynode voltage of the stages progressively. Divider circuit B is an example of a "progressive" divider, giving a compromise between gain, speed, and linearity. Other dividers can be conceived to achieve other compromises. It is generally recommended that the increase in voltage between one stage and the next be kept less than a factor of 2.
2. Wherever possible, the photomultiplier power supply should be arranged so that the cathode is earthed and the anode is at +HT, however, it is sometimes necessary to supply the tube with the anode earthed and the cathode at −HT. Under these circumstances, erratic noise and dark current are generally increased and unstable, particularly immediately after application of voltage. The glass envelope of the tube should be supported only by isolators having an insulation resistance of $> 10^{15}\ \Omega$.
3. Dark current is measured at ambient temperature, after a stabilization period of the tube in darkness ($\approx$ 1/4 h).
4. Pulse amplitude resolution for ^{137}Cs is measured with an NaI (Tl) cylindrical scintillator with a diameter of 32 mm and a height of 32 mm. The count rate used is $\approx 10^4$ c/s.
5. **The mean anode sensitivity deviation is measured by coupling an NaI (Tl) scintillator to the** window of the tube. Long term (16 h) deviation is measured by placing a ^{137}Cs source at a distance from the scintillator such that the scintillator count rate is $\approx 10^4$ c/s corresponding to an average anode current of $\approx$ **300 nA.**
   Mean pulse amplitude deviation after change of count rate is measured with a ^{137}Cs source at a distance of the scintillator such that the count rate can be changed from 10^4 c/s to 10^3 c/s corresponding to an average anode current of $\approx$ **1 μA and $\approx$ 0,1 μA respectively.**
   Both tests are carried out according to ANSI–N42–9–1972 of IEEE recommendations.
6. Measured with a pulsed-light source, with a pulse duration (FWHM) of < 1 ns, the cathode being completely illuminated. The rise time is determined between 10% and 90% of the amplitude of the anode pulse. The signal transit time is measured between the instant at which the illuminating pulse at the cathode becomes maximum, and the instant at which the anode pulse attains its maximum. Rise time, pulse duration and transit time vary as a function of high tension supply voltage V_b, approximately as $V_b^{-1/2}$.
7. Total HT supply voltage or the voltage at which the tube has an anode luminous sensitivity of 600 A/lm, whichever is lower.
8. Minimum value to obtain good collection in the input optics.
9. When calculating the anode voltage the voltage drop across the load resistor should be taken into account.
10. **For type XP2060B this range of temperatures is limited principally by stresses in the sealing layer of the base to the glass bulb. Where low temperature operation is contemplated, the supplier should be consulted.**
11. **A value of < 10 μA is recommended for applications requiring good stability.**

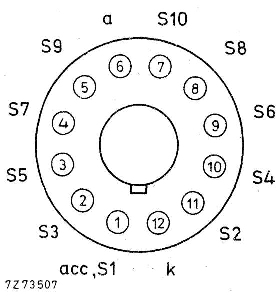
MECHANICAL DATA Dimensions in mm

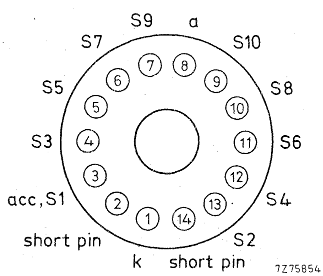
XP2060B



XP2060







Net mass: 69 g
Base: 12-pin (JEDEC B12-43)

ACCESSORIES

Socket:
- for XP2060B type FE1012
- for XP2060 type FE1112

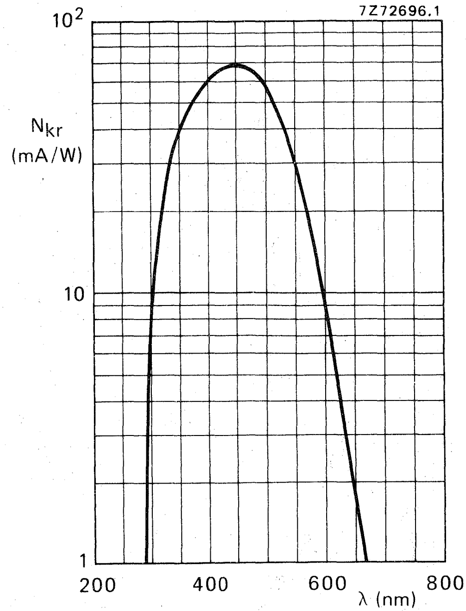


Fig. 3 Spectral sensitivity characteristic.

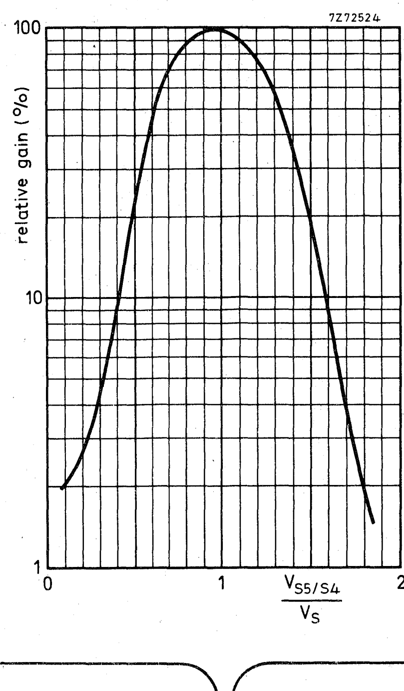


Fig. 4 Relative gain as a function of the voltage between S5 and S4, normalized to V_S. $V_{S6/S4}$ constant.

Note: Gain regulation by changing the voltage between S5 and S4 may cause a degradation of other parameters such as stability and linearity.

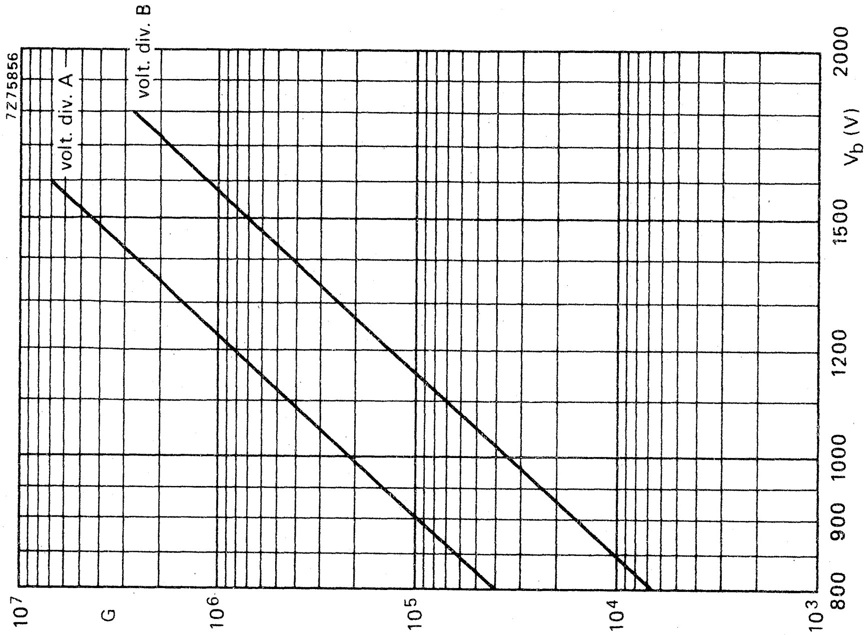


Fig. 6 Gain G as a function of supply voltage V_b.

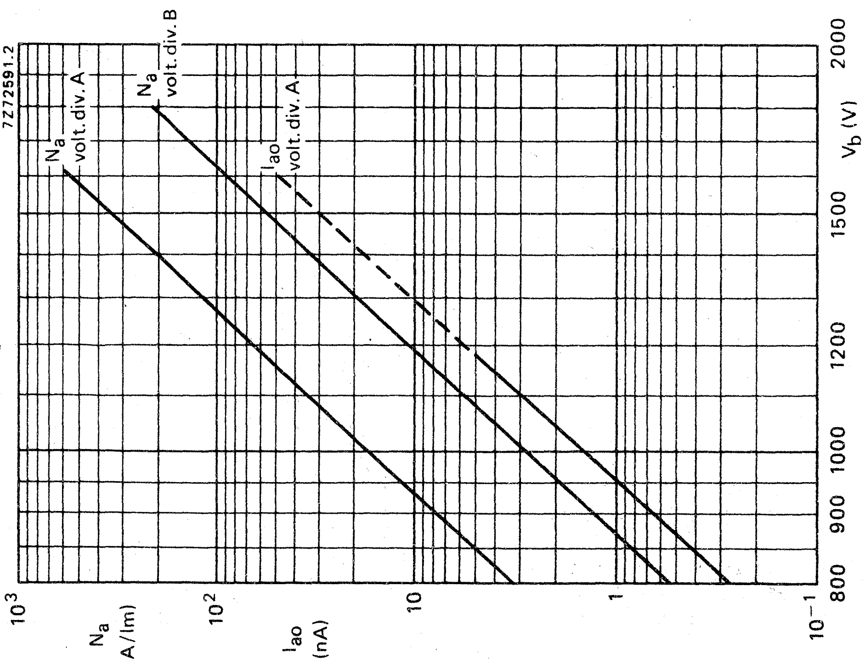


Fig. 5 Anode luminous sensitivity, N_a, and anode dark current, I_{ao}, as a function of supply voltage V_b.

10-STAGE PHOTOMULTIPLIER TUBE

- 44 mm useful diameter head-on type
- plano-plano window
- semi-transparent bi-alkaline type D photocathode
- high stability
- tubes, from serial number 9500 onwards, are provided with high gain first dynode
- for scintillation counting, laboratory and industrial photometry
- XP2202 has a 19-pin all-glass base; XP2202B has a 14-pin plastic base.

QUICK REFERENCE DATA

Spectral sensitivity characteristic	type D
Useful diameter of the photocathode	> 44 mm
Cathode spectral sensitivity at 400 nm	75 mA/W
Supply voltage for an anode spectral sensitivity of 60 kA/W at 400 nm	1400 V
Anode pulse rise time	≈ 3,5 ns
Pulse amplitude resolution (^{137}Cs)	≈ 7,2%
Pulse amplitude resolution (^{55}Fe)	≈ 42%
Linearity	
with voltage divider A	up to ≈ 100 mA
with voltage divider B	up to ≈ 200 mA

To be read in conjunction with *General Operational Recommendations Photomultiplier Tubes.*

GENERAL CHARACTERISTICS *

Window

Material	lime-glass
Shape	plano-plano
Refractive index at 550 nm	1,52

Photocathode (note 1)

Semi-transparent, head-on		
Material	Sb K Cs	
Useful diameter	> 44 mm	
Spectral sensitivity characteristic (Fig. 6)	type D	
Maximum spectral sensitivity	400 ± 30 nm	
Spectral sensitivity at 400 nm	typ. 75 mA/W > 60 mA/W	note 2

* Notes are given on pages 4 and 5.

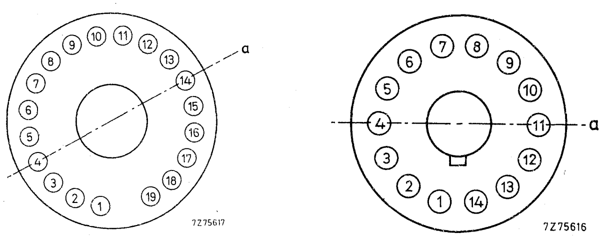
Multiplier system

Number of stages	10
Dynode structure	linear focused
Dynode material	Cu Be
Capacitances	
anode to final dynode	≈ 3 pF
anode to all	≈ 5 pF

Magnetic field

When the photocathode is illuminated uniformly, the anode current is halved (at V_{ht} = 1200 V, voltage divider A) at a magnetic flux density of:
0,2 mT perpendicular to axis a (see Fig. 1);
0,1 mT parallel to axis a.

It is recommended that the tube be screened from magnetic fields by a mu-metal shield protruding more than 15 mm beyond the photocathode.



XP2202 XP2202B

Fig. 1 Axis a with respect to base pins (bottom view).

RECOMMENDED CIRCUITS

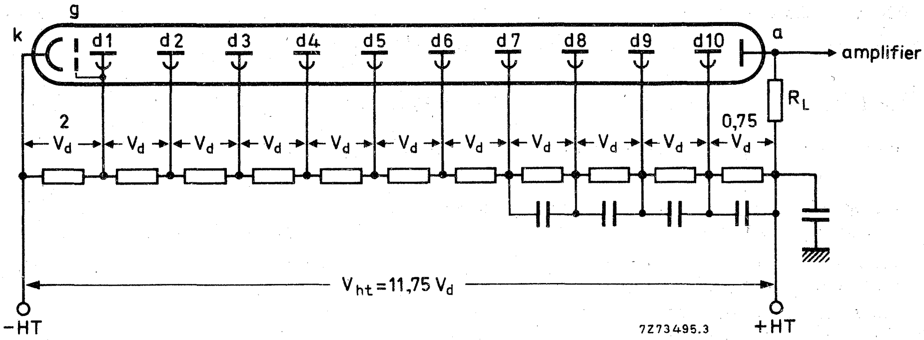


Fig. 2 Voltage divider A.

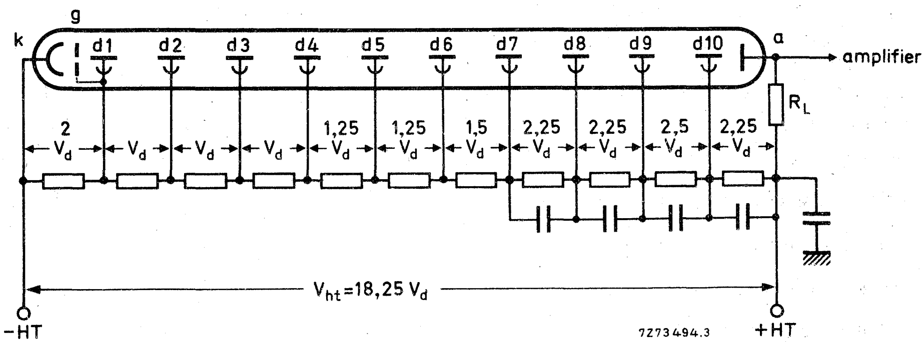


Fig. 3 Voltage divider B.

k = cathode
g = accelerating electrode (internally connected to d1)
d_n = dynode no.
a = anode
R_L = load resistor

Typical values of capacitors: 10 nF

TYPICAL CHARACTERISTICS

Note: All spectral sensitivities refer to a wavelength of 400 nm.

With voltage divider A (Fig. 2)		note 3
Supply voltage for an anode spectral sensitivity of 60 kA/W (Fig. 8)	$<$ 1700 V typ. 1400 V	
Anode dark current at an anode spectral sensitivity of 60 kA/W (Fig. 8)	$<$ 30 nA typ. 3 nA	notes 4,5
Pulse amplitude resolution for ^{137}Cs at an anode spectral sensitivity of 12 kA/W	≈ 7,2%	note 6
Pulse amplitude resolution for ^{55}Fe at an anode spectral sensitivity of 70 kA/W	≈ 42%	note 7
Mean anode sensitivity deviation		note 8
long term (16 h)	≈ 1%	
after change of count rate	≈ 1%	
versus temperature between 0 and +40 °C at 450 nm	≈ 0,2%/°C	
Anode current linear within 2% at V_{ht} = 1700 V	up to ≈ 100 mA	
With voltage divider B (Fig. 3)		note 3
Anode spectral sensitivity at V_{ht} = 1700 V (Fig. 8)	≈ 60 kA/W	
Anode pulse rise time at V_{ht} = 1700 V	≈ 3,5 ns	note 9
Anode pulse duration at half-height at V_{ht} = 1700 V	≈ 7 ns	note 9
Signal transit time at V_{ht} = 1700 V	≈ 35 ns	note 9
Anode current linear within 2% at V_{ht} = 1700 V	up to ≈ 200 mA	

LIMITING VALUES (Absolute maximum rating system)

Supply voltage	max. 1800 V	note 10
Continuous anode current	max. 0,2 mA	note 11
Voltage between first dynode and photocathode	max. 600 V min. 150 V	note 12
Voltage between consecutive dynodes	max. 300 V	
Voltage between anode and final dynode	max. 300 V min. 30 V	note 13
Ambient temperature range		
operational (for short periods of time)	max. +80 °C min. −30 °C	note 14
continuous operation and storage	max. +50 °C min. −30 °C	

Notes

1. The bi-alkaline photocathode has a significant resistance which increases rapidly with reducing temperature. It is therefore recommended that it should not be exposed to light of too great an intensity; the cathode current should be limited, for example, to 1 nA at room temperature or 0,1 nA at −30 °C. If too high a photocurrent is passed, the cathode can no longer be considered an equipotential surface, and the focusing of electrons onto the first dynode will be affected, resulting in departure from linearity. In applications with short pulse times the photocathode is able to deliver pulses containing 10^6 to 10^7 photoelectrons without disturbance.

Notes (continued)

2. Spectral sensitivity is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5K. Light is transmitted through an interferential filter.
3. To obtain a peak pulse current greater than that obtainable with divider A, it is necessary to increase the inter-dynode voltage of the stages progressively. Divider circuit B is an example of a "progressive" divider, giving a compromise between gain, speed, and linearity. Other dividers can be conceived to achieve other compromises. It is generally recommended that the voltage difference between one stage and the next is less than a factor of 2.
4. Wherever possible, the power supply should be arranged so that the cathode is earthed and the anode is at + HT, however, it is sometimes necessary to supply the tube with the anode earthed and the cathode at −HT. Under these circumstances, erratic noise and dark current are generally increased and unstable, particularly after application of voltage. The glass envelope of the tube should be supported only by insulators with an insulation resistance of $> 10^{15}$ ohm.
5. Dark current is measured at ambient temperature, after the tube has been in darkness for approx. 1 min. Lower values can be obtained after a longer stabilization period in darkness (approx. 30 min).
6. Pulse amplitude resolution for ^{137}Cs is measured with an NaI (Tl) cylindrical scintillator (Quartz et Silice ser. no. 7256 or equivalent) with a diameter of 44 mm and a height of 50 mm. The count rate used is $\approx 10^4$ c/s.
7. Pulse amplitude resolution for ^{55}Fe is measured with a NaI (Tl) cylindrical scintillator with a diameter of 25 mm and a height of 1 mm, provided with a beryllium window. The count-rate used is 2×10^3 c/s.
8. The mean anode sensitivity deviation is measured by coupling an NaI (Tl) scintillator to the window of the tube. Long term (16 h) deviation is measured by placing a ^{137}Cs source at a distance from the scintillator such that the count rate is $\approx 10^4$ c/s corresponding to an average anode current of ≈ 300 nA. Anode sensitivity deviation after change of count rate is measured with a ^{137}Cs source at a distance of the scintillator such that the count rate can be changed from 10^4 c/s to 10^3 c/s corresponding to an average anode current of ≈ 1 µA and ≈ 0,1 µA respectively. Both tests are carried out according to ANSI–N42–9–1972 of IEEE recommendations.
9. Measured with a pulsed light source, with a pulse duration (FWHM) of < 1 ns; the cathode being completely illuminated. The rise time is determined between 10% and 90% of the amplitude of the anode pulse. The signal transit time is measured between the instant at which the illuminating pulse at the cathode becomes maximum, and the instant at which the anode pulse attains its maximum. Rise time, pulse duration and transit time vary as a function of high tension supply voltage V_{ht}, approximately as $V_{ht}^{-1/2}$.
10. Total HT supply voltage or the voltage at which the tube has an anode spectral sensitivity of 600 kA/W, whichever is lower.
11. A value of < 10 µA is recommended for applications requiring good stability.
12. Minimum value to obtain good collection in the input optics.
13. When calculating the anode voltage the voltage drop across the load resistor should be taken into account.
14. For type XP2202B this range of temperatures is limited principally by stresses in the sealing layer of the base to the glass bulb. Where low temperature operation is contemplated, the supplier should be consulted.

MECHANICAL DATA

Dimensions in mm

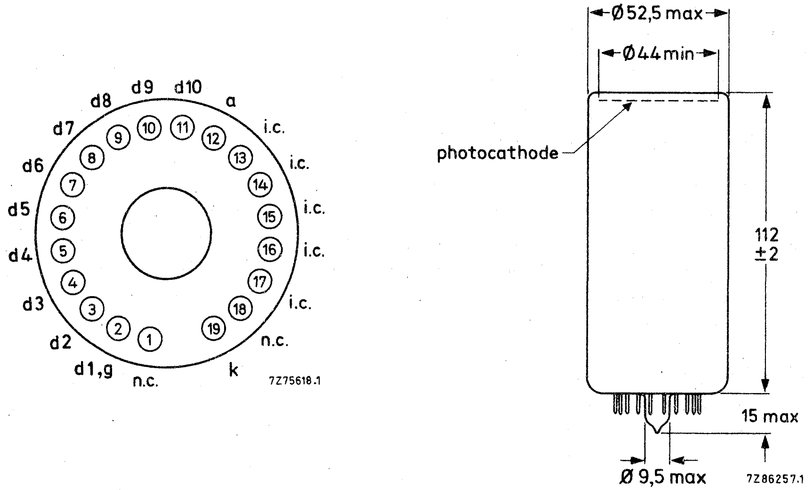
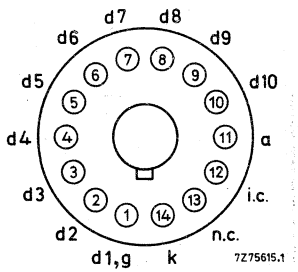


Fig. 4 XP2202.

Base	19-pin all-glass
Net mass	110 g

ACCESSORIES

Socket	type FE2019



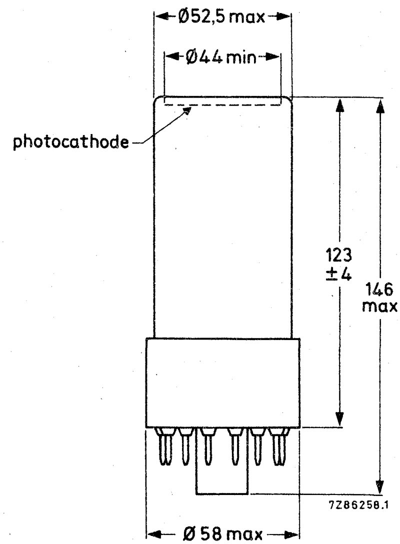


Fig. 5 XP2202B.

Base	14-pin (JEDEC B14-38)
Net mass	153 g

ACCESSORIES

Socket	type FE1014

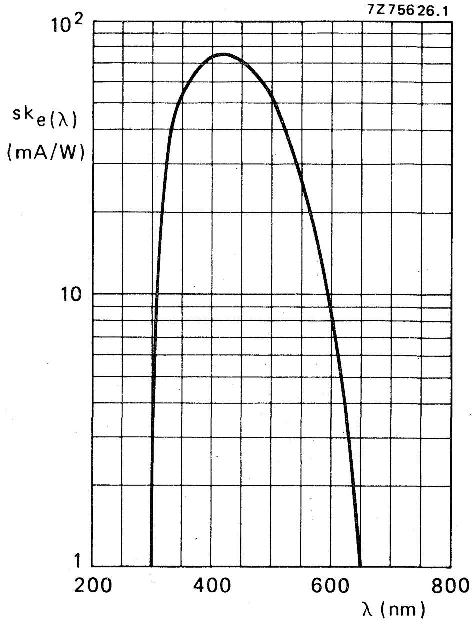


Fig. 6 Spectral sensitivity characteristic.

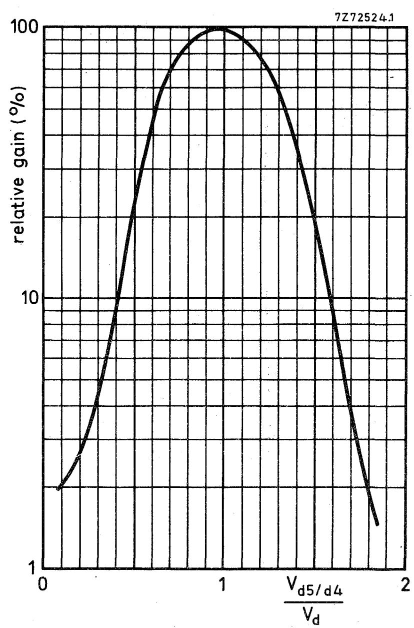


Fig. 7 Relative gain as a function of the voltage between d5 and d4, normalized to V_d; $V_{d6/d4}$ constant.

Note: Gain regulation by changing the voltage between d5 and d4 may cause a degradation of other parameters such as stability and linearity.

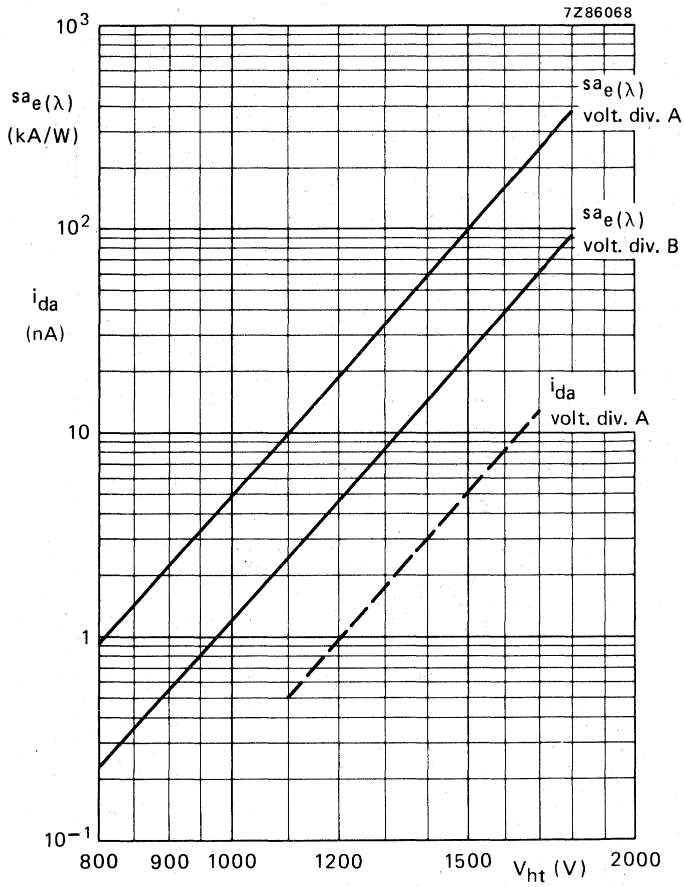


Fig. 8 Anode spectral sensitivity $sa_{e(\lambda)}$ at $\lambda = 400$ nm, and anode dark current i_{da} as a function of supply voltage V_{ht}.

i_{da} is given as a dotted line to indicate its principle behaviour only.

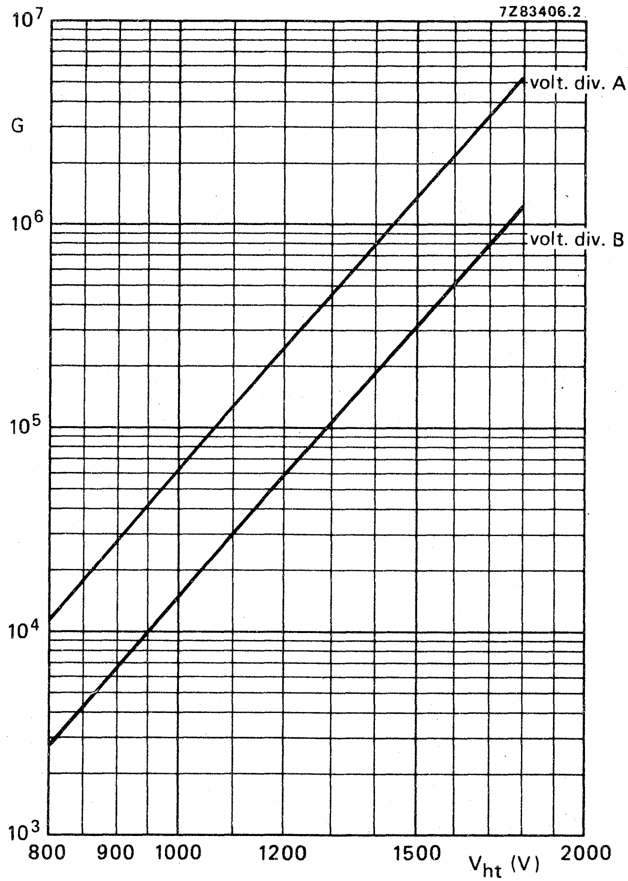


Fig. 9 Gain G as a function of supply voltage V_{ht}.

10-STAGE PHOTOMULTIPLIER TUBE

- 44 mm useful diameter head-on type
- plano-plano window
- semi-transparent tri-alkaline S20 (type T) photocathode
- high stability
- for industrial applications, e.g. lasers and flying spot scanners
- unilaterally interchangeable with XP1002

QUICK REFERENCE DATA

Spectral sensitivity characteristic	S20 (type T)
Useful diameter of the photocathode	> 44 mm
Spectral sensitivity of the photocathode at 698 nm	16 mA/W
Supply voltage for an anode luminous sensitivity = 60 A/lm	1350 V
Anode pulse rise time (with voltage divider B)	≈ 3,5 ns
Linearity	
with voltage divider A	up to ≈ 100 mA
with voltage divider B	up to ≈ 200 mA

To be read in conjunction with *General Operational Recommendations Photomultiplier Tubes.*

GENERAL CHARACTERISTICS

Window

Material	borosilicate
Shape	plano-plano
Refractive index at 550 nm	1,48

Photocathode

Semi-transparent, head-on	
Material	Sb Na K Cs
Useful diameter	> 44 mm
Spectral sensitivity characteristic (Fig. 5)	S20 (type T)
Maximum spectral sensitivity	420 ± 30 nm
Luminous sensitivity	≈ 165 μA/lm
Spectral sensitivity	
at 698 nm	typ. 16 mA/W > 7 mA/W
at 629 nm	≈ 30 mA/W

Multiplier system

Number of stages	10
Dynode structure	linear focused
Dynode material	Cu Be
Capacitances	
anode to final dynode	≈ 3 pF
anode to all	≈ 5 pF

Magnetic field

When the photocathode is illuminated uniformly the anode current is halved (at V_{ht} = 1200 V, voltage divider A) at a magnetic flux density of:

0,2 mT perpendicular to axis a (see Fig. 1);

0,1 mT parallel with axis a.

It is recommended that the tube be screened from magnetic fields by a mu-metal shield protruding > 15 mm beyond the photocathode.

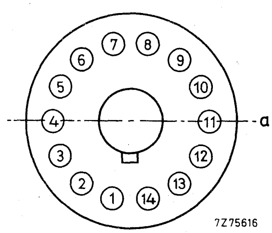


Fig. 1 Axis a with respect to base pins (botton view).

RECOMMENDED CIRCUITS

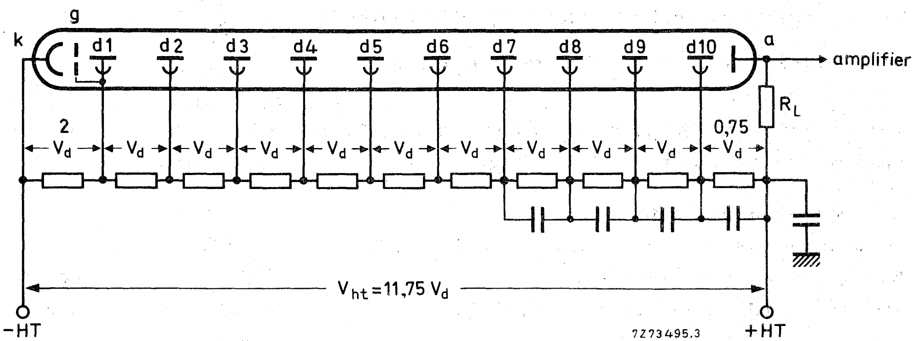


Fig. 2 Voltage divider A.

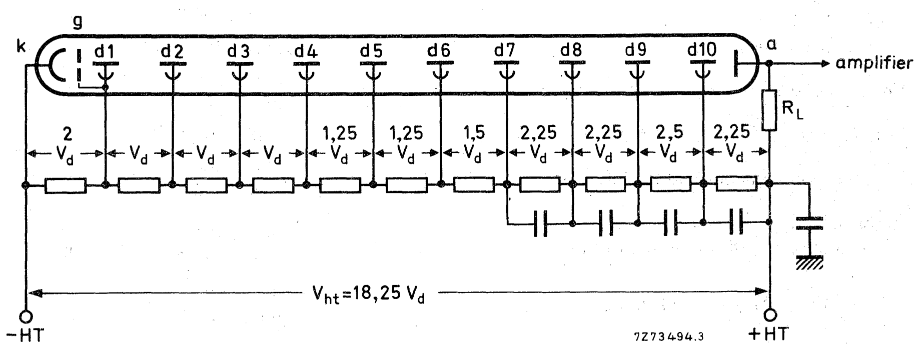


Fig. 3 Voltage divider B.

k = cathode
g = accelerating electrode (internally connected to d1)
d_n = dynode no.
a = anode
R_L = load resistor

Typical values of capacitors: 10 nF

TYPICAL CHARACTERISTICS *

With voltage divider A (Fig. 2)		note 1
Supply voltage for an anode luminous sensitivity = 60 A/lm (Fig. 7)	< 1550 V typ. 1350 V	
Anode dark current at an anode luminous sensitivity = 60 A/lm (Fig. 7)	< 50 nA typ. 3 nA	notes 2,3
Mean anode sensitivity deviation at V_{ht} = 1200 V, long term (16 h)	≈ 1%	note 4
Anode current linear within 2% at V_{ht} = 1700 V	up to 100 mA	
With voltage divider B (Fig. 3)		note 1
Anode luminous sensitivity at V_{ht} = 1700 V (Fig. 7)	≈ 55 A/lm	
Anode pulse rise time at V_{ht} = 1700 V	≈ 3,5 ns	note 5
Anode pulse duration at half height at V_{ht} = 1700 V	≈ 7 ns	note 5
Signal transit time at V_{ht} = 1700 V	≈ 35 ns	note 5
Anode current linear within 2% at V_{ht} = 1700 V	up to ≈ 200 mA	

LIMITING VALUES (Absolute maximum rating system)

Supply voltage	max. 1800 V	note 6
Continuous anode current	max. 0,2 mA	note 7
Voltage between first dynode and photocathode	max. 600 V min. 150 V	note 8
Voltage between consecutive dynodes	max. 300 V	
Voltage between anode and final dynode	max. 300 V min. 30 V	note 9
Ambient temperature range operational (for short periods of time)	max. +80 °C min. −30 °C	note 10
continuous operation and storage	max. +50 °C min. −30 °C	

* Notes are given on page 5.

Notes

1. To obtain a peak pulse current greater than that obtainable with divider A, it is necessary to increase the inter-dynode voltage of the stages progressively. Divider circuit B is an example of a "progressive" divider, giving a compromise between gain, speed, and linearity. Other dividers can be conceived to achieve other compromises. It is generally recommended that the voltage difference between one stage and the next is less than a factor of 2.
2. Wherever possible, the power supply should be arranged so that the cathode is earthed and the anode is at + HT, however, it is sometimes necessary to supply the tube with the anode earthed and the cathode at –HT. Under these circumstances, erratic noise and dark current are generally increased and unstable, particularly after application of voltage. The glass envelope of the tube should be supported only by insulators with an insulation resistance of $> 10^{15}$ ohm.
3. Dark current is measured at ambient temperature, after the tube has been in darkness for approx. 1 min. Lower values can be obtained after a longer stabilization period in darkness (approx. 30 min).
4. The mean anode sensitivity deviation measurement is carried out with light pulses at a count rate of 10^4 c/s resulting in an average anode current of 0,5 μA. See also *General Operational Recommendations Photomultiplier Tubes.*
5. Measured with a pulsed light source, with a pulse duration (FWHM) of < 1 ns; the cathode being completely illuminated. The rise time is determined between 10% and 90% of the amplitude of the anode pulse. The signal transit time is measured between the instant at which the illuminating pulse at the cathode becomes maximum, and the instant at which the anode pulse attains its maximum. Rise time, pulse duration and transit time vary as a function of high tension supply voltage V_{ht}, approximately as $V_{ht}^{-1/2}$.
6. Total HT supply voltage, or the voltage at which the tube has an anode luminous sensitivity of 600 A/lm, whichever is lower.
7. A value of < 10 μA is recommended for applications requiring good stability.
8. Minimum value to obtain good collection in the input optics.
9. When calculating the anode voltage the voltage drop across the load resistor should be taken into account.
10. This range of temperatures is limited principally by stresses in the sealing layer of the base to the glass bulb. Where low temperature operation is contemplated, the supplier should be consulted.

DEVELOPMENT SAMPLE DATA

MECHANICAL DATA

Dimensions in mm

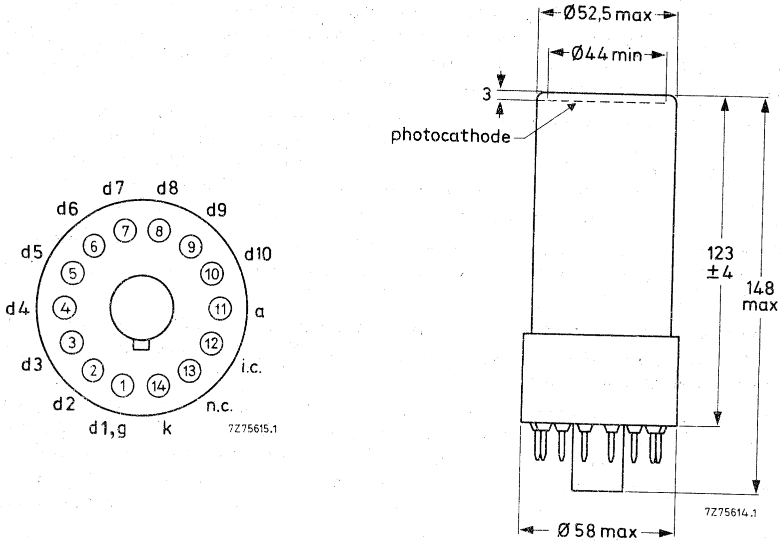


Fig. 4.

Base	14-pin (JEDEC B14-38)
Net mass	144 g

ACCESSORIES

Socket	type FE1014

DEVELOPMENT SAMPLE DATA

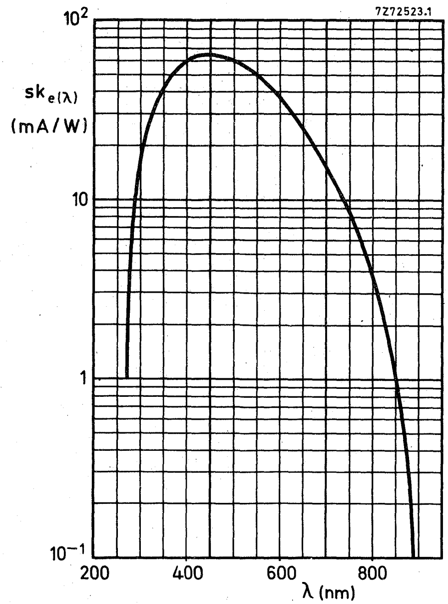


Fig. 5 Spectral sensitivity characteristic.

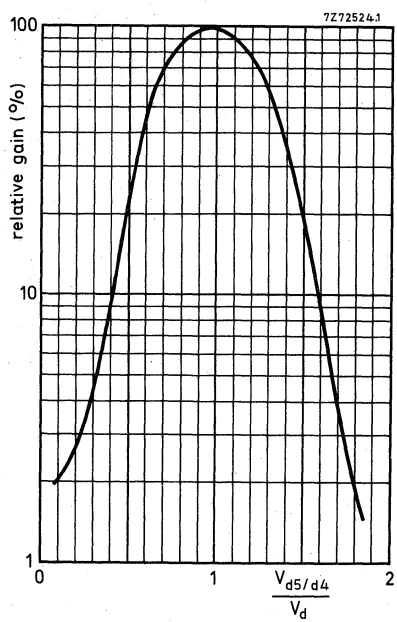


Fig. 6 Relative gain as a function of the voltage between d5 and d4 normalized to V_d; $V_{d6/d4}$ constant.

Note: Gain regulation by changing the voltage between d5 and d4 may cause a degradation of other parameters such as stability and linearity.

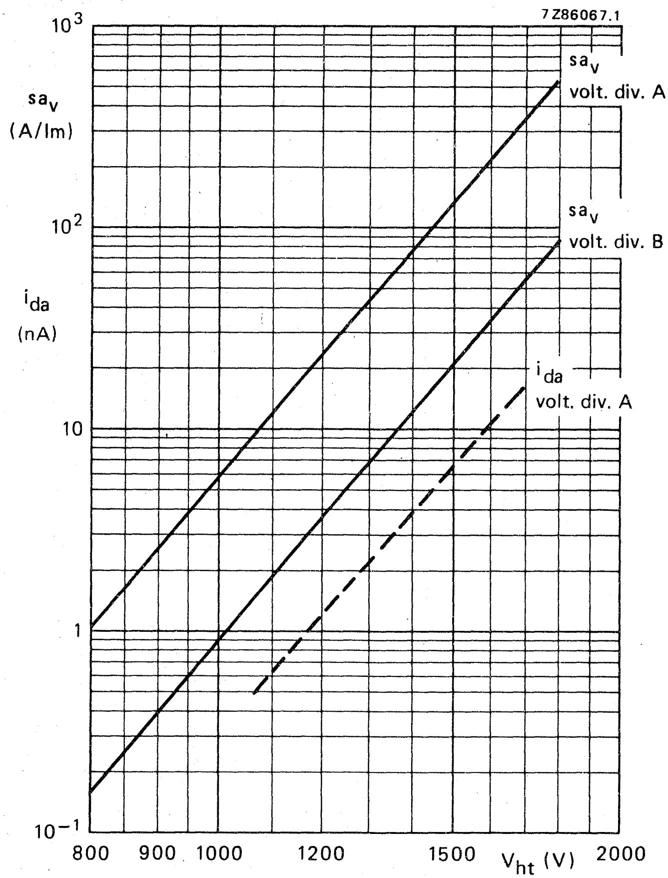


Fig. 7 Anode luminous sensitivity, sa_v, and anode dark current i_{da} as a function of supply voltage V_{ht}.

i_{da} is given as a dotted line to indicate its principle behaviour only.

12-STAGE PHOTOMULTIPLIER TUBE

- 44 mm useful diameter head-on types
- plano-plano window
- semi-transparent bi-alkaline type D photocathode
- high gain and very good pulse linearity
- good single electron spectrum resolution, for tubes with high gain first dynode (from serial number 7000 onwards)
- For high energy physics experiments and industrial applications
- XP2212 (with 19-pin base) is pin-compatible with XP2232 and XP2262;
  XP2212B (with 20-pin base) is pin-compatible with XP2232B and XP2262B, and unilaterally pin-compatible with 56AVP-family tubes.

QUICK REFERENCE DATA

Spectral sensitivity characteristic	type D
Useful diameter of the photocathode	> 44 mm
Quantum efficiency at 400 nm	23%
Cathode spectral sensitivity at 400 nm	75 mA/W
Supply voltage for a gain of 3 x 10^7	1900 V
Pulse amplitude resolution for ^{137}Cs	≈ 7,2%
Anode pulse rise time (with voltage divider B)	≈ 4 ns
Linearity	
with voltage divider A (Fig. 2)	up to ≈ 100 mA
with voltage divider B (Fig. 3)	up to ≈ 250 mA

To be read in conjunction with *General Operational Recommendations Photomultiplier Tubes.*

GENERAL CHARACTERISTICS*

Window

Material	lime glass
Shape	plano-plano
Refractive index at 550 nm	1,52

Photocathode (note 1)

Semi-transparent, head-on		
Material	Sb K Cs	
Useful diameter	> 44 mm	
Spectral sensitivity characteristic (Fig. 6)	type D	
Maximum spectral sensitivity	400 ± 30 nm	
Quantum efficiency at 400 nm	23%	
Spectral sensitivity at 400 nm	typ. 75 mA/W	
	> 60 mA/W	note 2

* Notes are given on page 5.

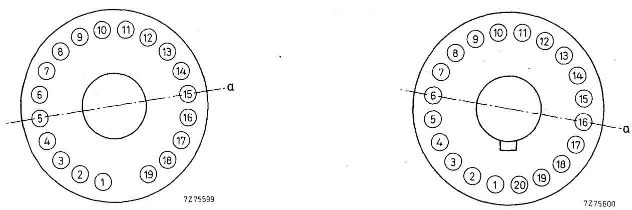
Multiplier system

Number of stages	12
Dynode structure	linear focused
Dynode material	Cu Be
Capacitances	
anode to final dynode	≈ 3 pF
anode to all	≈ 5 pF

Magnetic field

When the photocathode is illuminated uniformly, the anode current is halved (at V_{ht} = 1400 V, voltage divider A) at a magnetic flux density of:
0,2 mT perpendicular to axis a (see Fig. 1);
0,1 mT parallel to axis a.

It is recommended that the tube be screened from magnetic fields by a mu-metal shield protruding > 15 mm beyond the photocathode.



XP2212 XP2212B

Fig. 1 Axis a with respect to base pins (bottom view).

RECOMMENDED CIRCUITS

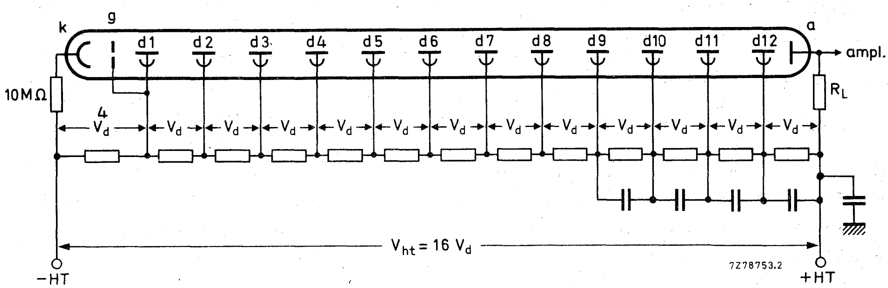


Fig. 2 Voltage divider A.

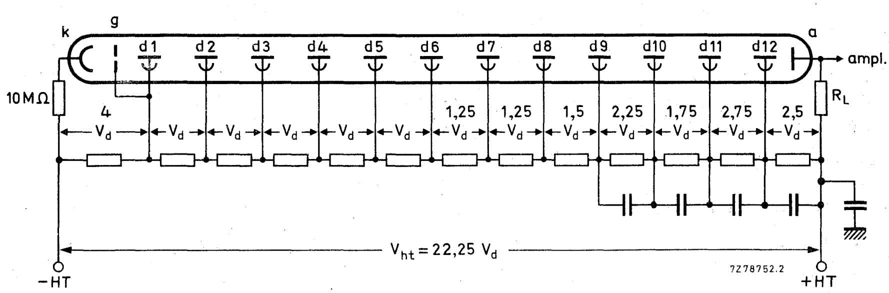


Fig. 3 Voltage divider B.

k = cathode

g = accelerating electrode (internally connected to d1 in XP2212B).

d_n = dynode no.

a = anode

R_L = load resistor

Typical values of capacitors: 1 nF

The cathode resistor of 10 MΩ limits the current should there be unintentional contact between the coating and earth when the anode is earthed.

TYPICAL CHARACTERISTICS*

Note: All spectral sensitivities refer to a wavelength of 400 nm.

With voltage divider A (Fig. 2)		note 3
Supply voltage for a gain of 3 x 10^7 (Fig. 8)	< 2400 V typ. 1900 V	
Anode dark current at a gain of 3 x 10^7 (Fig. 8)	≈ 15 nA	note 4
Background noise at a gain of 3 x 10^7	typ. 1500 c/s < 10^4 c/s	notes 4,5
Pulse amplitude resolution for ^{137}Cs at an anode spectral sensitivity of 70 kA/W	≈ 7,2%	note 6
Anode current linear within 2% at V_{ht} = 1900 V	up to ≈ 100 mA	
Mean anode sensitivity deviation		note 7
long term (16 h)	≈ 1%	
after change of count rate	≈ 1%	
versus temperature between 0 and +40 °C at 450 nm	≈ 0,2 %/°C	
Single electron spectrum, peak to valley ratio, at a gain of 3 x 10^7	≈ 2	note 8
With voltage divider B (Fig. 3)		note 3
Gain at V_{ht} = 2000 V (Fig. 8)	≈ 7 x 10^6	
Anode pulse rise time at V_{ht} = 2000 V	≈ 4 ns	note 9
Anode pulse duration at half height at V_{ht} = 2000 V	≈ 8 ns	note 9
Signal transit time at V_{ht} = 2000 V	≈ 36 ns	note 9
Signal transit time difference between the centre of the photocathode and 18 mm from the centre at V_{ht} = 2000 V	≈ 5 ns	
Anode current linear within 2% at V_{ht} = 2000 V	up to ≈ 250 mA	

LIMITING VALUES (Absolute maximum rating system)

Supply voltage	max. 2500 V	note 10
Continuous anode current	max. 0,2 mA	note 11
Voltage between first dynode and photocathode	max. 800 V min. 300 V	note 12
Voltage between consecutive dynodes	max. 400 V	
Voltage between anode and final dynode	max. 600 V min. 80 V	note 13
Ambient temperature range		
operational (for short periods of time)	max. +80 °C min. −30 °C	note 14
continuous operation and storage	max. +50 °C min. −30 °C	

* Notes are given on pages 5 and 6.

Notes

1. The bi-alkaline photocathode has a significant resistance which increases rapidly with reducing temperature. It is therefore recommended that it should not be exposed to light of too great an intensity; the cathode current should be limited, for example, to 1 nA at room temperature or 0,1 nA at −30 °C. If too high a photocurrent is passed, the cathode can no longer be considered an equipotential surface, and the focusing of electrons onto the first dynode will be affected, resulting in departure from linearity. In applications with short pulse times the photocathode is able to deliver pulses containing 10^6 to 10^7 photoelectrons without disturbance.
2. Spectral sensitivity is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5K. Light is transmitted through an interferential filter.
3. To obtain a peak pulse current greater than that obtainable with divider A, it is necessary to increase the inter-dynode voltage of the stages progressively. Divider circuit B is an example of a "progressive" divider, giving a compromise between gain, speed, and linearity. Other dividers can be conceived to achieve other compromises after consulting the supplier.
4. Wherever possible, the power supply should be arranged so that the cathode is earthed and the anode is at + HT, however, it is sometimes necessary to supply the tube with the anode earthed and the cathode at −HT. Under these circumstances, erratic noise and dark current are generally increased and unstable, particularly immediately after application of voltage. The tube is provided with a conductive coating connected to the cathode. It is recommended that, if a metal shield is used this be kept at photocathode potential. This implies safety precautions to protect the user. The envelope of the tube should be supported only by insulators with an insulation resistance of $> 10^{15}$ Ω.
5. Noise is measured at ambient temperature. After having been stored with its protective hood, the tube is placed in darkness with V_{ht} set to a value to give a gain of 3 x 10^7. After a 5 min. stabilization period noise pulses with a threshold of 1 pC (corresponding to 0,2 photoelectron) are recorded. Lower values can be obtained after a longer stabilization period.
6. Pulse amplitude resolution for ^{137}Cs is measured with a NaI (Tl) cylindrical scintillator (Quartz et Silice ser. no.: 7256 or equivalent) with a diameter of 44 mm and a height of 50 mm. The count-rate used is $\approx 10^4$ c/s.
7. The mean anode sensitivity deviation is measured by coupling an NaI (Tl) scintillator to the window of the tube. Long term (16 h) deviation is measured by placing a ^{137}Cs source at a distance from the scintillator such that the count rate is $\approx 10^4$ c/s corresponding to an average anode current of ≈ 300 nA. Anode sensitivity deviation after change of count rate is measured with a ^{137}Cs source at a distance of the scintillator such that the count rate can be changed from 10^4 c/s to 10^3 c/s corresponding to an average anode current of ≈ 1 μA and ≈ 0,1 μA respectively. Both tests are carried out according to ANSI–N42–9–1972 of IEEE recommendations.
8. Peak to valley ratio is defined as the single electron peak value divided by the minimum value to the left of the peak.
9. Measured with a pulsed-light source, with a pulse duration (FWHM) of < 1 ns, the cathode being completely illuminated. The rise time is determined between 10% and 90% of the amplitude of the anode pulse. The signal transit time is measured between the instant at which the illuminating pulse at the cathode becomes maximum, and the instant at which the anode pulse attains its maximum. Rise time, pulse duration and transit time vary as a function of high tension supply voltage V_{ht}, approximately as $V_{ht}^{-1/2}$.
   Non-inductive resistors of 51 Ω are connected in the base of type XP2212B to d_{11} and d_{12}. See also *General Operational Recommendations Photomultiplier Tubes*.
10. Total HT supply voltage, or the voltage at which the tube has a gain of 2 x 10^8, whichever is lower.
11. A value of < 10 μA is recommended for applications requiring good stability.
12. Minimum value to obtain good collection in the input optics.

Notes (continued)

13. When calculating the anode voltage the voltage drop across the load resistor should be taken into account.
14. For type XP2212B this range of temperatures is limited principally by stresses in the sealing layer of the base to the glass bulb. Where low temperature operation is contemplated, the supplier should be consulted.

MECHANICAL DATA

Dimensions in mm

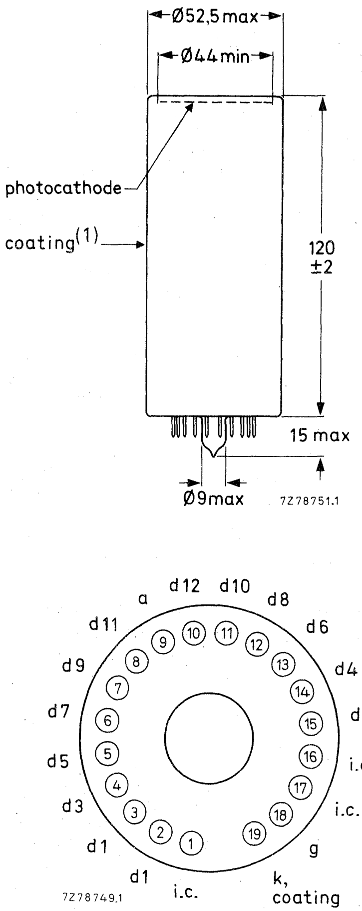


Fig. 4 XP2212.

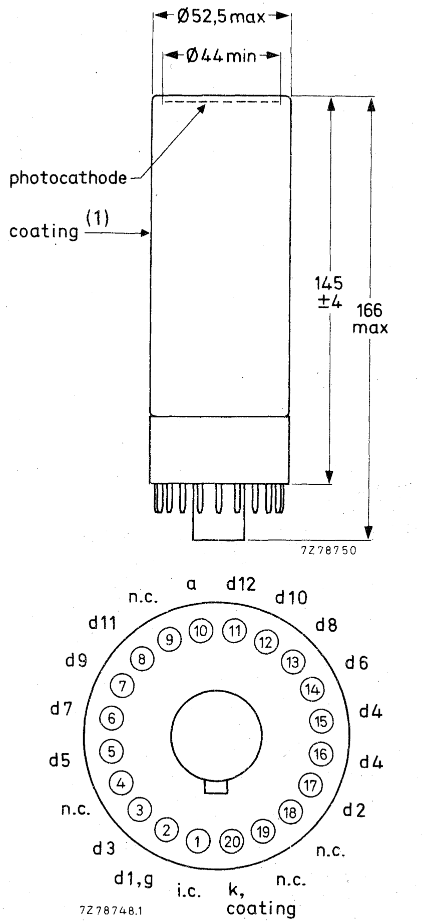


Fig. 5 XP2212B.

Base 19-pin all glass
Net mass 111 g

Base 20-pin (IEC 67-1-42a, JEDEC B20-102)
Net mass 148 g

(1) **Warning**

The envelope of the tube is covered with a conductive coating, connected to the cathode. On top of this a black paint is applied which is neither guaranteed to be light tight nor isolating. Care should be taken to avoid hazard due to electric shock.

ACCESSORIES

Socket

for XP2212	type FE2019
for XP2212B	type FE1020

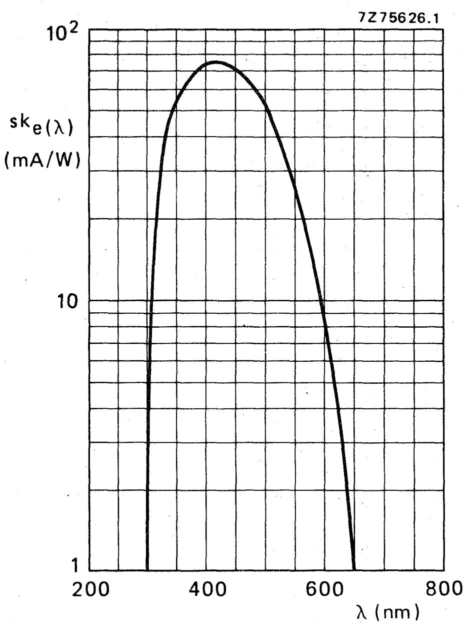


Fig. 6 Spectral sensitivity characteristic.

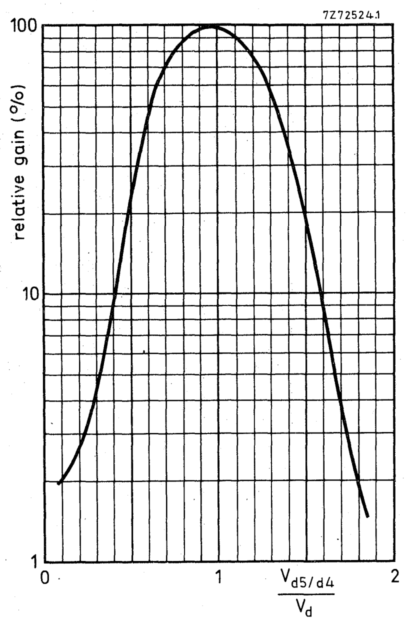


Fig. 7 Relative gain as a function of the voltage between d5 and d4 normalized to V_d. $V_{d6/d4}$ constant.

Note: Gain regulation by changing the voltage between d5 and d4 may cause a degradation of other parameters such as stability and linearity.

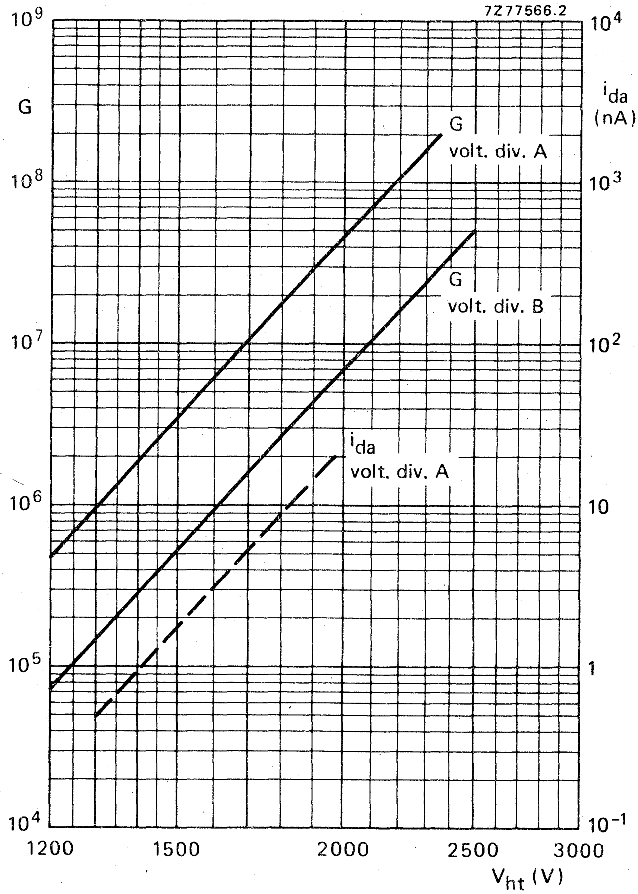


Fig. 8 Gain G and anode dark current, I_{da}, as a function of supply voltage V_{ht}.

I_{da} is given as a dotted line to indicate its principle behaviour only.

12-STAGE PHOTOMULTIPLIER TUBE

The XP2230 and XP2230B are 44 mm useful diameter head-on photomultiplier tubes with a plano-concave window and a semi-transparent bialkaline type D photocathode.
The tubes are intended for use in nuclear physics where the number of photons to be detected is very low. The tubes feature a high cathode sensitivity and a good linearity combined with very low background noise and very good time characteristics. They are especially useful in high-energy physics experiments such as coincidence measurements, Cerenkov detection etc. The XP2230 has a 21-pin all-glass base.

The XP2230B is provided with a 20-pin plastic base. This version is unilaterally interchangeable with the 56AVP-family tubes.

QUICK REFERENCE DATA

Spectral sensitivity characteristic		type D		
Useful diameter of the photocathode		>	44	mm
Quantum efficiency at 401 nm			28	%
Spectral sensitivity of the photocathode at 401 nm			85	mA/W
Supply voltage for a gain $G = 3 \times 10^7$			2300	V
Background noise		≈	600	c/s
Pulse amplitude resolution for ^{137}Cs		≈	7,5	%
Anode pulse rise time (with voltage divider B')		≈	1,6	ns
Linearity (with voltage divider B)	up to	≈	280	mA
Signal transit time distribution at V_b = 2500 V	σ	≈	0,35	ns

To be read in conjunction with "General Operational Recommendations Photomultiplier tubes".

GENERAL CHARACTERISTICS

Window

Material	borosilicate
Shape	plano-concave
Refractive index at 550 nm	1,48

Photocathode [1]

Semi-transparent, head-on

Material		Sb K Cs		
Useful diameter		>	44	mm
Spectral sensitivity characteristic (Fig. 4)		type D		
Maximum spectral sensitivity at			400 ± 30	nm
Quantum efficiency at 401 nm			28	%
Spectral sensitivity at 401 ± 3 nm [2]		typ.	85	mA/W
		>	65	mA/W

Electron optical input system

This consists of : the photocathode, k, and the accelerating electrode, acc, for type XP2230B internally connected to S1.

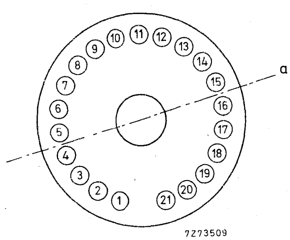
Multiplier system

Number of stages			12	
Dynode structure		linear focused		
Dynode material			CuBe	
Capacitances				
Anode to all	C_a	≈	6	pF
Anode to final dynode	$C_{a/S12}$	≈	4	pF

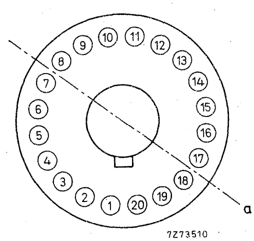
Magnetic field

See Fig. 9

It is recommended that the tube be screened against the influence of magnetic fields by a mu-metal shield protruding > 15 mm beyond the photocathode.



XP2230



XP2230B

Axis a with respect to base pins (bottom view)

Notes see page 5.

RECOMMENDED CIRCUITS

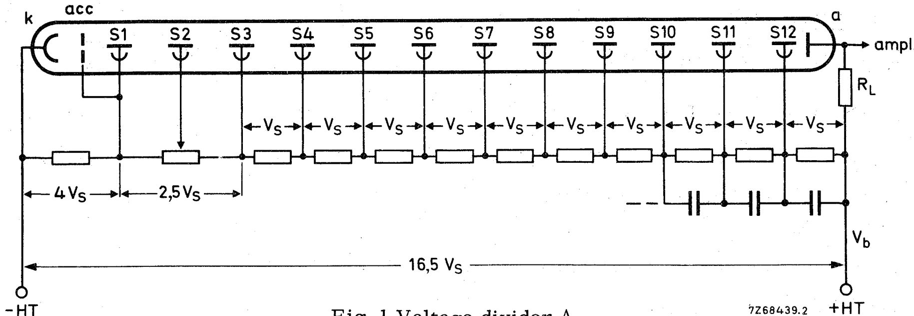


Fig. 1 Voltage divider A

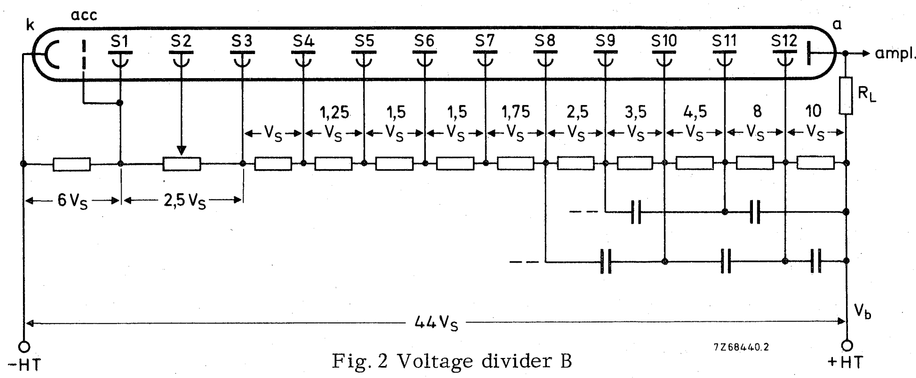


Fig. 2 Voltage divider B

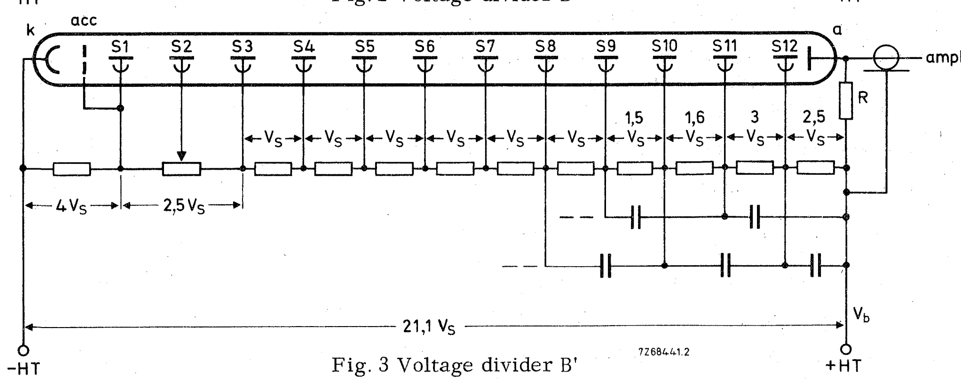


Fig. 3 Voltage divider B'

k = cathode

acc = accelerating electrode

S_n = dynode no. n

R_L = load resistor

a = anode

R = This resistor serves to connect the anode when the output cable is not terminated.
Recommended value : 10 kΩ

Typical value of capacitors : 1 nF

TYPICAL CHARACTERISTICS

With voltage divider A (Fig. 1)	3)				
Supply voltage for a gain G = 3 x 10^7 (Fig. 6)			typ.	2300	V
			<	2600	V
Anode dark current at G = 3 x 10^7 (Fig. 6)	4) 5)		typ.	7	nA
			<	25	nA
Background noise at G = 3 x 10^7 (Fig. 5)	6)		≈	600	c/s
Pulse amplitude resolution for ^{137}Cs at V_b = 1200 V	7)		≈	7,5	%
Anode pulse rise time at V_b = 2000 V	8)		≈	1,8	ns
Anode pulse duration at half height at V_b = 2000 V	8)		≈	3,8	ns
Signal transit time at V_b = 2000 V	8)		≈	28	ns
Signal transit time difference between the centre of the photocathode and 18 mm from the centre at V_b = 2000 V	8)		≈	0,6	ns
Anode current linear within 2% at V_b = 2000 V up to			≈	25	mA
Obtainable peak anode current			≈	100	mA
With voltage divider B (Fig. 2)	3)				
Gain G at V_b = 3000 V (Fig. 6)			≈	5 x 10^6	
Anode pulse rise time at V_b = 3000 V	8)		≈	1,6	ns
Anode pulse duration at half height at V_b = 3000 V	8)		≈	3	ns
Signal transit time at V_b = 3000 V	8)		≈	31	ns
Signal transit time difference between the centre of the photocathode and 18 mm from the centre at V_b = 3000 V	8)		≈	0,65	ns
Anode current linear within 2% at V_b = 3000 V up to			≈	280	mA
Obtainable peak anode current			≈	0,5 to 1	A
With voltage divider B' (Fig. 3)	3)				
Gain G at V_b = 2500 V (Fig. 6)			≈	2 x 10^7	
Anode pulse rise time at V_b = 2500 V	8)		≈	1,6	ns
Anode pulse duration at half height at V_b = 2500 V	8)		≈	2,7	ns
Signal transit time at V_b = 2500 V	8)		≈	28	ns
Signal transit time distribution at V_b = 2500 V	9)	σ	≈	0,35	ns
Signal transit time difference between the centre of the photocathode and 18 mm from the centre at V_b = 2500 V	8)		≈	0,6	ns

Anode current linear within 2% at V_b = 2500 V up to	≈	70	mA
Obtainable peak anode current	≈	250	mA

---

1) The bialkaline photocathode has a significant resistance which increases rapidly with reducing temperature. It is thus recommended that it should not be subjected to light of too great an intensity; the cathode current should be limited to, for example, 1 nA at room temperature or 0,01 nA at −80 °C.
If too high a photocurrent is passed, the cathode can no longer be considered to be an equipotential surface, and the focusing of electrons onto the first dynode will be affected, resulting in departures of linearity.

2) Measuring equipment is calibrated by comparison with a Schwartz thermocouple.

3) To obtain a peak pulse current greater than that obtainable with divider A, it is necessary to increase the inter-dynode voltages of the stages progressively. Divider circuits B and B' are examples of progressive dividers, each giving a compromise between gain, speed, and linearity. Other dividers can be conceived to achieve other compromises. It is generally recommended that the increase in voltage between one stage and the next be kept less than a factor of 2.

4) Wherever possible, the photomultiplier power supply should be arranged so that the photocathode is earthed and the anode is at +HT, however, it is sometimes necessary to supply the tube with the anode earthed and the cathode at −HT. Under these circumstances, erratic noise and dark current are generally increased and unstable, particularly immediately after application of voltage. It is recommended that, if a metal shield is used, this be kept at cathode potential. This implies safety precautious to protect the user. The glass envelope of the tube should be supported only by isolators having an insulation resistance of > 10^{15} Ω.

5) Dark current is measured at ambient temperature, after a stabilization period of the tube in darkness (≈ 1/4 h).

6) After having been stored with its protective hood, the tube is placed in darkness with V_b set to a value to give a gain of 3 x 10^7.
After a 30 min stabilization period noise pulses with a threshold of 4,25 x 10^{-13} C (corresponding to 0,1 photoelectron) are recorded. (See Fig. 5).

7) Pulse amplitude resolution for ^{137}Cs is measured with a NaI(Tl) cylindrical scintillator with a diameter of 44 mm and a height of 50 mm. The count rate is ≈ 10^3 c/s.

8) Measured with a pulsed-light source with a pulse duration of < 1 ns; the cathode being completely illuminated.
The rise time is determined between 10% and 90% of the amplitude of the anode pulse.
The signal transit time is measured between the instant at which the illuminating pulse at the cathode becomes maximum, and the instant at which the anode pulse attains its maximum.
Rise time, pulse duration, and transit time vary as a function of the HT supply voltage, V_b, approximately as $V_b^{-\frac{1}{2}}$.

9) Transit time fluctuations of single electrons leaving the photocathode result in a transit time distribution at the anode. This distribution is characterized by its standard deviation σ.

LIMITING VALUES (Absolute max. rating system)

Supply voltage	1)	max.	3000	V
Continuous anode current	2)	max.	0,2	mA
Voltage between first dynode and photocathode	3)	max.	800	V
		min.	300	V
Voltage between consecutive dynodes (except S12 and S11)		max.	400	V
Voltage between dynode S12 and dynode S11		max.	600	V
Voltage between anode and final dynode	4)	max.	700	V
		min.	80	V
Ambient temperature range				
XP2230				
Operational (for short periods of time)		max.	+80	°C
		min.	−80	°C
Continuous operation and storage		max.	+50	°C
		min.	−80	°C
XP2230B				
Operational (for short periods of time)	5)	max.	+80	°C
		min.	−30	°C
Continuous operation and storage		max.	+50	°C
		min.	−30	°C

1) Total supply voltage, or the voltage at which the tube has a gain of 2×10^8, whichever is lower.

2) A value of < 10 μA is recommended for applications requiring good stability.

3) Minimum value to obtain good collection in the input optics.

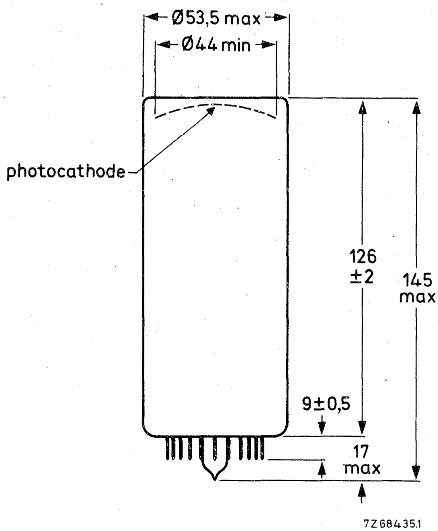
4) When calculating the anode voltage the voltage drop across the load resistor should be taken into account.

5) For type XP2230B this range of temperatures is limited principally by stresses in the sealing layer of the base to the glass bulb.
When low temperature operation is contemplated, the supplier should be consulted.

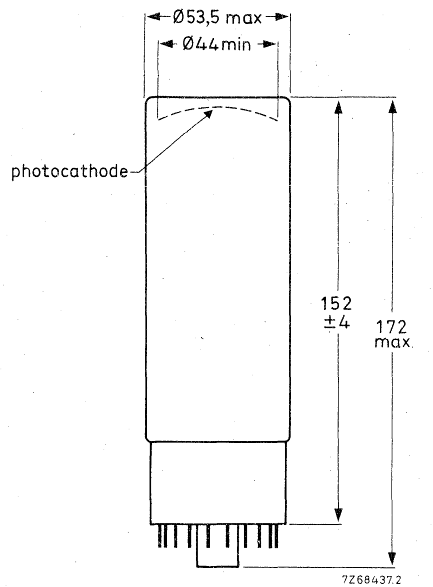
MECHANICAL DATA

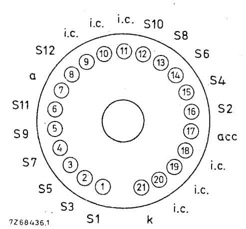
Dimensions in mm

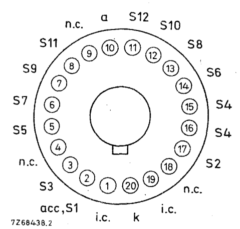
XP2230



XP2230B







Base	21-pin all-glass	Base: 20-pin (IEC 67-I-42a, JEDEC B20-102)
Net mass	160 g	190 g

ACCESSORIES

Socket	for XP2230 type FE2021	for XP2230B type FE1020

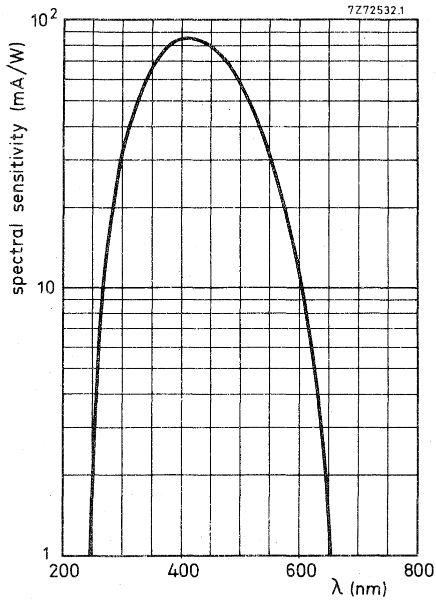


Fig. 4 Spectral sensitivity characteristic.

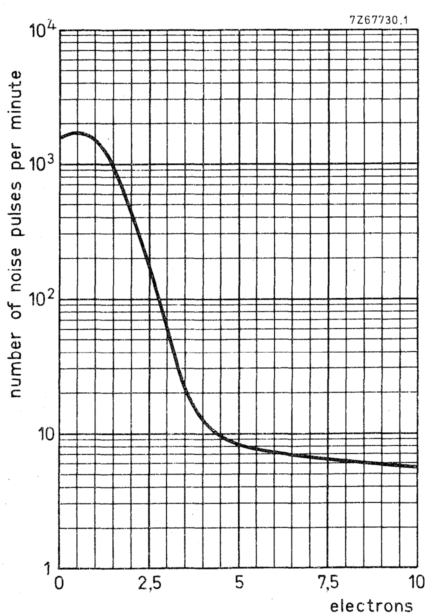


Fig. 5 Typical background spectrum from 0,1 to 10 equivalent photoelectrons, at a gain of 3×10^7, voltage divider A.

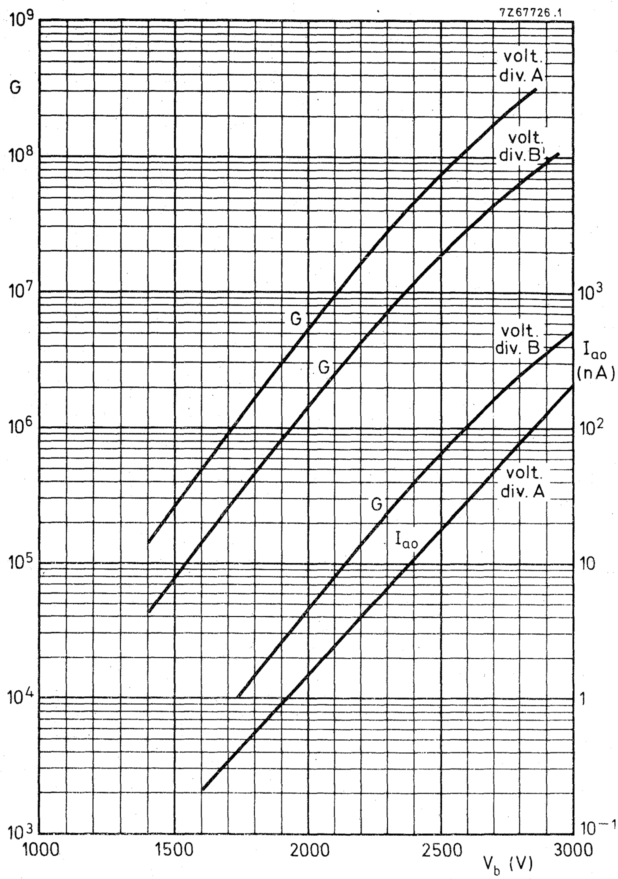


Fig. 6

Gain G, and anode dark current, I_{ao}, as a function of supply voltage V_b.

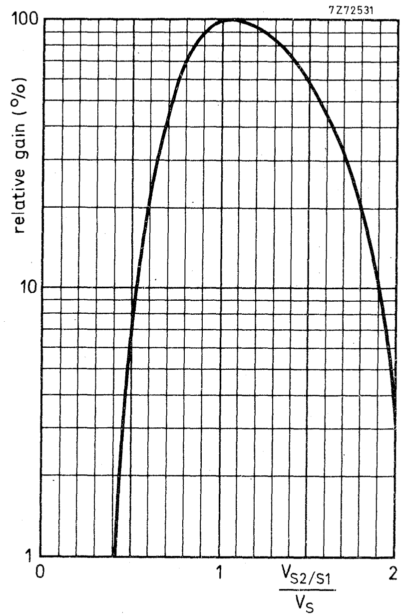


Fig. 7
Relative gain as a function of the voltage between dynodes S_2 and S_1, normalized to V_S.
$V_{S3/S1}$ constant.

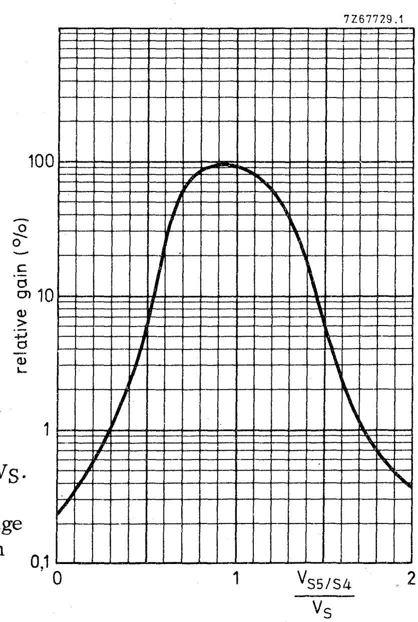
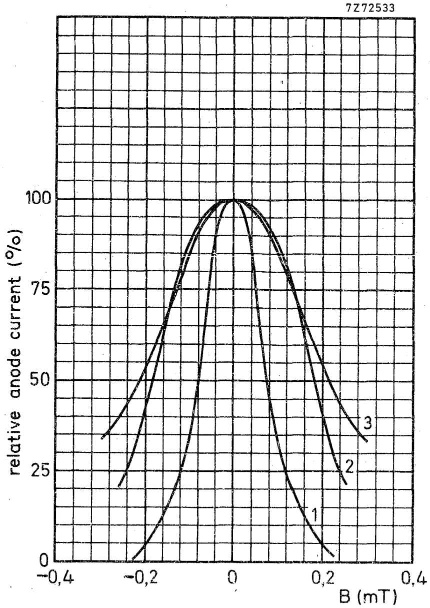


Fig. 8 Relative gain as a function of the voltage between S5 and S4, normalized to V_S.
$V_{S6/S4}$ constant.
Note: Gain regulation by changing the voltage between S_5 and S_4 may cause a degradation of other parameters such as stability and linearity.

Fig. 9
Relative anode current as a function of the magnetic flux density B.
Voltage divider A, V_b = 2300 V.
1 B // axis a)
2 B ⊥ axis a)
3 B // tube axis



12-STAGE PHOTOMULTIPLIER TUBE

The XP2233B is a 44 mm useful diameter head-on photomultiplier tube with a plano-concave window and a semi-transparent trialkaline S20 (type T) photocathode. The tube is intended for use in low light level physics experiments in the red and near infrared part of the spectrum such as laser detection, pollution monitoring, life time measurements. The tube also features good time characteristics.
The XP2233B is unilaterally interchangeable with 56AVP-family tubes.

QUICK REFERENCE DATA

Spectral sensitivity characteristic		S20 (type T)		
Useful diameter of the photocathode		>	44	mm
Cathode spectral sensitivity at 698 nm			15	mA/W
Supply voltage for a gain of 3×10^7			2050	V
Anode pulse rise time (with voltage divider B)		≈	2,0	ns
Linearity				
with voltage divider A	up to	≈	100	mA
with voltage divider B	up to	≈	250	mA

To be read in conjunction with *General Operational Recommendations Photomultiplier Tubes.*

GENERAL CHARACTERISTICS

Window

Material	borosilicate		
Shape	plano-concave		
Refractive index at 550 nm		1,48	

Photocathode

Semi-transparent, head-on			
Material	Sb Na K Cs		
Useful diameter	>	44	mm
Spectral sensitivity characteristic (Fig. 5)	S20 (type T)		
Maximum spectral sensitivity at		420 ± 30	nm
Spectral sensitivity			
at 698 ± 7 nm	typ.	15	mA/W
	>	7	mA/W
at 629 ± 3 nm	≈	30	mA/W
Luminous sensitivity	≈	150	μA/lm

Multiplier system

Number of stages		12
Dynode structure		linear focused
Dynode material		Cu Be
Capacitances		
anode to final dynode	≈	3 pF
anode to all	≈	5 pF

Magnetic field

When the cathode is illuminated uniformly, the anode current is halved (at V_b = 1400 V, voltage divider A) at a magnetic flux density of:
0,2 mT perpendicular to axis a (see Fig. 1)
0,1 mT parallel with axis a.

It is recommended that the tube be screened against the influence of magnetic fields by a mu-metal shield protruding > 15 mm beyond the photocathode.

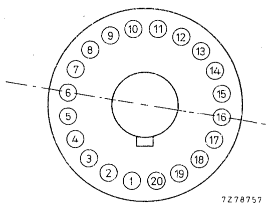


Fig. 1 Axis a with respect to base pins (bottom view).

RECOMMENDED CIRCUITS

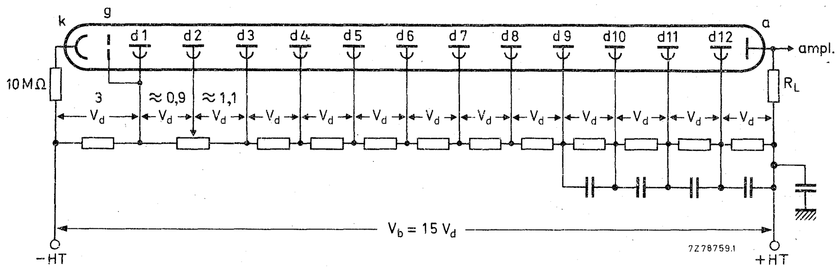


Fig. 2 Voltage divider A.

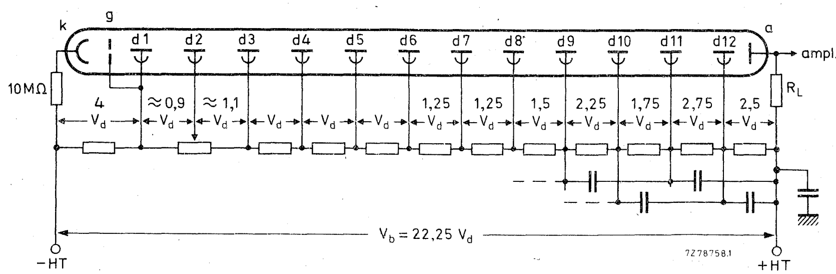


Fig. 3 Voltage divider B.

k = cathode
g = accelerating electrode
d_n = dynode no.:
R_L = load resistor
a = anode

Typical values of capacitors 1 nF.

The cathode resistor of 10 MΩ limits the current should there be unintentional contact between the coating and earth when the anode is earthed.
The voltage, $V_{d2\text{-}d1}$, to be adjusted for maximum signal.

TYPICAL CHARACTERISTICS

	notes				
With voltage divider A (Fig. 2)	1				
Supply voltage for a gain of 3×10^7 (Fig. 7)			<	2500	V
			typ.	2050	V
Anode dark current at a gain of 3×10^7 (Fig. 7)	2,3		<	1500	nA
			typ.	60	nA
Anode pulse rise time at V_b = 2050 V	4		≈	2,2	ns
Anode pulse duration at half-height at V_b = 2050 V	4		≈	3,6	ns
Signal transit time at V_b = 2050 V	4		≈	30	ns
Anode current linear within 2% at V_b = 2050 V		up to	≈	100	mA
With voltage divider B (Fig. 3)	1				
Gain at V_b = 2400 V (Fig. 7)			≈	2×10^7	
Anode pulse rise time at V_b = 2400 V	4		≈	2,0	ns
Anode pulse duration at half-height at V_b = 2400 V	4		≈	3,2	ns
Signal transit time at V_b = 2400 V	4		≈	30	ns
Signal transit time difference between the centre of the photocathode and 18 mm from the centre at V_b = 2400 V	4		≈	0,7	ns
Anode current linear within 2% at V_b = 2400 V		up to	≈	250	mA

LIMITING VALUES (absolute maximum rating system)

	notes			
Supply voltage	5	max.	2500	V
Continuous anode current	9	max.	0,2	mA
Voltage between accelerating electrode, g, and photocathode		max.	800	V
Voltage between first dynode and photocathode	6	max.	800	V
		min.	300	V
Voltage between consecutive dynodes		max.	400	V
Voltage between anode and final dynode	7	max.	600	V
		min.	80	V
Ambient temperature range	8			
operational (for short periods of time)		max.	+80	°C
		min.	−30	°C
continuous operation and storage		max.	+50	°C
		min.	−30	°C

Notes

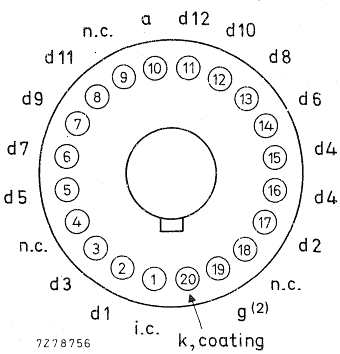
1. To obtain a peak pulse current greater than that obtainable with voltage divider A, it is necessary to increase the inter-dynode voltages of the stages progressively. Divider circuit B is an example of a "progressive" divider giving a compromise between gain, speed and linearity. Other dividers can be conceived to achieve other compromises after consulting the supplier.
2. Wherever possible, the power supply should be arranged so that the cathode is earthed and the anode is at + HT, however, it is sometimes necessary to supply the tube with the anode earthed and the cathode at −HT. Under these circumstances, erratic noise and dark current are generally increased and unstable, particularly immediately after application of voltage. The tube is provided with a conductive coating connected to the cathode. It is recommended that, if a metal shield is used this be kept at photocathode potential. This implies safety precautions to protect the user. The envelope of the tube should be supported only by isolators having an insulation resistance of $> 10^{15}\ \Omega$.
3. Dark current is measured at ambient temperature, after a stabilization period of the tube in darkness ($\approx$ ¼ h).
4. Measured with a pulsed-light source, with a pulse duration (FWHM) of < 1 ns, the cathode being completely illuminated. The rise time is determined between 10% and 90% of the amplitude of the anode pulse. The signal transit time is measured between the instant at which the illuminating pulse at the cathode becomes maximum, and the instant at which the anode pulse attains its maximum. Rise time, pulse duration and transit time vary as a function of high tension supply voltage V_b, approximately as $V_b^{-1/2}$. Non-inductive resistors of 51 Ω are connected in the base of the tube to d_{11} and d_{12}. See also General Operational Recommendations Photomultiplier Tubes.
5. Total high tension supply voltage, or the voltage at which the tube has a gain of 2×10^8, whichever is lower.
6. Minimum value to obtain good collection in the input optics.
7. When calculating the anode voltage the voltage drop across the load resistor should be taken into account.
8. This range of temperatures is limited principally by stresses in the sealing layer of the base to the glass bulb. Where low temperature operation is contemplated, the supplier should be consulted.
9. A value of $< 10\ \mu A$ is recommended for applications requiring good stability.

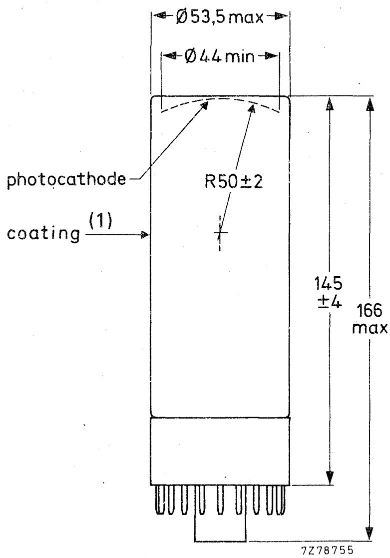
MECHANICAL DATA

Dimensions in mm

(1) **Warning:**

The envelope of the tube is covered with a conductive coating, connected to the cathode. On top of this a black paint is applied which is neither guaranteed to be light tight nor isolating.
Care should be taken to avoid hazard due to electric shock.





(2) Grid is connected to pin 19 starting from serial no. 1606.

Fig. 4.

Base	20-pin (IEC 67-1-42a, JEDEC B20-102)
Net mass	176 g

ACCESSORIES

Socket	type FE1020

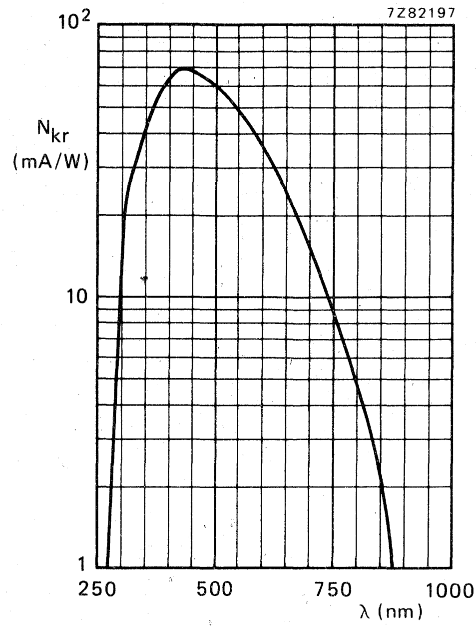


Fig. 5 Spectral sensitivity characteristic.

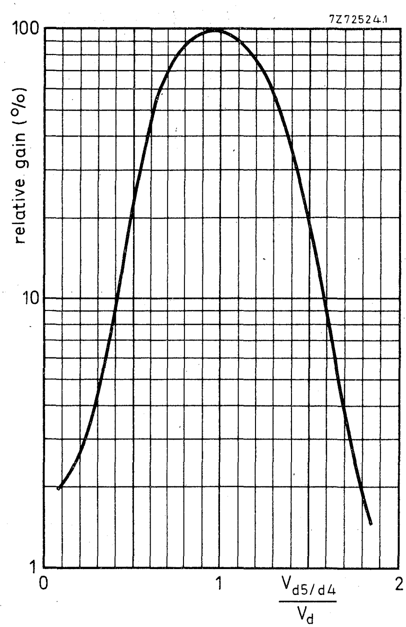


Fig. 6 Relative gain as a function of the voltage between S5 and S4, normalized to V_S. $V_{S6/S4}$ constant.

Note: Gain regulation by changing the voltage between S5 and S4 may cause a degradation of other parameters such as stability and linearity.

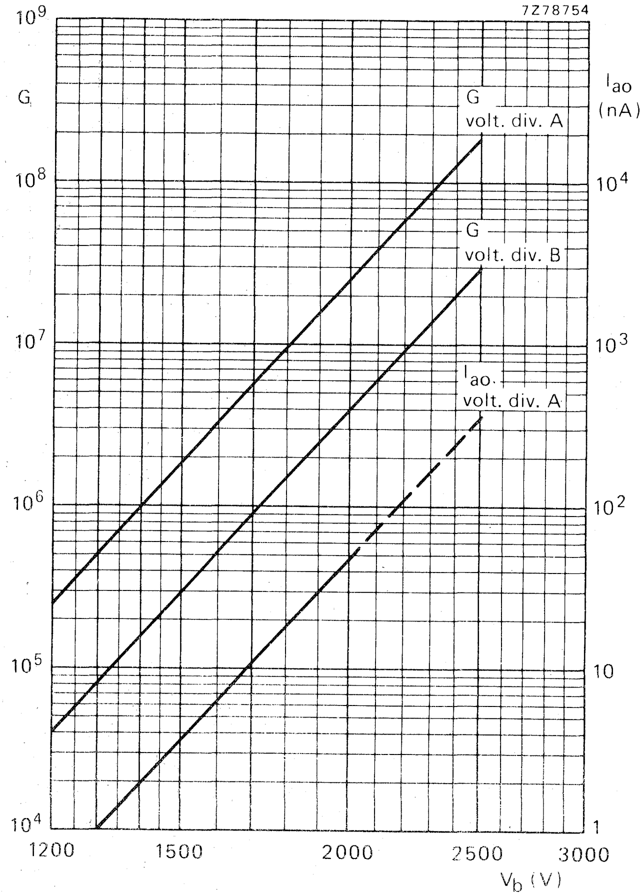


Fig. 7 Gain G, and anode dark current I_{ao}, as a function of supply voltage V_b.

The XP2262 replaces XP2232
The XP2262B replaces XP2232B, 56AVP and 56DVP

12-STAGE PHOTOMULTIPLIER TUBE

- 44 mm useful diameter head-on type
- plano-concave window
- semi-transparent bi-alkaline type D photocathode
- high cathode sensitivity
- very good linearity and time characteristics
- good single electron spectrum resolution
- for high-energy physics experiments
- XP2262 (with 19-pin base) is interchangeable with XP2232;
  XP2262B (with 20-pin base) is: interchangeable with XP2232B;
  pin-compatible with XP2020 and XP2230B;
  unilaterally pin-compatible with 56AVP-family tubes.

QUICK REFERENCE DATA *

Spectral sensitivity characteristic	type D	
Useful diameter of the photocathode	> 44 mm	
Quantum efficiency at 400 nm	25%	
Cathode blue sensitivity	10,5 μA/lmF	note 1
Single electron spectrum resolution	70%	
Supply voltage for a gain of 3×10^7	1850 V	
Pulse amplitude resolution for ^{137}Cs	≈ 7,2%	
Anode pulse rise time (with voltage divider B)	≈ 2,0 ns	
Linearity		
with voltage divider A (Fig. 2)	up to ≈ 100 mA	
with voltage divider B (Fig. 3)	up to ≈ 250 mA	

To be read in conjunction with *General Operational Recommendations Photomultiplier Tubes.*

GENERAL CHARACTERISTICS *

Window

Material	lime-glass
Shape	plano-concave
Refractive index at 550 nm	1,52

* Notes are given on page 5.

Photocathode (note 2)

Semi-transparent, head-on

Material	Sb K Cs	
Useful diameter	> 44 mm	
Spectral sensitivity characteristic (Fig. 6)	type D	
Maximum spectral sensistivity	400 ± 30 nm	
Luminous sensitivity	≈ 70 μA/lm	note 3
Blue sensitivity	typ. 10,5 μA/lmF > 9,0 μA/lmF	note 1
Spectral sensitivity at 400 nm	≈ 80 mA/W	note 4
Quantum efficiency at 400 nm	25%	

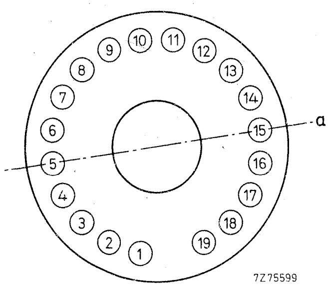
Multiplier system

Number of stages	12
Dynode structure	linear focused
Dynode material	Cu Be
Capacitances	
anode to final dynode	≈ 3 pF
anode to all	≈ 5 pF

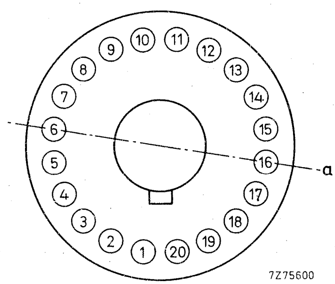
Magnetic field

When the photocathode is illuminated uniformly, the anode current is halved at V_{ht} = 1400 V, voltage divider A at a magnetic flux density of:
0,2 mT perpendicular to axis a (see Fig. 1);
0,1 mT parallel with axis a.

It is recommended that the tube be screened against the influence of magnetic fields by a mu-metal shield protruding > 15 mm beyond the photocathode.



XP2262



XP2262B

Fig. 1 Axis a with respect to base pins (bottom view).

DEVELOPMENT SAMPLE DATA

RECOMMENDED CIRCUITS

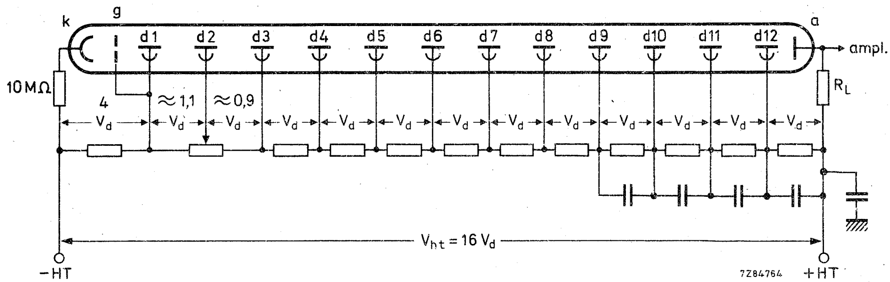


Fig. 2 Voltage divider A.

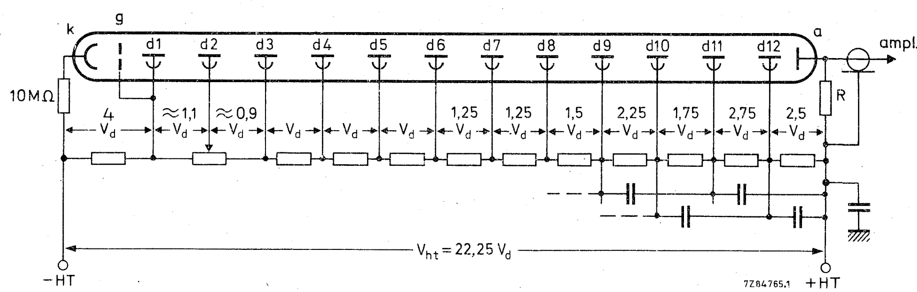


Fig. 3 Voltage divider B.

k = cathode;
g = accelerating electrode;
d_n = dynode no.;
R_L = load resistor;
a = anode.

Typical values of capacitors 1 nF.

The cathode resistor of 10 MΩ limits the current should there be unintentional contact between the coating and earth when the anode is earthed.
The voltage, $V_{d2\text{-}d1}$, to be adjusted for maximum signal and optimum single electron spectrum resolution.

Resistor R (Fig. 3) connects the anode if the output cable is not terminated. Recommended value of R: 10 kΩ.

TYPICAL CHARACTERISTICS*

With voltage divider A (Fig. 2)

Supply voltage for a gain of 3×10^7 (Fig. 8)	< 2400 V typ. 1850 V	note 5
Anode dark current at a gain of 3×10^7 (Fig. 8)	$\approx$ 10 nA	note 6
Background noise at a gain of 3×10^7	typ. 1×10^3 c/s $< 6 \times 10^3$ c/s	note 7
Single electron spectrum at a gain of 3×10^7 (Fig. 7)		
resolution	$\approx$ 70%	note 8
peak to valley ratio	$\approx$ 3	note 9
Anode pulse rise time at V_{ht} = 1900 V	$\approx$ 2,3 ns	note 10
Anode pulse duration at half height at V_{ht} = 1900 V	$\approx$ 3,7 ns	note 10
Signal transit time at V_{ht} = 1900 V	$\approx$ 31 ns	note 10
Pulse amplitude resolution for ^{137}Cs at an anode blue sensitivity of 10 A/lmF	$\approx$ 7,2%	notes 1,11
Anode current linear within 2% at V_{ht} = 1900 V	up to $\approx$ 100 mA	
Mean anode sensitivity deviation		note 12
long term (16 h)	$\approx$ 1 %	
after change of count rate	$\approx$ 1 %	
versus temp. between 0 °C and 40 °C at 450 nm	$\approx$ 0,2 %/°C	

With voltage divider B (Fig. 3)

		note 5
Gain at V_{ht} = 2400 V (Fig. 8)	$\approx 6 \times 10^7$	
Anode pulse rise time at V_{ht} = 2200 V	$\approx$ 2,0 ns	note 10
Anode pulse duration at half height at V_{ht} = 2200 V	$\approx$ 3 ns	note 10
Signal transit time at V_{ht} = 2200 V	$\approx$ 30 ns	note 10
Signal transit time difference between the centre of the photocathode and 18 mm from the centre at V_{ht} = 2200 V	$\approx$ 0,7 ns	
Anode current linear within 2% at V_{ht} = 2000 V	up to $\approx$ 250 mA	

LIMITING VALUES (absolute maximum rating system) *

Supply voltage	max. 2500 V	note 13
Continuous anode current	max. 0,2 mA	note 14
Voltage between first dynode and photocathode	max. 800 V min. 300 V	note 15
Voltage between consecutive dynodes	max. 400 V	
Voltage between anode and final dynode	max. 600 V min. 80 V	note 16
Ambient temperature range		
operational (for short periods of time)	max. +80 °C min. −30 °C	note 17
continuous operation and storage	max. +50 °C min. −30 °C	

* Notes are given on page 5.

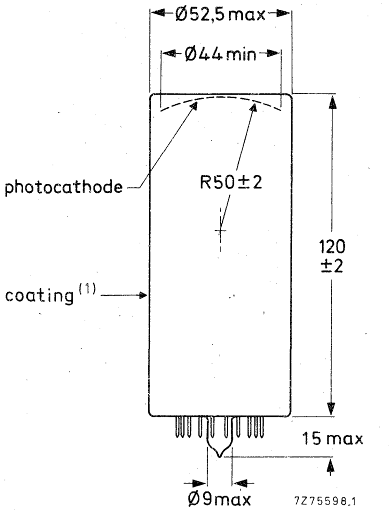
NOTES

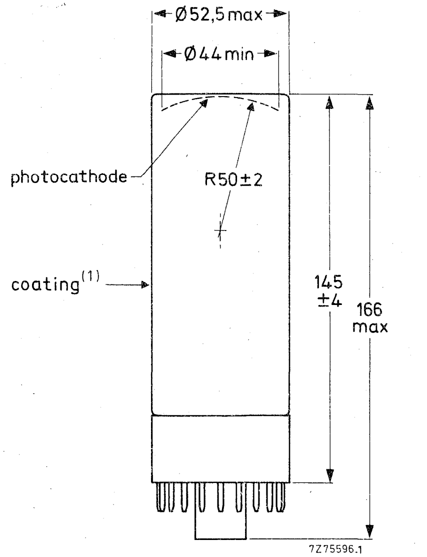
1. Blue sensitivity, expressed in μA/lmF, is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5K. Light is transmitted through a blue filter (Corning CS no. 5-58, polished to half stock thickness).
2. The bialkaline photocathode has a significant resistance which increases rapidly with reducing temperature. It is therefore recommended that it should not be exposed to light of too great an intensity; the cathode current should be limited, for example, to 1 nA at room temperature or 0,1 nA at -30 °C. If too high a photocurrent is passed, the cathode can no longer be considered an equipotential surface, and the focusing of electrons onto the first dynode will be affected, resulting in departure from linearity.
3. Luminous sensitivity is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5 K.
4. Spectral sensitivity is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5 K. Light is transmitted through an interferential filter. Spectral sensitivity at 400 nm, expressed in A/W, can be estimated by multiplying the blue sensitivity, expressed in A/lmF, by $7{,}6 \times 10^3$ for this type of tube.
5. To obtain a peak pulse current greater than that obtainable with divider A, it is necessary to increase the inter-dynode voltage of the stages progressively. Divider circuit B is an example of a "progressive" divider, giving a compromise between gain, speed, and linearity. Other dividers can be conceived to achieve other compromises. It is generally recommended that the increase in voltage between one stage and the next be kept less than a factor of 2.
6. Wherever possible, the power supply should be arranged so that the cathode is earthed and the anode is at +HT, however, it is sometimes necessary to supply the tube with the anode earthed and the cathode at −HT. Under these circumstances, erratic noise and dark current are generally increased and unstable, particularly immediately after application of voltage. The glass envelope of the tube should be supported only by insulators with an insulation resistance of $> 10^{15}\ \Omega$.
7. Noise is measured at ambient temperature. After having been stored with its protective hood, the tube is placed in darkness with V_{ht} set to a value to give a gain of 3×10^7. After a 5 min. stabilization period noise pulses with a threshold of 1 pC (corresponding to 0,2 photoelectron) are recorded. Lower values can be obtained after a longer stabilization period.
8. The single electron spectrum resolution to be optimized by adjusting the dynode 2 voltage.
9. Peak to valley ratio is defined as the single electron peak value divided by the minimum value to the left of the peak.
10. Measured with a pulsed-light source, with a pulse duration (FWHM) of < 1 ns, the cathode being completely illuminated. The rise time is determined between 10% and 90% of the amplitude of the anode pulse. The signal transit time is measured between the instant at which the illuminating pulse at the cathode becomes maximum, and the instant at which the anode pulse attains its maximum. Rise time, pulse duration and transit time vary as a function of high tension supply voltage V_{ht}, approximately as $V_{ht}^{-1/2}$.
    Non-inductive resistors of 51 Ω are connected in the base of type XP2262B to d_{11} and d_{12}. See also *General Operational Recommendations Photomultiplier Tubes*.
11. Pulse amplitude resolution for ^{137}Cs is measured with a NaI (Tl) cylindrical scintillator (Quartz et Silice ser. no.: 7256 or equivalent) with a diameter of 44 mm and a height of 50 mm. The count-rate used is $\approx 10^4$ c/s.

12. The mean anode sensitivity deviation is measured by coupling an NaI (Tl) scintillator to the window of the tube. Long term (16 h) deviation is measured by placing a ^{137}Cs source at a distance from the scintillator such that the count rate is $\approx 10^4$ c/s corresponding to an average anode current of $\approx$ 300 nA. Anode sensitivity deviation after change of count rate is measured with a ^{137}Cs source at a distance of the scintillator such that the count rate can be changed from 10^4 c/s to 10^3 c/s corresponding to an average anode current of $\approx$1 μA and $\approx$ 0,1 μA respectively. Both tests are carried out according to ANSI–N42–9–1972 of IEEE recommendations.
13. Total HT supply voltage, or the voltage at which the tube has a gain of 2 x 10^8, whichever is lower.
14. A value of $< 10\ \mu$A is recommended for applications requiring good stability.
15. Minimum value to obtain good collection in the input optics.
16. When calculating the anode voltage the voltage drop across the load resistor should be taken into account.
17. For type XP2262B this range of temperatures is limited principally by stresses in the sealing layer of the base to the glass bulb. Where low temperature operation is contemplated, the supplier should be consulted.

MECHANICAL DATA

Dimensions in mm





DEVELOPMENT SAMPLE DATA

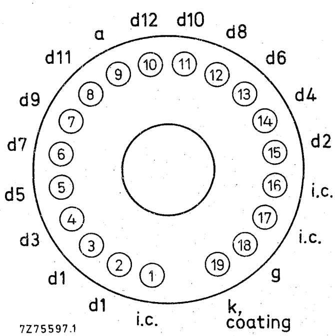


Fig. 4 XP2262.

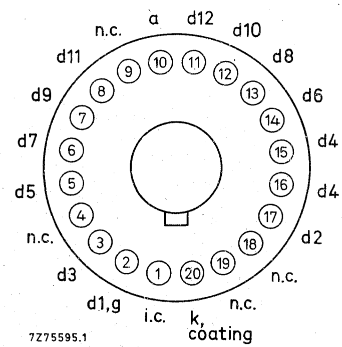


Fig. 5 XP2262B.

Base	19-pin all glass
Net mass	125 g

Base	20-pin (IEC67-1-42a, JEDEC B20-102)
Net mass	162 g

ACCESSORIES

Socket
for XP2262 type FE 2019
for XP2262B type FE 1020

(1) **Warning:**

The envelope of the tube is covered with a conductive coating, connected to the cathode. On top of this a black paint is applied which is neither guaranteed to be light tight nor isolating.
Care should be taken to avoid hazard due to electric shock.

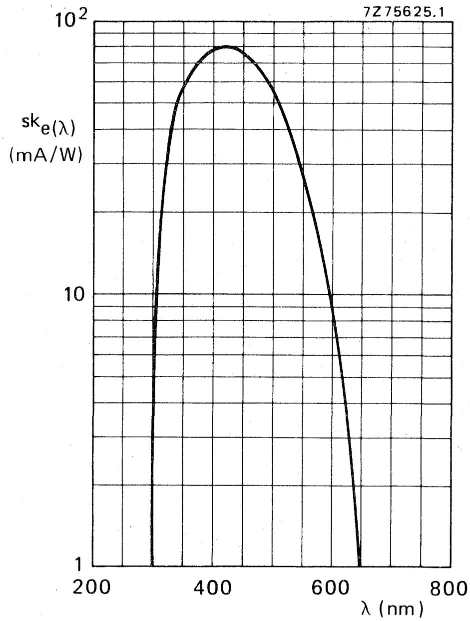


Fig. 6 Spectral sensitivity characteristic.

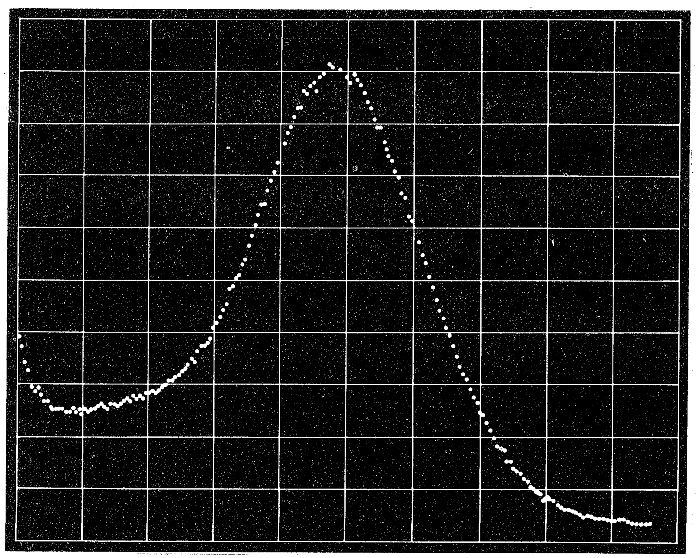


Fig. 7 Single electron spectrum obtained with an XP2262 tube.

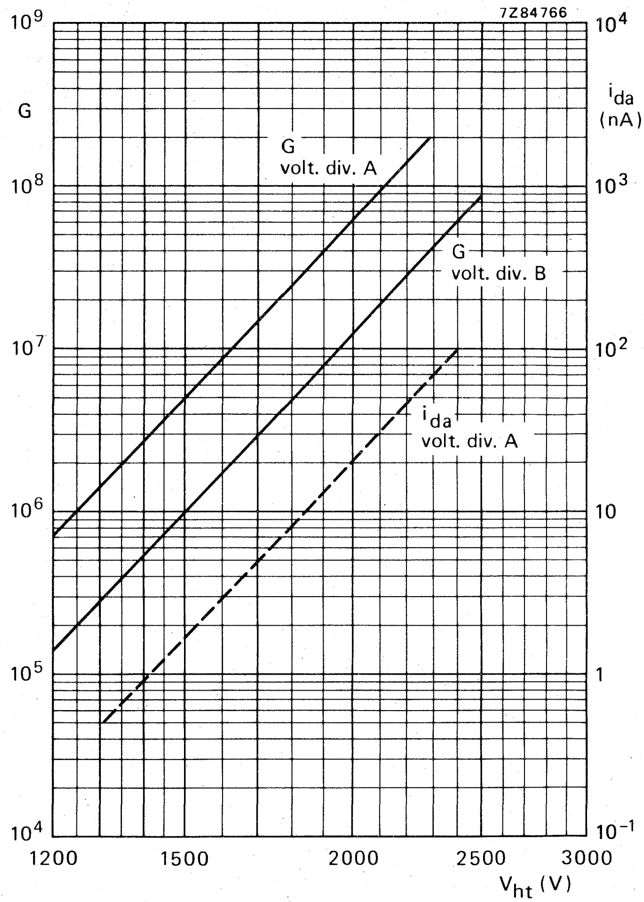


Fig. 8 Gain G and anode dark current, I_{da}, as a function of supply voltage V_{ht}.

I_{da} is given as a dotted line to indicate its principle behaviour only.

DEVELOPMENT SAMPLE DATA

10-STAGE PHOTOMULTIPLIER TUBE

- 23 mm useful diameter head-on type
- Flat window
- Semi-transparent bi-alkaline type D photocathode
- For high-energy physics and scintillation counting where good time characteristics are required, e.g. coincidence measurements and Cerenkov light detection
- Pin-compatible with PM1980

QUICK REFERENCE DATA*

Spectral sensitivity characteristic	type D	
Useful diameter of the photocathode	> 23 mm	
Cathode blue sensitivity	10,8 μA/lmF	note 1
Supply voltage for anode blue sensitivity = 10 A/lmF (note 1)	1300 V	
Pulse amplitude resolution for ^{137}Cs	≈ 7,7%	
Anode pulse rise time (with voltage divider B)	≈ 1,9 ns	
Linearity with voltage divider A (Fig. 2)	≈ 30 mA	
Linearity with voltage divider B (Fig. 3)	≈ 80 mA	

To be read in conjunction with *General Operational Recommendations Photomultiplier Tubes.*

GENERAL CHARACTERISTICS*

Window

Material	lime glass	
Shape	plano-concave	
Refractive index at 400 nm	1,54	

Photocathode (note 2)

Semi-transparent, head-on

Material	Sb K Cs	
Useful diameter	> 23 mm	
Spectral sensitivity characteristic (Fig. 5)	type D	
Wavelength for maximum spectral sensitivity	400 ± 30 nm	
Luminous sensitivity	≈ 65 μA/lm	note 3
Blue sensitivity	typ. 10,8 μA/lmF > 8,0 μA/lmF	note 1
Spectral sensitivity at 400 nm	≈ 75 mA/W	note 4

* Notes are given on page 5.

Multiplier system	
Number of stages	10
Dynode structure	linear focused
Dynode material	Cu Be
Capacitances	
anode to final dynode	≈ 2 pF
anode to all	≈ 4 pF

Magnetic field

When the photocathode is illuminated uniformly the anode current is halved (at V_{ht} = 1200 V, voltage divider A) at a magnetic flux density of:

0,4 mT perpendicular to axis a (see Fig. 1);
0,2 mT parallel to axis a.

It is recommended that the tube be screened from magnetic fields by a mu-metal shield protruding > 15 mm beyond the photocathode.

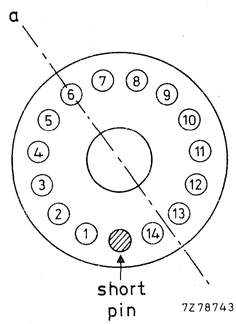


Fig. 1 Axis a with respect to base pins (bottom view).

RECOMMENDED CIRCUITS

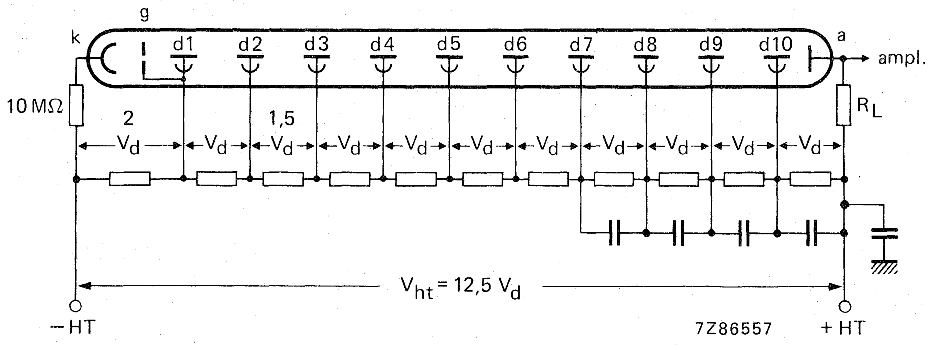


Fig. 2 Voltage divider A.

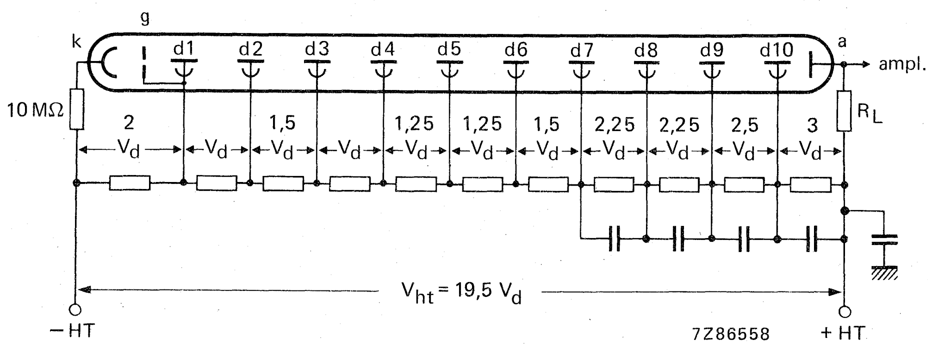


Fig. 3 Voltage divider B.

k = cathode
g = accelerating electrode
d_n = dynode no.
a = anode
R_L = load resistor

Typical value of capacitors: 1 nF

The cathode resistor of 10 MΩ limits the current should there be unintentional contact between an outer coating and earth when the anode is earthed.

TYPICAL CHARACTERISTICS*

With voltage divider A (Fig. 2)		note 5
Supply voltage for an anode blue sensitivity of 10 A/lmF	$<$ 1600 V typ. 1300 V	note 1
Anode radiant sensitivity at 400 nm and V_{ht} = 1300 V	$\approx$ 70 kA/W	
Gain at V_{ht} = 1300 V (Fig. 7)	$\approx 0{,}9 \times 10^6$	
Anode dark current at an anode blue sensitivity of 10 A/lmF	$<$ 20 nA typ. 1 nA	notes 1,6,7
Pulse amplitude resolution for ^{137}Cs at an anode blue sensitivity of 10 A/lmF	$\approx$ 7,7%	notes 1,8
Anode pulse rise time at V_{ht} = 1500 V	$\approx$ 2,1 ns	note 9
Anode pulse duration at half height at V_{ht} = 1500 V	$\approx$ 3,5 ns	note 9
Signal transit time at V_{ht} = 1500 V	$\approx$ 23 ns	note 9
Anode current-linear within 2% at V_{ht} = 1500 V	up to $\approx$ 30 mA	
With voltage divider B (Fig. 3)		note 5
Gain at V_{ht} = 1800 V (Fig. 7)	$\approx 3 \times 10^6$	
Anode pulse rise time at V_{ht} = 1800 V	$\approx$ 1,9 ns	note 9
Anode pulse duration at half height at V_{ht} = 1800 V	$\approx$ 3,0 ns	note 9
Signal transit time at V_{ht} = 1800 V	$\approx$ 23 ns	note 9
Signal transit time difference between the centre of the photocathode and 11 mm from the centre at V_{ht} = 1800 V	$\approx$ 0,8 ns	note 9
Anode current linear within 2% at V_{ht} = 1800 V	up to $\approx$ 80 mA	

LIMITING VALUES (Absolute maximum rating system)*

Supply voltage	max. 1900 V	note 10
Continuous anode current	max. 0,2 mA	
Voltage between first dynode and photocathode	max. 350 V min. 150 V	note 11
Voltage between consecutive dynodes	max. 250 V	
Voltage between anode and final dynode	max. 300 V min. 30 V	note 12
Ambient temperature range operational (for short periods of time)	max. + 80 °C min. −30 °C	
continuous operation and storage	max. + 50 °C min. −30 °C	

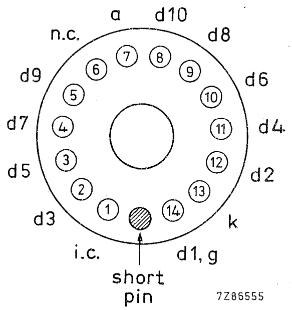
* Notes are given on page 5.

Notes

1. Blue sensitivity, expressed in μA/lmF, is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5K. Light is transmitted through a blue filter (Corning CS no. 5-58, polished to half stock thickness).
2. The bi-alkaline photocathode has a significant resistance which increases rapidly with reducing temperature. It is therefore recommended that it should not be exposed to light of too great an intensity; the cathode current should be limited, for example, to 1 nA at room temperature or 0,1 nA at –30 °C. If too high a photocurrent is passed, the cathode can no longer be considered an equipotential surface, and the focusing of electrons onto the first dynode will be affected, resulting in departure from linearity. In applications with short pulse times the photocathode is able to deliver pulses containing 10^6 to 10^7 photoelectrons without disturbance.
3. Luminous sensitivity is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5K.
4. Spectral sensitivity is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5K. Light is transmitted through an interferential filter. Spectral sensitivity at 400 nm, expressed in A/W, can be estimated by multiplying the blue sensitivity, expressed in A/lmF, by 7×10^3 for this type of tube.
5. To obtain a peak pulse current greater than that obtainable with divider A, it is necessary to increase the inter-dynode voltage of the stages progressively. Divider circuit B is an example of a "progressive" divider, giving a compromise between gain, speed, and linearity. Other dividers can be conceived to achieve other compromises after consulting the supplier.
6. Wherever possible, the power supply should be arranged so that the cathode is earthed and the anode is at + HT, however, it is sometimes necessary to supply the tube with the anode earthed and the cathode at –HT. Under these circumstances, erratic noise and dark current are generally increased and unstable, particularly immediately after application of voltage.
   The envelope of the tube should be supported only by insulators with an insulation resistance of $> 10^{15}\ \Omega$.
7. Dark current is measured at ambient temperature, after the tube has been in darkness for approx. 1 min. Lower values can be obtained after a longer stabilization period in darkness (approx. 30 min).
8. Pulse amplitude resolution for ^{137}Cs is measured with an NaI (Tl) cylindrical scintillator (Quartz et Silice serial no. 1162 or equivalent) with a diameter of 22 mm and a height of 6 mm. The count rate used is $\approx 10^4$ c/s.
9. Measured with a pulsed light source, with a pulse duration (FWHM) of < 1 ns; the cathode being completely illuminated. The rise time is determined between 10% and 90% of the amplitude of the anode pulse. The signal transit time is measured between the instant at which the illuminating pulse at the cathode becomes maximum, and the instant at which the anode pulse attains its maximum. Rise time, pulse duration and transit time vary as a function of high tension supply voltage V_{ht}, approximately as $V_{ht}^{-1/2}$.
10. Total HT supply voltage, or the voltage at which the tube has a gain of 2×10^7, whichever is lower.
11. Minimum value to obtain good collection in the input optics.
12. When calculating the anode voltage the voltage drop across the load resistor should be taken into account.

MECHANICAL DATA

Dimensions in mm



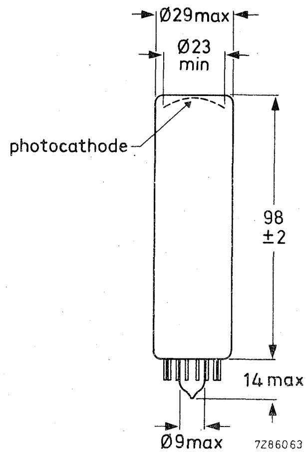


Fig. 4.

Base	14-pin all-glass
Net mass	34 g

ACCESSORIES

Socket	type FE1114

DEVELOPMENT SAMPLE DATA

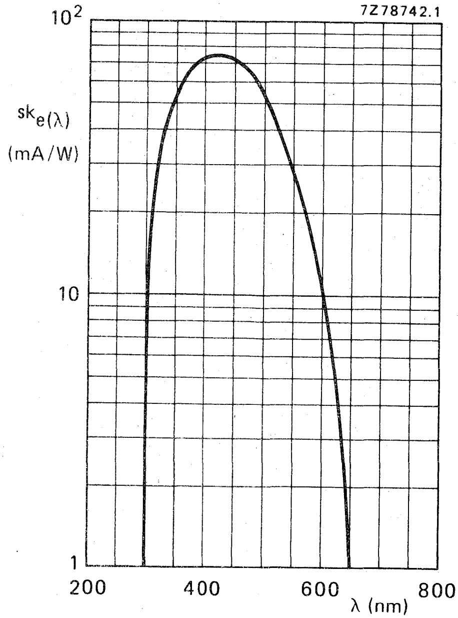


Fig. 5 Spectral sensitivity characteristic.

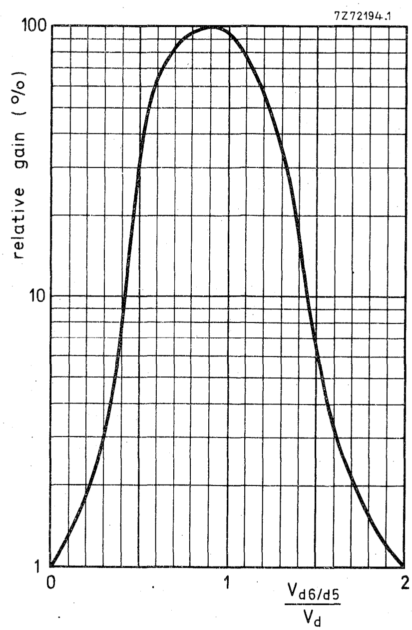


Fig. 6 Relative gain as a function of the voltage between d_6 and d_5, normalized to V_d. $V_{d7/d5}$ constant.

Note: Gain regulation by changing the voltage between d_6 and d_5 may cause a degradation of other parameters such as stability and linearity.

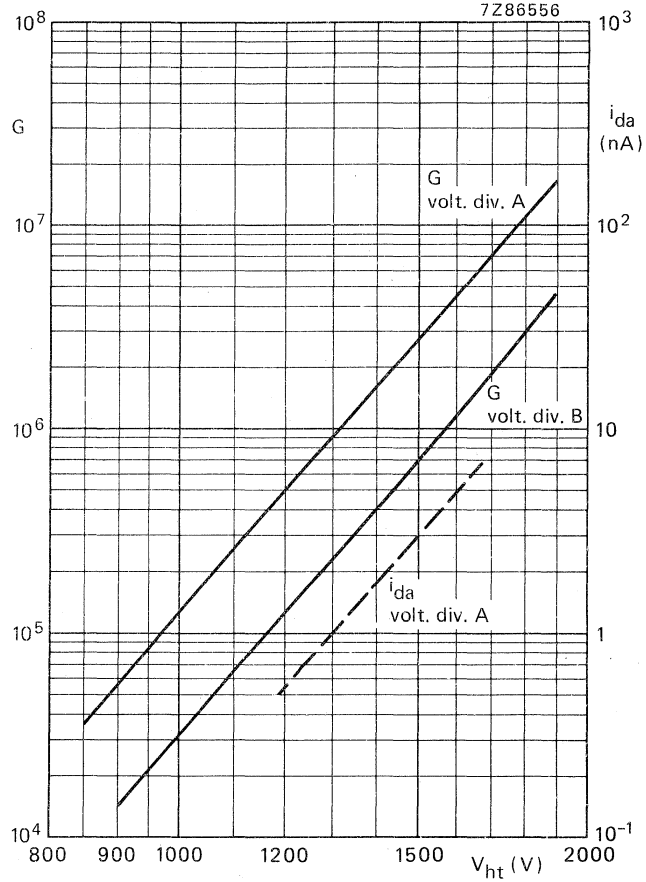


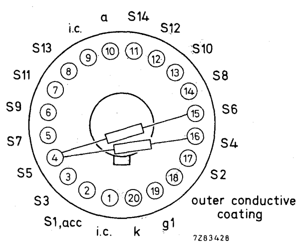
Fig. 7 Gain G and anode dark current I_{da} as a function of the supply voltage V_{ht}.

I_{da} is given as a dotted line to indicate its principle behaviour only.

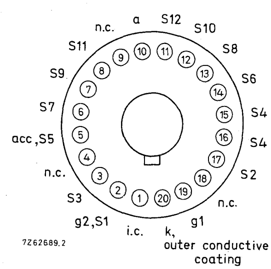
Our well known 56AVP family photomultiplier tubes with 44 mm photocathode diameter are replaced by more modern tubes with improved characteristics.

obsolete type	photo-cathode	dynodes	seated length mm	replacement type	photo-cathode	dynodes	seated length mm
56AVP	S11 (A)	14	170	XP2020	D	12	170
				XP2230B	D	12	152
				XP2262B	D	12	145
56CVP	S1 (C)	10	152	no replacement			
56DUVP	DU	14	170	XP2020Q	DU	12	170
56DVP	D	14	170	XP2020	D	12	170
				XP2230B	D	12	152
				XP2262B	D	12	145
56TUVP	TU	14	170	PM2254B	TU	12	170
56TVP	S20 (T)	14	170	XP2233B	S20 (T)	12	145

All replacement types have 12 stage multipliers and are unilaterally interchangeable with the 56AVP family tubes. By connection of dynode S_4 to pins 15 and 16 of the plastic base, the resistors between S_4-S_5 and between S_5-S_6 are short-circuited in bleeders wired for the 56AVP family tubes as indicated in figures below.



14-stage.



12-stage.

10-STAGE PHOTOMULTIPLIER TUBE

The 150CVP is a 32 mm useful diameter head-on photomultiplier tube with a flat window and a semi-transparent S1 (type C) photocathode.
The tube is intended for use in applications where a good sensitivity in the red and near-infrared part of the spectrum is required, such as laser detection and pollution monitoring.

QUICK REFERENCE DATA				
Spectral sensitivity characteristic		S1 (type C)		
Useful diameter of the photocathode		>	32	mm
Spectral sensitivity of the photocathode at 903 nm			1,4	mA/W
Supply voltage for anode luminous sensitivity = 10 A/lm			1600	V
Anode pulse rise time (with voltage divider B)		≈	3,5	ns
Linearity, with voltage divider A	up to	≈	30	mA
with voltage divider B	up to	≈	100	mA

To be read in conjunction with "General Operational Recommendations Photomultiplier Tubes".

GENERAL CHARACTERISTICS

Window

Material	borosilicate		
Shape	plano-plano		
Refractive index at 550 nm		1,48	

Photocathode

Semi-transparent, head-on

Material	Ag O Cs		
Useful diameter	>	32	mm
Spectral sensitivity characteristic (Fig. 3)	S1 (type C)		
Maximum spectral sensitivity at		800 ± 100	nm

Luminous sensitivity		typ.	20	μA/lm
		>	15	μA/lm
Spectral sensitivity at 903 ± 8 nm			1,4	mA/W
at 1060 ± 10 nm		≈	0,12	mA/W

Electron optical input system

This system consists of: the photocathode, k; a metallized part of the glass envelope internally connected to the photocathode; an accelerating electrode, acc, internally connected to S1.

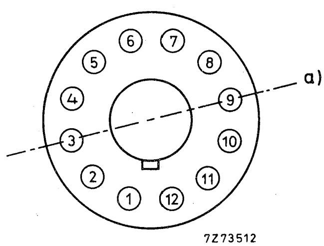
Multiplier system

Number of stages		10		
Dynode structure		linear focused		
Dynode material		Cu-Be		
Capacitance				
Anode to all	C_a	≈	5	pF
Anode to final dynode	$C_{a/S10}$	≈	3	pF

Magnetic field

See Fig. 4

It is recommended that the tube be screened against the influence of magnetic fields by a mu-metal shield protruding > 15 mm beyond the photocathode.



Axis a) with respect to base pins (bottom view)

RECOMMENDED CIRCUITS

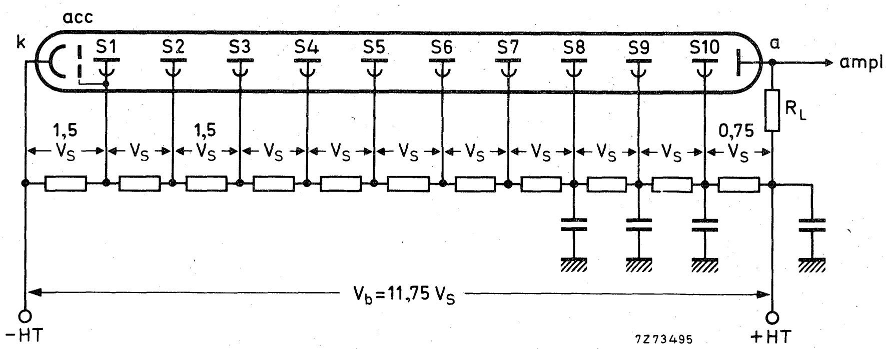


Fig. 1 Voltage divider A

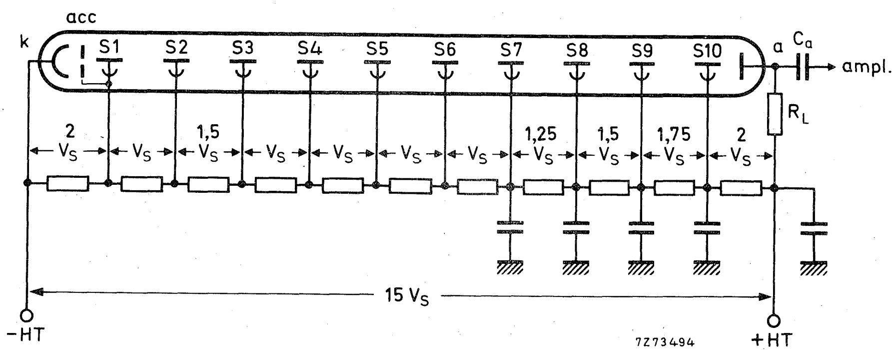


Fig. 2 Voltage divider B

k = cathode

acc = accelerating electrode

S_n = dynode no. n

a = anode

R_L = load resistor

Typical values of capacitors: 10 nF

TYPICAL CHARACTERISTICS

With voltage divider A (Fig. 1) [1]

Supply voltage for an anode luminous sensitivity N_a = 10 A/lm (Fig. 5)			<	1700	V
			typ.	1600	V
Anode dark current at N_a = 10 A/lm (Fig. 5)	2)3)		<	10	μA
			typ.	2	μA
Anode current linear within 2% at V_b = 1700 V		up to	≈	30	mA

With voltage divider B (Fig. 2)

Anode luminous sensitivity at V_b = 1700 V (Fig. 5)			≈	5	A/lm
Anode pulse rise time at V_b = 1700 V	4)		≈	3,5	ns
Anode pulse duration at half height at V_b = 1700 V	4)		≈	6	ns
Signal transit time at V_b = 1700 V	4)		≈	34	ns
Anode current linear within 2% at V_b = 1700 V		up to	≈	100	mA

LIMITING VALUES (Absolute max. rating system)

Supply voltage	5)	max.	1800	V
Continuous anode current	6)	max.	20	μA
Voltage between first dynode and photocathode	7)	max.	500	V
		min.	120	V
Voltage between consecutive dynodes		max.	300	V
Voltage between anode and final dynode	8)	max.	300	V
		min.	30	V
Ambient temperature range				
Operational (for short periods of time)	6)9)	max.	+50	°C
		min.	−30	°C
Continuous operation and storage		max.	+50	°C
		min.	−30	°C

Notes see page 5.

Notes to page 4

1) To obtain a peak pulse current greater than that obtainable with divider A, it is necessary to increase the inter-dynode voltage of the stages progressively. Divider circuit B is an example of a "progressive" divider, giving a compromise between gain, speed, and linearity. Other dividers can be conceived to achieve other compromises. It is generally recommended that the increase in voltage between one stage and the next be kept less than a factor of 2.

2) Wherever possible, the photomultiplier power supply should be arranged so that the cathode is earthed and the anode is at +HT, however, it is sometimes necessary to supply the tube with the anode earthed and the cathode at −HT. Under these circumstances, erratic noise and dark current are generally increased and unstable, particularly immediately after application of voltage. The glass envelope of the tube should be supported only by isolators having an insulation resistance of $> 10^{15}\ \Omega$.

3) Dark current for S1(type C) photocathodes is measured at a temperature of 20 °C. The dark current varies sharply with temperature. See also note 6.

4) Measured with a pulsed-light source, with a pulse duration (FWHM) of < 1 ns, the cathode being completely illuminated.
The rise time is determined between 10% and 90% of the amplitude of the anode pulse. The signal transit time is measured between the instant at which the illuminating pulse at the cathode becomes maximum, and the instant at which the anode pulse attains its maximum. Rise time, pulse duration and transit time vary as a function of high tension supply voltage V_b, approximately as $V_b^{-1/2}$.

5) Total HT supply voltage or the voltage at which the tube has an anode luminous sensitivity of 60 A/lm , whichever is lower.

6) As the dark current increases by a factor of 2 for every 7 °C increase in temperature, the anode sensitivity should be limited so that the continuous anode current limit is not exceeded.

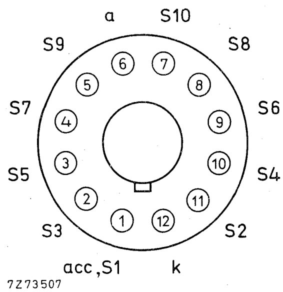
7) Minimum value to obtain good collection in the input optics.

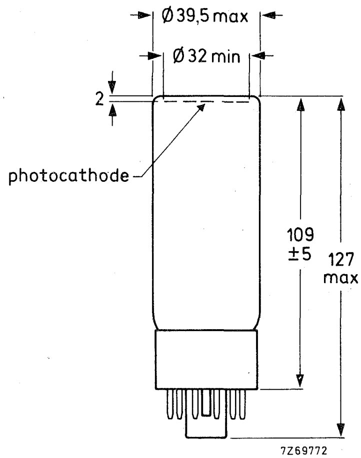
8) When calculating the anode voltage the voltage drop across the load resistor should be taken into account.

9) This range of temperatures is limited principally by stresses in the sealing layer of the base to the glass bulb.
Where low temperature operation is contemplated, the supplier should be consulted.

MECHANICAL DATA

Dimensions in mm





Net mass : 80 g

Base : 12-pin (JEDEC B12-43)

ACCESSORIES

Socket : type FE1012

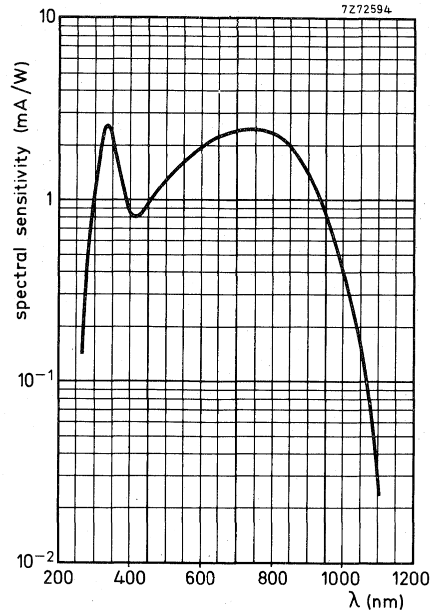


Fig. 3
Spectral sensitivity characteristic.

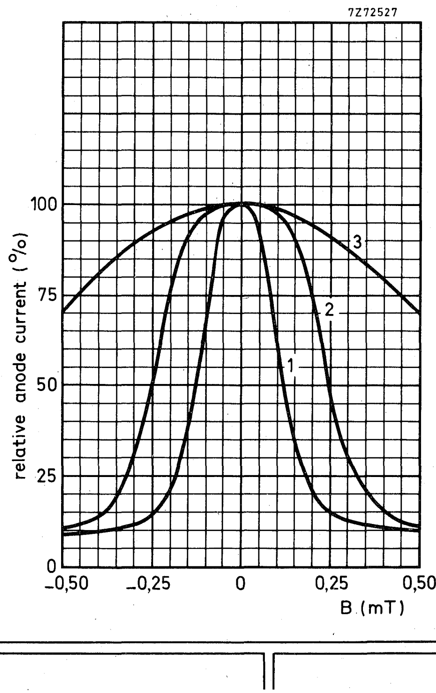


Fig. 4
Relative anode current as a function of the magnetic flux density B
1. B ⊥ tube axis, // axis a
2. B ⊥ tube axis, ⊥ axis a
3. B // tube axis

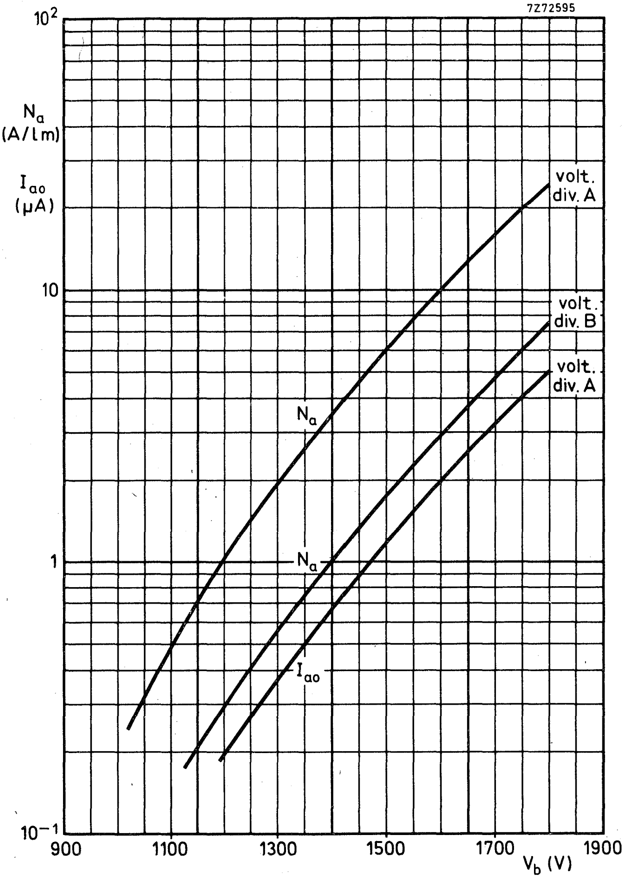


Fig. 5
Anode luminous sensitivity, N_a, and anode dark current, I_{ao}, as a function of supply voltage V_b.

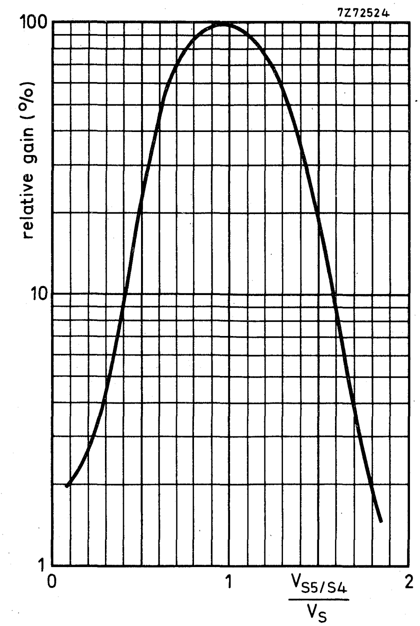


Fig. 6
Relative gain as a function of the voltage between S_5 and S_4, normalized to V_S.
$V_{S6/S4}$ constant.
Note: Gain regulation by changing the voltage between S_5 and S_4 may cause a degradation of other parameters such as stability and linearity.

PHOTOTUBES

SURVEY OF TYPES

photocathode dimensions mm	tube type	status	spectral response				
			S11 (A)	S1 (C)	S4	S20 (T)	bi-alkaline Sb Rb Cs
ϕ 20	AV29	N					X
	XA1002	D			X		
	XA1003	D		X			
ϕ 30	150AV	D	X				
ϕ 40	TVHC40	M				X	
ϕ 102	AVHC201	M			X		
22 x 11	92AG	O	X				
	92AV	O	X				
	90CG	O		X			
	90CV	O		X			

Status code

N = New design type. Recommended for new equipment design; production quantities available *after date of publication.*

D = Design type. Recommended for equipment design; production quantities available *at date of publication.*

M = Maintenance type. No longer recommended for equipment production; available for maintenance of existing equipment.

O = Obsolescent type. Available until present stocks are exhausted. Abridged data are included in this Handbook.

LIST OF SYMBOLS

Supply voltage	V_b
Cathode current	I_k
Anode series resistance	R_a
Sensitivity	N
Capacitance, anode to cathode	C_{ak}
Ambient temperature	t_{amb}
Envelope temperature	t_{env}

GENERAL OPERATIONAL RECOMMENDATIONS
PHOTOTUBES

1. GENERAL

1.1 **Phototubes** are photoelectric devices of the emissive type, as distinct from the barrier-layer and photo-conductive cells. They may be divided into two groups :

1. Vacuum phototubes,
2. Gas-filled phototubes

For a vacuum phototube, the anode current for a fixed quantity of light, is constant at anode voltages above a certain low value known as the "saturation voltage".
The gas-filled phototube contains a quantity of inert gas, the ionizing potential of which is generally somewhat higher than the saturation voltage of an equivalent vacuum phototube, so that the anode current is substantially constant between the saturation voltage and the voltage at which ionization commences. Above this voltage range, ionization increases, resulting in a progressive increase in anode current.
Since a gas-filled phototube operates at a higher voltage than the ionizing potential it will have a greater sensitivity than a similar vacuum phototube.
Within the operating ranges of both groups of phototubes the anode current is directly proportional to the quantity of light incident on the cathode surface.

1.2 Spectral response

The materials used for the photocathode are of great importance to the spectral response. Many substances show photoemission, but often differ greatly in their spectral sensitivity and quantum yield.

1.2.1 The S11 (A-type) tubes are equipped with a semi-transparent caesium antimony photocathode on an MnO_2 layer, evaporated on the inside of a glass window. These types are sensitive to radiation in the visible region of the spectrum and have their maximum sensitivity at approximately 420 nm.

1.2.2 The S13 (U-type) tubes have the same photocathodes as the S11 tubes, but are provided with a fused silica (quartz) window, giving them a sensitivity that extends into the ultraviolet region of the spectrum.

1.2.3 The S1 (C-type) tubes have a semi-transparent caesium-on-silver-oxide photocathode on a glass window.
The sensitivity lies mainly in the red and near infrared regions of the spectrum, with a maximum at approximately 800 nm.

1.2.4 The S20 (T-type) tubes have a tri-alkaline (Sb-Na-K-Cs) semi-transparent photocathode on a glass window. This photocathode has a good sensitivity from the ultraviolet to the near infrared part of the spectrum, with a maximum at approximately 420 nm.

1.2.5 The S4 tubes have a Sb-Cs emission layer deposited on an opaque substrate. This photocathode is intended for use in applications with relatively high illumination in the visible region of the spectrum.

Spectral response curves are given in the data sheets of each type.

2. INTERPRETATION OF CHARACTERISTICS

In general the characteristics given in the data sheets are typical values. The "typical value" of a parameter is the median of the frequency distribution of the parameter measured on a large number of tubes.
In some cases maximum or minimum values are stated. These values are defined on test-limits carried out on each tube. Approximate values are given when these values are obtained from batch sample data.

2.1 Cathode luminous sensitivity

The cathode luminous sensitivity is defined (IEC) as the quotient of the photocurrent of the cathode by the incident luminous flux, expressed in amperes per lumen.
The cathode current, I_k, (corrected for dark current) is about 100 nA.

The voltage used should be sufficient to ensure saturation.
The sensitivity is given by: $N_k = \frac{I_k}{\phi}$
where ϕ is the luminous flux, in lumen, of a tungsten filament lamp having a colour temperature of 2856 K.

2.2 Cathode radiant sensitivity

The cathode radiant sensitivity is the quotient of the photocurrent of the cathode by the incident radiant power, expressed in amperes per watt (IEC).

2.3 Absolute spectral sensitivity

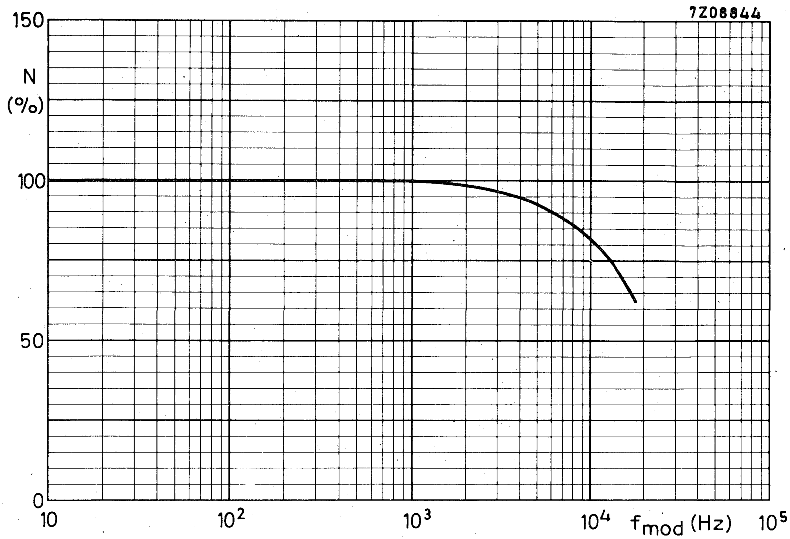
The absolute spectral sensitivity is the radiant sensitivity for monochromatic radiation of a stated wavelength (IEC).
Measurements of this parameter are carried out with a tungsten filament lamp with a colour temperature of 2856 K and spectral filters. Tolerances of the spectral filters are stated in the tube data. The measuring equipment is calibrated by comparison with a Schwartz thermocouple.

2.4 **Dark current** is the current flowing in a photoelectric device in the absence of irradiation (IEC).
Possible causes of dark current are electrical leakage, thermionic emission, field emission, residual gas ionization, and glass fluorescence.

2.5 Time characteristics

2.5.1 The **anode pulse rise time** of a phototube is defined as the time required for the amplitude to rise from a stated low percentage to a stated higher percentage of maximum value when the photocathode receives a delta function light pulse. Normally the 10% and 90% levels are considered.

2.5.2 The **sensitivity** of gas-filled phototubes decreases with **frequency**. At a frequency of 15000 Hz this decrease is about 3 dB; see Figure below.



Frequency response curve

3. **THERMAL DATA**

Ambient temperature. The temperature of the photocathode may not be too high otherwise evaporation of the emissive cathode layer may result, with consequent reduction in sensitivity and life. As it is difficult to measure this temperature a limiting value for the ambient temperature is given in the published data sheets. It must be considered, however, that even when the ambient temperature in the immediate vicinity of the phototube is not beyond the limit, an excessive temperature rise of the photocathode can be caused, e.g. by infrared heat radiation. If the possibility of this radiation exists, a suitable filter should be inserted in the optical path to minimize this effect.

4. **OPERATING NOTES**

Stability during life. Where a gas-filled phototube is continuously operated at its maximum rated voltage its sensitivity may fall by as much as 50%, during 500 hours.
Vacuum phototubes are inherently more stable.

The stability of both types of phototube will be improved if the current density of the photocathode is reduced (e.g. by reducing the incident light or enlarging the illuminated area of the photocathode).
Particularly with gas-filled phototubes, reduction of the anode voltage will improve the stability.

Phototubes must not be exposed to strong radiation, such as direct sunlight, even during idle periods.

A loss of sensitivity of both vacuum and gas-filled phototubes during operation will be wholly or partially restored during idle periods.

Prevention of glow discharge. Gas-filled phototubes must not be operated above the published maximum voltage since a glow discharge, indicated by a faint blue glow in the bulb, may occur which adversely affects the good operation of the phototube, and can even result in rapid destruction of the photocathode. If accidental over-running can be expected, the anode resistance should have a value of at least 0,1 MΩ.
Where it is necessary to use the maximum operating voltage a stabilized supply is recommended.

5. **MOUNTING**

If no restrictions are made in the individual published data sheets, phototubes may be mounted in any position.

6. **STORAGE**

It is necessary that phototubes always be stored in darkness.

7. **LIMITING VALUES**

The limiting values of phototubes are given in the absolute maximum rating system.

8. **OUTLINE DIMENSIONS**

The outline dimensions are given in mm.

PHOTOTUBE

- Head-on type vacuum diode with 20 mm useful diameter photocathode
- Flat window
- Semi-transparent bi-alkaline photocathode
- Fast, large-area detector for medium and high light levels
- For precision photometry and for detection in high-magnetic fields (high energy physics)

QUICK REFERENCE DATA*

Spectral sensitivity characteristic	Fig. 2	
Useful diameter of the photocathode	> 20 mm	
Blue sensitivity of the photocathode	10,5 μA/lmF	note 1
Spectral sensitivity of the photocathode at 400 nm	80 mA/W	
Anode voltage	⩽ 1500 V	
Pulse rise time	≈ 3 ns	
Capacitance, anode to cathode	≈ 6 pF	

To be read in conjunction with *General Operational Recommendations Phototubes*

GENERAL CHARACTERISTICS*

Window

Material	lime glass
Shape	plano-plano
Refractive index at 400 nm	1,54

Photocathode

Type	semi-transparent, head-on	
Material	Sb Rb Cs	
Useful diameter	> 20 mm	
Spectral sensitivity characteristic	see Fig. 2	
Wavelength for maximum spectral sensitivity	420 ± 30 nm	
Spectral sensitivity at 400 nm	≈ 80 mA/W	note 2
Luminous sensitivity	≈ 100 μA/lm	note 3
Blue sensitivity	typ. 10,5 μA/lmF > 7,0 μA/lmF	note 1

* Notes are on page 3.

Operating characteristics

Operating voltage, d.c.	1 to 1000 V	
Saturation voltage for anode current = 100 nA	≈ 10 V	
Dark current at V_{ht} = 350 V and R.H. 50 to 60%	typ. 10 pA < 100 pA	note 4
Anode pulse rise time at V_{ht} = 350 V	≈ 3 ns	
Capacitance, anode to cathode	≈ 6 pF	
Recommended angle between magnetic flux density and tube axis	< 70°	
Anode sensitivity drop at a magnetic flux density of 0,3 T, at an angle of 70° with respect to the tube axis, and V_{ht} = 300 V (see also Fig. 4)	≈ 10%	

LIMITING VALUES (Absolute maximum rating system)*

Anode voltage, d.c.	max.	1500 V	
Cathode current			
peak	max.	50 nA/mm^2	
mean, averaging time 1 s	max.	70 pA/mm^2	
Total cathode current			
peak, at V_{ht} = 1000 V	max.	15 μA	notes 5, 6
mean, averaging time 1 s	max.	20 nA	notes 5, 6
Ambient temperature range			
operational (for short periods of time)	max.	+ 80 °C	
	min.	−30 °C	
continuous operation and storage	max.	+ 50 °C	
	min.	−30 °C	

STABILITY

For most tubes, the decrease of anode sensitivity after 72 h, at a cathode current of 20 nA, V_{ht} = 350 V, is anticipated to be less than 2%.

For maximum stability it is recommended that the cathode current be minimized.

Warnings

1. After an idle period of more than 8 days a high voltage level should be applied in steps.
2. The cathode should not be exposed to direct sunlight.
3. The cathode is connected to the external conductive coating of the tube. Take care to avoid electric shock.

* Notes are on page 3.

Notes

1. Blue sensitivity, expressed in μA/lmF, is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5K. Light is transmitted through a blue filter (Corning CS no. 5-58, polished to half stock thickness).
2. Spectral sensitivity is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5K. Light is transmitted through an interferential filter. Spectral sensitivity at 400 nm, expressed in A/W, can be estimated by multiplying the blue sensitivity, expressed in A/lmF, by $7{,}7 \times 10^3$ for this type of tube.
3. Luminous sensitivity is measured with a tungsten filament lamp with a colour temperature of 2856 ± 5K.
4. Dark current is measured at ambient temperature, after the tube has been in darkness for approx. 1 min. As the dark current is a leakage current, it is approximately proportional to the applied voltage. It can be minimized by operating the tube in a dry atmosphere (R.H. $< 10\%$).
5. Cathode uniformly illuminated.
6. The relationship between the incident luminous flux and the cathode current is linear (within measuring errors) when the anode voltage is higher than the saturation voltage.

DEVELOPMENT SAMPLE DATA

MECHANICAL DATA

Dimensions in mm

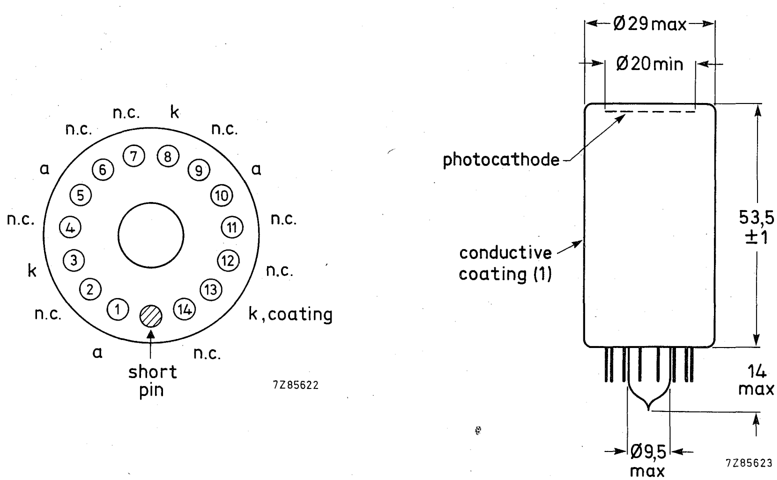


Fig. 1.

Base	14-pin all-glass
Net mass	25 g

(1) The envelope of the tube is covered with a conductive coating, connected to the cathode. Take care to avoid electric shock.

ACCESSORIES

Socket: type FE1114

Note: If minimum leakage current is required it is advised to use separate anode and cathode connections instead of a socket.

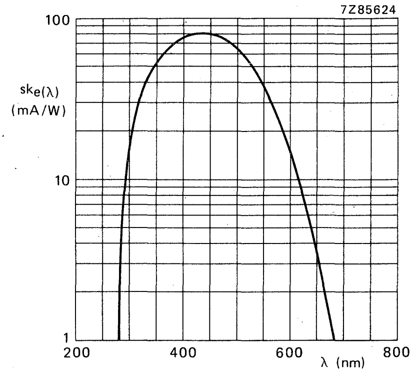


Fig. 2 Spectral sensitivity characteristic.

Curves of Figs 3 and 4 are typical results from measurements performed at CERN Experiment R808.

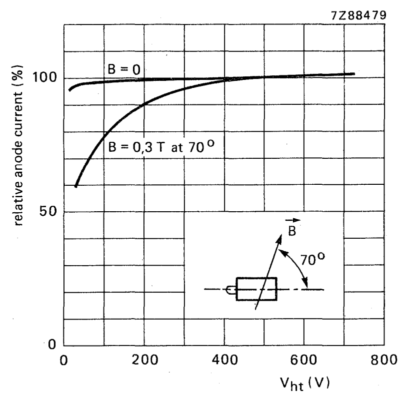


Fig. 3 Relative anode current as a function of supply voltage; typical curves. Tube is in a magnetic field with flux densities B = 0 or 0,3 T; angle between flux density and tube axis is 70°. (Curves by courtesy of CERN, Geneva.)

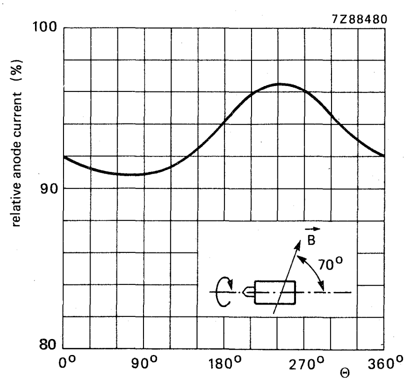


Fig. 4 Relative anode current as a function of tube rotation angle; typical curve. Tube is in a magnetic field with flux density B = 0,3 T; angle between flux density and tube axis is 70 °; V_{ht} = 300 V. (Curve by courtesy of CERN, Geneva.)

PHOTOTUBE

The AVHC201 is a 102 mm useful diameter head-on phototube with a flat window and an opaque S4 photocathode. The tube is intended for use in applications with relatively high illumination and features a short rise time and a high linearity.

QUICK REFERENCE DATA			
Spectral sensitivity characteristic	S4		
Useful diameter of the photocathode		102	mm
Spectral sensitivity of the photocathode at 437 nm		40	mA/W
Anode voltage	up to	5	kV
Rise time		1	ns
Linearity	up to	30	A

To be read in conjunction with "General Operational Recommendations Phototubes".

CHARACTERISTICS

Photocathode

Opaque head-on, flat

Material		Sb Cs		
Useful diameter		>	102	mm
Spectral sensitivity characteristic Fig. 1		S4		
Maximum spectral sensitivity at			400 ± 50	nm
Luminous sensitivity	1)	typ.	35	μA/lm
		>	20	μA/lm
Spectral sensitivity at 437 ± 5 nm	2)	≈	40	mA/W

Notes see page 3.

Operating characteristics

Dark current at V_b = 2,5 kV	3)		typ.	1	nA
			<	10	nA
Saturation voltage			see note 4		
Rise time	5)		≈	1	ns
Anode current linear within 10% at V_b = 2,5 kV up to	6)		≈	30	A
			≥	20	A
Capacitance, anode to cathode		C_{ak}	<	25	pF

LIMITING VALUES (Absolute max. rating system)

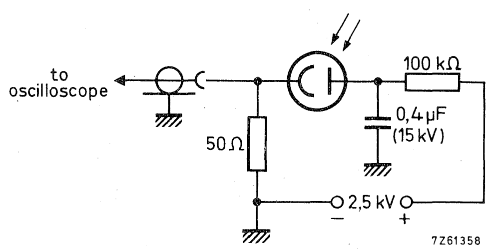
Anode voltage, d.c.		max.	5	kV	
Total cathode current,	8)				
peak		max.	100	A	
mean, averaging time 1 s		max.	10	μA	
Ambient temperature		max.	60	°C	7)
		min.	−40	°C	

REMARKS

After an idle period of more than 8 days, the dark current needs some hours to return to its normal value.

The cathode should not be exposed to direct sunlight.

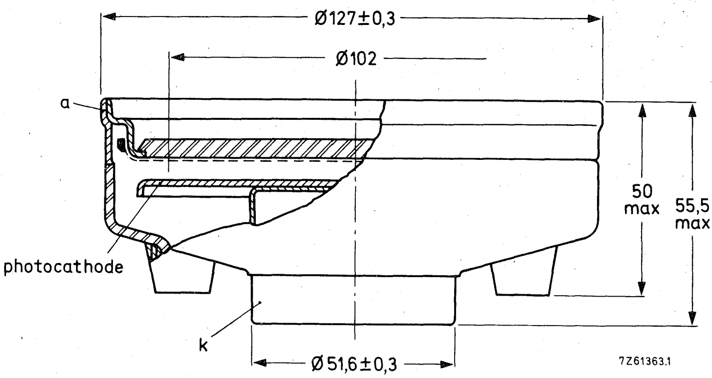
MEASURING CIRCUIT



MECHANICAL DATA

Dimensions in mm

Net mass : 530 g



Distance anode - cathode 4,6 mm

Notes

1) Cathode luminous sensitivity is measured by means of a tungsten filament lamp of colour temperature 2856 ± 5 K.

2) Measuring equipment is calibrated by comparison with a Schwartz thermocouple.

3) Dark current is measured at 25 °C after a stabilization period in darkness, with anode voltage applied, of 0,5 h.

4) Due to the geometry of the device and the high electric field strength the anode current increases with anode voltage and wavelength (see Fig. 2).

5) Measured with a pulsed-light source, with a pulse duration of < 1 ns, the cathode being completely illuminated.

6) The linearity is measured with a light pulse with:
pulse duration = 1 μs
pulse energy = 35 J (2 Mlm)
pulse repetition frequency = 2 p.p.min
Blue filter inserted in light path.
The linearity is observed on a X - Y oscilloscope by comparison with a standard phototube.
The cathode current may not exceed a peak value of 100 A.

7) During not more than some hours.

8) Cathode completely illuminated.

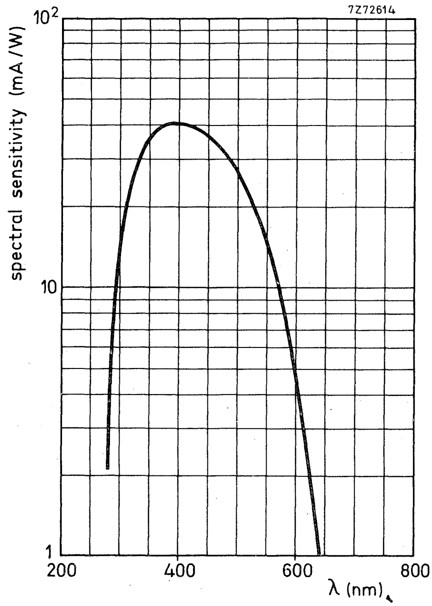


Fig. 1

Spectral sensitivity characteristic

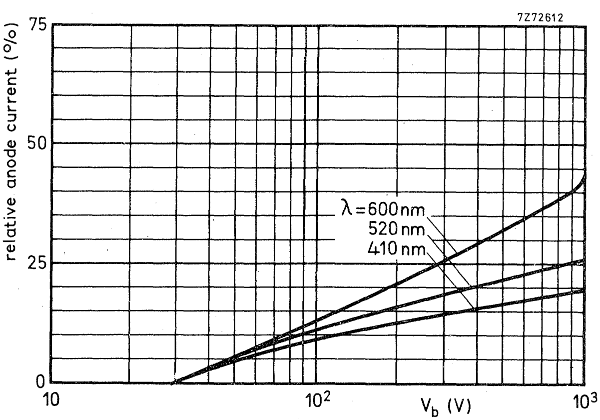


Fig. 2

Relative anode current as a function of anode voltage; wavelength as parameter.

PHOTOTUBE

The TVHC40 is a 40 mm useful diameter head-on phototube with a flat window and an opaque S20 (type T) photocathode. The tube is intended for use in applications with a relatively high illumination especially in LASER detectors and features a short rise time and a high linearity.

QUICK REFERENCE DATA			
Spectral sensitivity characteristic		S20 (type T)	
Useful diameter of the photocathode		40	mm
Spectral sensitivity of the photocathode at 420 nm		70	mA/W
at 698 nm		10	mA/W
Anode voltage	up to	5	kV
Rise time		0,4	ns
Linearity	up to	6	A

To be read in conjunction with "General Operational Recommendations Phototubes".

CHARACTERISTICS

Photocathode

Opaque head-on

Material			Sb K Na Cs	
Useful diameter		>	40	mm
Spectral sensitivity characteristic Fig. 1			S20 (type T)	
Maximum spectral sensitivity at			450 ± 100	nm
Luminous sensitivity	1)	≈	150	μA/lm
Spectral sensitivity at 437 ± 5 nm	2)	≈	70	mA/W
at 698 ± 7 nm		≈	10	mA/W
		≥	5	mA/W

Notes see page 3.

Operating characteristics

Dark current at V_b = 2,5 kV	3)	typ. <	0,15 5	nA nA
Saturation voltage	4)		100	V
Rise time	5)	≈	0,4	ns
Anode current linear within 10% at V_b = 2,5 kV up to		≈ ≥	6 5	A A
Capacitance, anode to cathode			3	pF

LIMITING VALUES (Absolute max. rating system)

Anode voltage, d.c.	max.	5	kV
Total cathode current,			
peak	max.	10	A
mean, averaging time 1 s	max.	10	μA

REMARKS

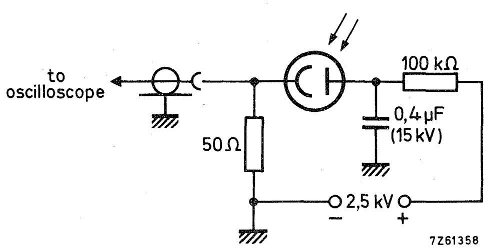
After an idle period of more than 8 days, the dark current needs some hours to return to its normal value.

The cathode should not be exposed to direct sunlight.

ACCESSORIES

Socket : type SC110

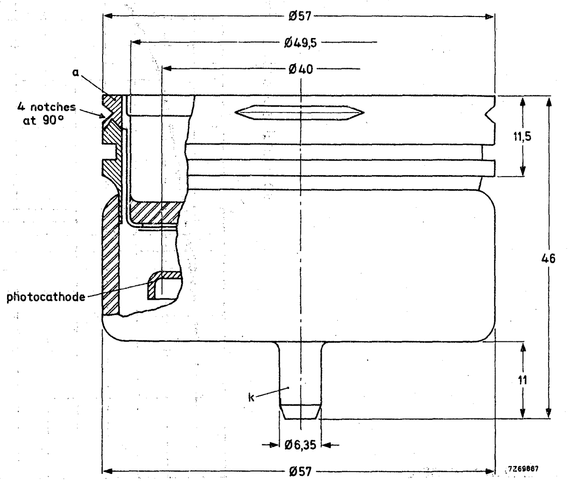
MEASURING CIRCUIT



MECHANICAL DATA

Dimensions in mm

Net mass : 85 g



Distance anode - cathode 6 mm

Notes

1) Cathode luminous sensitivity is measured by means of a tungsten filament lamp of colour temperature 2856 ± 5 K.

2) Measuring equipment is calibrated by comparison with a Schwartz thermocouple.

3) Dark current is measured at 25 °C after a stabilization period in darkness, with anode voltage applied, of 0,5 h.

4) Due to the geometry of the device and the high electric field strength the anode current is more or less dependent on the anode voltage and the wavelength of the irradiation.

5) Measured with a pulsed-light source, with a pulse duration (FWHM) of < 1 ns, the cathode being completely illuminated.
Tube mounted in socket SC110.

6) The linearity is measured with a light pulse with:
pulse duration = 1 μs
pulse energy = 35 J (2 Mlm)
pulse repetition frequency = 2 p.p.min
Blue filter inserted in light path.
The linearity is observed on a X - Y oscilloscope by comparison with a standard phototube.
The cathode current may not exceed a peak value of 100 A.

7) During not more than some hours.

8) Cathode completely illuminated.

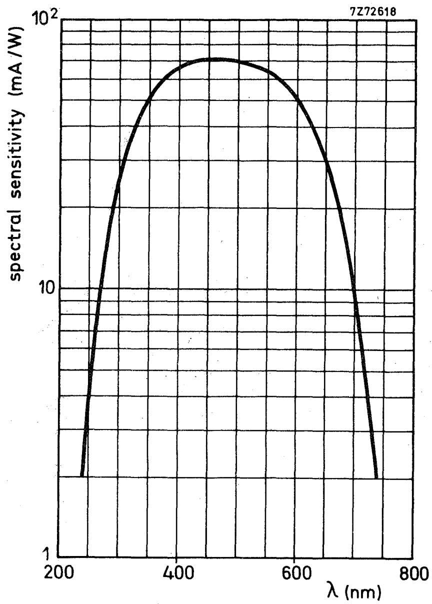


Fig. 1

Spectral sensitivity characteristic

PHOTOTUBE

The XA1002 is a 20 mm useful diameter head-on phototube with a flat window and an opaque S4 photocathode. The tube is intended for use in applications with relatively high illumination and high peak currents.

QUICK REFERENCE DATA			
Spectral sensitivity characteristic	S4		
Useful diameter of the photocathode		20	mm
Spectral sensitivity of the photocathode at 437 ± 5 nm		35	mA/W
Anode voltage	up to	4	kV
Rise time		≈ 0,2	ns
Linearity	up to	8	A

To be read in conjunction with "General Operational Recommendations Phototubes".

CHARACTERISTICS

Photocathode

Opaque head-on, flat surface

Material		Sb-Cs		
Useful diameter		>	20	mm
Spectral sensitivity characteristic Fig. 1		S4		
Maximum spectral sensitivity at			400 ± 50	nm
Luminous sensitivity	1)	typ.	30	µA/lm
		>	20	µA/lm
Spectral sensitivity at 437 ± 5 nm	2)	≈	35	mA/W

Notes see page 3.

Operating characteristics

Dark current at V_b = 2,5 kV	3)	typ. <	0,5 5	nA nA
Saturation voltage		see note 4		
Rise time	5)	≈	0,2	ns
Anode current linear within 5% at V_b = 4 kV up to	6)7)	≈ ≥	8 5	A A
Capacitance, anode to cathode		C_{ak}	2	pF

LIMITING VALUES (Absolute max. rating system)

Anode voltage, d.c.	max.	4	kV
Total cathode current,			
peak	max.	10	A
mean, averaging time 1 s	max.	10	μA
Ambient temperature	max. min.	+60 −40	°C 8) °C

REMARKS

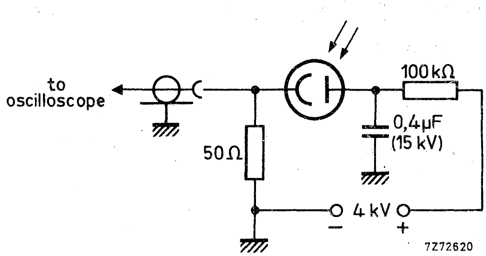
After an idle period of more than 8 days, the dark current needs some hours to return to its normal value.

The cathode should not be exposed to direct sunlight.

ACCESSORIES

Socket : type 56041

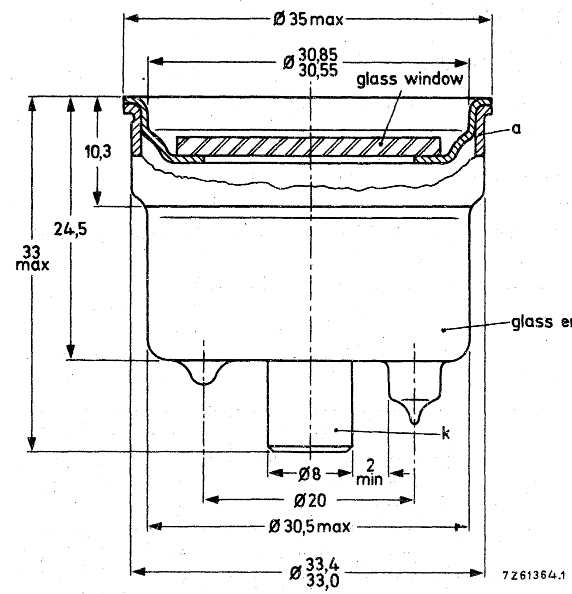
MEASURING CIRCUIT



Notes see pages 3 and 4.

MECHANICAL DATA Dimensions in mm

Net mass : 300 g



Transmission of anode grid	85%
Distance anode - cathode	3,5 mm

Notes

[1]) Cathode luminous sensitivity is measured by means of a tungsten filament lamp of colour temperature 2856 ± 5 K.

[2]) Measuring equipment is calibrated by comparison with a Schwartz thermocouple.

[3]) Dark current is measured at 25 °C after a stabilization period in darkness, with anode voltage applied, of ≈ 0,5 h.

[4]) Due to the geometry of the device and the high electric field strength the anode current increases with anode voltage and wavelength. See Fig. 2.

[5]) Measured with a pulsed-light source, with a pulse duration (FWHM) of < 1 ns, the cathode being completely illuminated. Tube mounted in socket 56041.

[6]) When the tube is used with socket 56041 with a build-in capacitor of 500 pF this linearity is obtained only if the electrical charge transported by the pulse - or pulse train - does not exceed 1 μC. To prevent a considerable decrease in anode voltage when measuring light pulses of high magnitude and/or long duration, an external capacitor should be mounted between anode and earth (chassis).

The value can be calculated with:

$$V_a = V_b - \Delta V = V_b - \frac{I}{C}\,\Delta t$$

in which : $V_a > 2$ kV
I = peak current
Δt = pulse duration

7) The linearity is measured with a light pulse with
pulse duration = 1 µs
pulse energy = 35 J (2 Mlm)
pulse repetition frequency = 2 p.p.min
Blue filter inserted in light path.
The linearity is observed on an X - Y oscilloscope by comparison with a standard phototube.
The cathode current may not exceed a peak value of 10 A.

8) During not more than some hours.

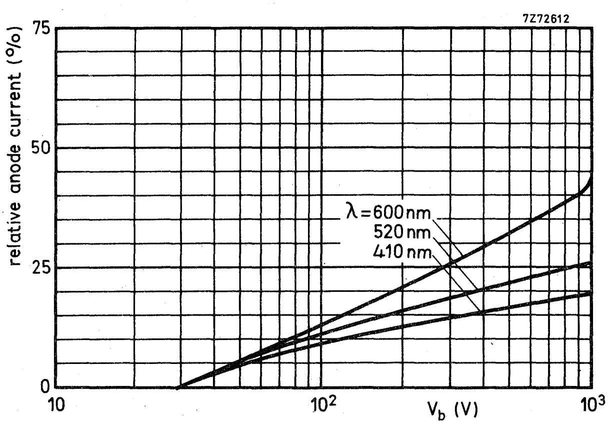


Fig. 1

Relative anode current as a function of anode voltage; wavelength as parameter.

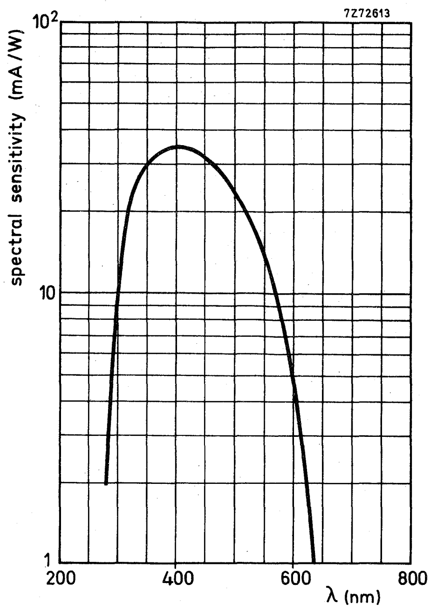


Fig. 2

Spectral sensitivity curve

PHOTOTUBE

The XA1003 is a 20 mm useful diameter head-on phototube with a flat window and an opaque S1 photocathode. The tube is intended for use in applications with **relatively high** illumination especially for use as LASER detector.

QUICK REFERENCE DATA			
Spectral sensitivity characteristic		S1 (type C)	
Useful diameter of the photocathode		20	mm
Spectral sensitivity of the photocathode at 800 nm		2,5	mA/W
Anode voltage	up to	2,5	kV
Rise time		0,2	ns
Linearity	up to	1	A

To be read in conjunction with "General Operational Recommendations Phototubes".

CHARACTERISTICS

Photocathode

Opaque head-on, flat surface

Material		AgO-Cs		
Useful diameter		>	20	mm
Spectral sensitivity characteristic Fig. 1		S1 (type C)		
Maximum spectral sensitivity at			800 ± 100	nm
Luminous sensitivity	1)	typ.	20	μA/lm
		>	15	μA/lm
Spectral sensitivity at 903 ± 8 nm	2)	≈	1,4	mA/W
1060 ± 10 nm		≈	0,12	mA/W

Notes see page 3.

Operating characteristics

Dark current at V_b = 2,5 kV	3)	typ.	5	nA
		<	10	nA
Saturation voltage		see note 4		
Rise time	5)	≈	0,2	ns
Anode current linear within 5% at V_b = 2,5 kV up to	6)7)	≈	1	A
		≥	0,8	A
Capacitance, anode to cathode		C_{ak}	2	pF

LIMITING VALUES (Absolute max. rating system)

Anode voltage, d.c.	max.	2,5	kV	
Total cathode current,				
peak	max.	2	A	
mean, averaging time 1 s	max.	1	μA	
Ambient temperature	max.	60	°C	8)
	min.	-40	°C	

REMARKS

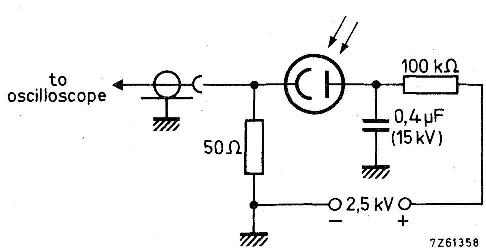
After an idle period of more than 8 days, the dark current needs some hours to return to its normal value.

The cathode should not be exposed to direct sunlight.

ACCESSORIES

Socket : type 56041

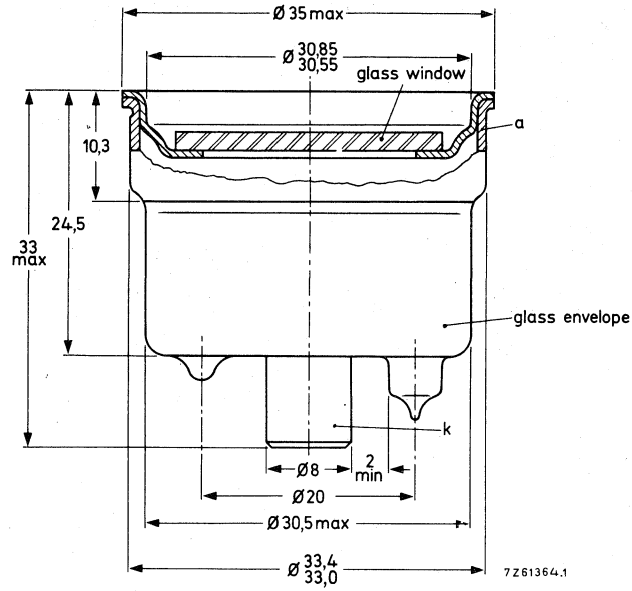
MEASURING CIRCUIT



Notes see pages 3 and 4.

MECHANICAL DATA Dimensions in mm

Net mass : 33 g



Transmission of anode grid 85%
Distance anode-cathode 3, 5 mm

Notes

1) Cathode luminous sensitivity is measured by means of a tungsten filament lamp of colour temperature 2856 ± 5 K.

2) Measuring equipment is calibrated by comparison with a Schwartz thermocouple.

3) Dark current is measured at 20 °C after a stabilization period in darkness, with anode voltage applied, of ≈ 0, 5 h.

4) Due to the geometry of the device and the high electric field strength the anode current is more or less dependent on the anode voltage and the wavelength of irradiation.

5) Measured with a pulsed-light source, with a pulse duration (FWHM) of < 1 ns, the cathode being completely illuminated. Tube mounted in socket 56041.

6) When the tube is used with socket 56041, with a build-in capacitor of 500 pF, this linearity is obtained only if the electrical charge transported by the pulse - or pulse train - does not exceed 1 μC.
To prevent a considerable decrease in anode voltage when measuring pulses of high magnitude and/or long duration an external capacitor should be mounted between anode and earth (chassis).
The value can be calculated with:

$$V_a = V_b - \Delta V = V_b - \frac{I}{C}\,\Delta t$$

in which : $V_a > 2$ kV
I = peak current
Δt = pulse duration

7) The linearity is measured with a light pulse with
pulse duration = 1 μs
pulse energy = 35 J (2 Mlm)
pulse repetition frequency = 2 p.p.min

The linearity is observed on an X - Y oscilloscope by comparison with a standard phototube.
The cathode current may not exceed a peak value of 2 A.

8) During not more than some hours.

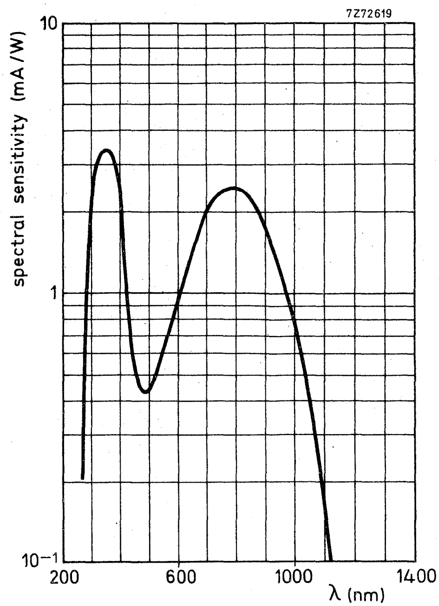


Fig. 1

Spectral sensitivity characteristic. With this type of cathode the sensitivity of each individual tube can deviate considerably from the curve shown: the maximum at 800 nm may be less pronounced and the curve may be flat between 550 nm and 950 nm and extend to ≈ 1200 nm.

PHOTOTUBES

	gas filled tubes		vacuum tubes	
	90CG	92AG	90CV	92AV
Maximum anode supply voltage	90 V	90 V	250 V	100 V
Luminous sensitivity	125 μA/lm	130 μA/lm	20 μA/lm	45 μA/lm
Spectral sensitivity characteristic	S1 (type C)	S11 (type A)	S1 (type C)	S11 (type A)
Projected sensitive area	3,0 cm^2	2,1 cm^2	3,0 cm^2	2,1 cm^2
Maximum outline dimensions	ϕ 19 mm x 54 mm			

These phototubes are available until present stocks are exhausted.

PHOTOTUBE

The 150AV is a 30 mm useful diameter head-on phototube with a flat window and a semi-transparent S11 (type A) photocathode. The tube is intended for use in high precision photometry and for measurement of quickly changing light phenomena and features a high stability and linearity.

QUICK REFERENCE DATA		
Spectral sensitivity characteristic	S11 (type A)	
Useful diameter of the photocathode	30	mm
Spectral sensitivity of the photocathode at 437 nm	60	mA/W
Anode voltage	1 to 90	V

To be read in conjunction with "General Operational Recommendations Phototubes".

CHARACTERISTICS

Photocathode

Semi-transparent head-on				
Material		Cs-Sb		
Useful diameter		>	30	mm
Spectral sensitivity characteristic Fig. 1		S11 (type A)		
Maximum spectral sensitivity at			420 ± 30	nm
Luminous sensitivity	1)	typ.	70	μA/lm
		>	35	μA/lm
Spectral sensitivity at 437 ± 5 nm	2)	≈	60	mA/W

Notes see page 3.

Operating characteristics

Operating voltage, d.c.			1 to 90	V
Saturation voltage				
for a luminous flux of 0,05 lm		≈	4,5	V
0,01 lm		≈	1	V
Dark current at V_b = 1 V	3)	typ.	1	pA
		<	2	pA
Rise time at V_b = 50 V			14	ns
Capacitance, anode to cathode		C_{ak}	13	pF

LIMITING VALUES (Absolute max. rating system)

Anode voltage, d.c.		max.	100	V
Cathode current per mm^2,				
peak		max.	50	nA/mm^2
mean, averaging time 1 s		max.	70	pA/mm^2
Total cathode current,	4)5)			
peak		max.	35	µA
mean, averaging time 1 s		max.	500	nA
Ambient temperature		max.	60	°C 6)
		min.	−40	°C

LIFE EXPECTANCY

With a cathode current of 2 µA the decrease in sensitivity may be:
at 400 nm 0,4%/h
at 560 nm 0,8%/h.

With an average cathode current of 50 nA the sensitivity will not decrease more than 10% of its initial value between zero and 500 operating hours.

To attain high stability it is recommended that the cathode current be kept as low as possible.

REMARKS

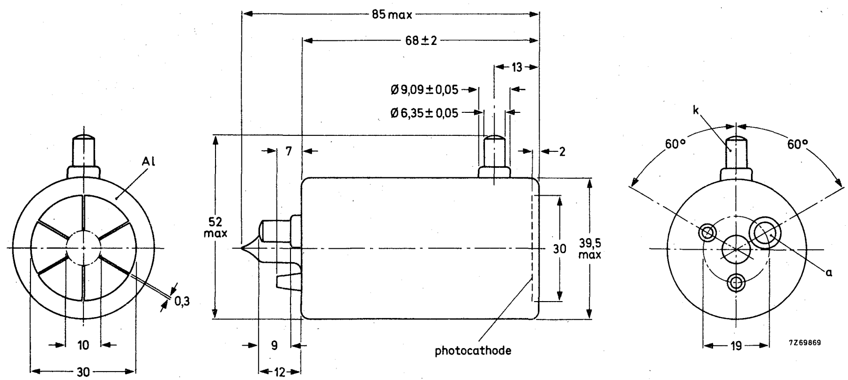
After an idle period of more than 8 days, the dark current needs some hours to return to its normal value.

The cathode should not be exposed to direct sunlight.

MECHANICAL DATA

Dimensions in mm

Net mass : 60 g



An external guard ring significantly decreases the dark current (≈ 10^{-14} A). This can be obtained by applying a ring of silver paste.

Notes

1) Cathode luminous sensitivity is measured by means of a tungsten filament lamp of colour temperature 2856 ± K.

2) Measuring equipment is calibrated by comparison with a Schwartz thermocouple.

3) Dark current is measured at 25 °C after a stabilization period in darkness, with anode voltage applied, of 0, 5 h. The dark current is approximately proportional to the applied voltage.
An external guard ring, made of silver paste, may be put on the tube envelope when the tube is used with very low cathode current.

4) Cathode uniformly illuminated.

5) The relation between the incident luminous flux and the cathode current is linear within measuring errors provided the anode voltage is higher than the saturation voltage.

6) During not more than some hours.

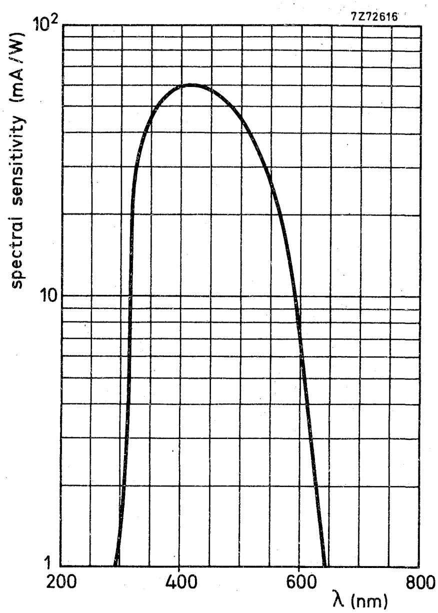


Fig. 3

Spectral sensitivity characteristic

SINGLE CHANNEL ELECTRON MULTIPLIERS

SURVEY OF TYPES

type	status	shape	input		output	
					open ended	closed
B310AL/01*	M	spiral	circular	ϕ 1,25 mm	X	
B310BL/01*	M	spiral	circular	ϕ 1,25 mm		X
B312AL/01*	M	spiral	rectangular	2 mm x 8 mm	X	
B312BL/01*	M	spiral	rectangular	2 mm x 8 mm		X
B314AL/01*	M	spiral	rectangular	2 mm x 8 mm	X	
B314BL/01*	M	spiral	rectangular	2 mm x 8 mm		X
B318AL/01*	M	spiral	conical	ϕ 5 mm	X	
B318BL/01*	M	spiral	conical	ϕ 5 mm		X
B330AL/01*	M	C-shaped	circular	ϕ 1,25 mm	X	
B330BL/01*	M	C-shaped	circular	ϕ 1,25 mm		X
B419AL/01	M	spiral	conical	ϕ 10 mm	X	
B419BL/01	M	spiral	conical	ϕ 10 mm		X
X910AL	D	spiral	circular	ϕ 2,2 mm	X	
X910BL	D	spiral	circular	ϕ 2,2 mm		X
X913AL	D	spiral	rectangular	3,5 mm x 15,5 mm	X	
X913BL	D	spiral	rectangular	3,5 mm x 15,5 mm		X
X914AL	D	spiral	rectangular	3,5 mm x 15,5 mm	X	
X914BL	D	spiral	rectangular	3,5 mm x 15,5 mm		X
X919AL	D	spiral	conical	ϕ 10 mm	X	
X919BL	D	spiral	conical	ϕ 10 mm		X
X959AL	D	spiral	conical	ϕ 15 mm	X	
X959BL	D	spiral	conical	ϕ 15 mm		X

Status code

N = **New design type.** Recommended for new equipment design; production quantities available *after date of publication.*

D = **Design type.** Recommended for equipment design; production quantities available *at date of publication.*

M = **Maintenance type.** No longer recommended for equipment production; available for maintenance of existing equipment.

* Will be replaced by channel electron multipliers of X800 series, which are in development.

SINGLE CHANNEL ELECTRON MULTIPLIERS

PRINCIPLES OF OPERATION

A single channel electron multiplier is a small, curved, glass tube, the inside wall of which is coated with high-resistance material. If a potential is applied between the ends of the tube, the resistive surface becomes a continuous dynode, electrically analogous to the separate dynodes of a conventional photomultiplier together with the resistive chain used to establish the separate dynode potentials.

The channel electron multiplier operates in vacuum. For space research, the environmental vacuum is sufficient, and there is then no window separating the multiplier from the radiation source. In the laboratory, the multiplier must be used in a vacuum chamber.

An electron entering the low-potential end of the channel multiplier generates secondary electrons on collision with the wall of the tube. These are accelerated along the tube until they strike the wall again, where they generate further secondary electrons. This avalanching process produces a large number of electrons at the positive end of the tube. This is illustrated in Fig. 1.

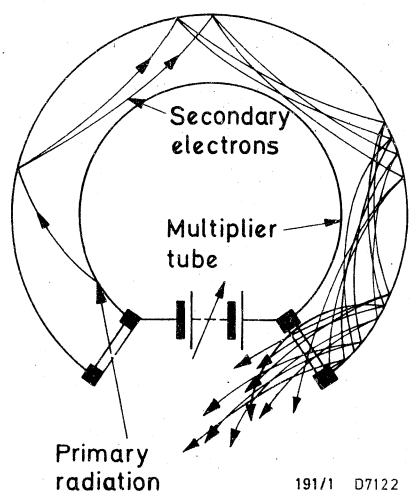


Fig. 1. Illustration of electron multiplication

A channel multiplier thus responds to an input of one electron by producing an output pulse of charge. This pulse may contain up to about 10^8 electrons and its duration (full width at half height) is about 10 nanoseconds. The amplitude of the resulting voltage pulse depends of course upon the values of resistance and capacitance in the anode circuit of the multiplier. The gain (Fig. 2) is an exponential and very steep function of voltage for values below 10^7. Above 10^7, saturation effects are observed which will be discussed later.

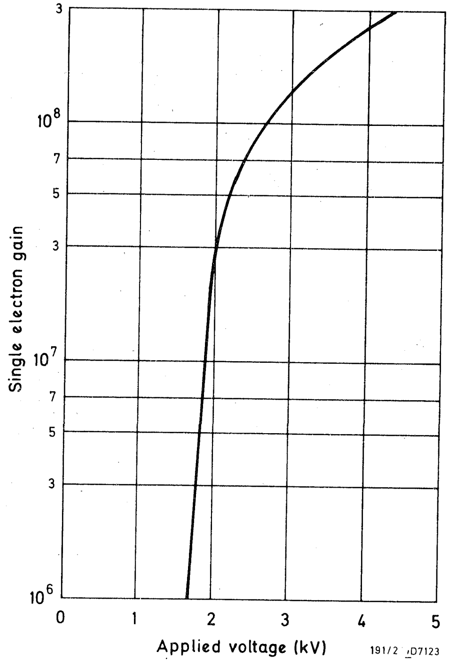


Fig. 2. Variation of gain with applied voltage

The multiplier will respond to ions, β particles, X-rays, or any other sufficiently energetic radiation. The detection efficiency of a channel multiplier is different for different forms and energies of excitation, but any particle or quantum capable of exciting an electron from the dynode surface has a finite probability of detection, (see Figs 7 and 8). Since the resistive coating is continuous, many electron paths are possible, and the number of stages of multiplication is thus indeterminate. The electron trajectories are scaled in proportion to the dimensions of the channel for a given applied voltage. Thus, if the length-to-diameter ratio is preserved, the same multiplication processes go on, and the same gain is achieved, irrespective of the absolute length of the channel. In practice, it is necessary for the length-to-diameter ratio to exceed about 30: 1. Channels are almost invariably curved, and the gain is then less critically dependent on the length-to-diameter ratio. The ratios actually used are between 50: 1 and 100: 1.

IONIC FEEDBACK

The tube forming the channel multiplier is curved because the gain of a straight tube would be sensitive to changes in ambient pressure. When the first cloud of electrons nears the output end of the multiplier, it is sufficiently dense to ionise a considerable number of the residual gas atoms in the tube. These positive ions drift under the influence of the applied field towards the more negative potential at the input end of the channel.
If the channel is straight, the ions may acquire considerable energy before they collide with the wall of the tube. Consequently they may release from the wall electrons which

initiate a further process of multiplication through the tube, resulting in a spurious output pulse. This process is repeated, and thus a sequence of "afterpulses" may be observed. This pulse train lasts typically for about a microsecond, until the capacity of the channel is exhausted and the pulse train dies out.

In a curved tube, the ions strike the wall of the tube before they have acquired sufficient energy to release secondary electrons. Electron multiplication is unaffected however, since electrons need acquire an energy of only about 50 eV to release secondary electrons from the wall. The output of the curved multiplier is therefore independent of the ambient pressure, provided it does not exceed 50 mN/m^2*. Above this pressure, spurious pulses occur, and effects similar to those seen with straight channels are observed.

SATURATION DUE TO SPACE CHARGE

One of the more significant aspects of the behaviour of a channel multiplier is the saturation effect caused by space-charge limitation. When the total amount of charge in the electron cloud in a channel multiplier reaches nearly 10^9 electrons, the gain cannot increase further. The space charge repels the emitted secondary electrons so that they strike the wall before acquiring sufficient energy from the field to make useful multiplying collisions. The space-charge limit is unaffected by the channel diameter. Increasing the applied voltage increases the amplitude of those pulses which would not otherwise have reached $\approx 10^9$ electrons, but as the maximum charge output cannot exceed this level, the amplitude of all pulses tends to the same value. The multiplier thus has a narrow pulse-height distribution. When it is operated in the saturated mode, it is analogous to a Geiger counter, producing a pulse of a given amplitude irrespective of the manner of its excitation. It is unable in this condition to give information about the number of particles simultaneously striking the input or about their energy.

When the multiplier is not operated in its saturated mode, that is when the gain is less than 10^7, there is some proportionality between input and output. However, there is a spread of pulse amplitudes because of the many possible electron paths through the multiplier. The pulse-amplitude distribution is exponential: smaller pulses are more probable than larger ones by an amount exponentially dependent on the amplitude.

SATURATION DUE TO FIELD DISTORTION

In a straight channel, ionic feedback gives rise to a pulse train about 1 microsecond in duration which may contain a total charge of more than 10^9 electrons. The pulse train dies out only when the field inside the channel is distorted by wall-charging to such an extent that the multiplication process can no longer sustain feedback.

The field is restored during a "dead time", after which an output pulse can again be observed. The dead time depends on the resistance of the channel and may be some tens of microseconds.

The dead-time effect may be caused by a single event in a straight channel. This is not possible, however, in curved channels because the probability of ionic feedback is very low, and the pulse train is replaced by a single pulse of about 10 nanoseconds duration which is space-charge limited to about 10^9 electrons. Consequently, the curved channel may produce two pulses of the same amplitude separated in time only by the pulse duration. However, if the mean pulse repetition rate is high, the field inside the channel is

*approximately 5×10^{-4} torr

SATURATION DUE TO FIELD DISTORTION (Contd.)

distorted. A state of dynamic equilibrium is achieved: the mean gain is reduced so that the average rate of flow of charge in the output pulses is less than the current flowing in the channel wall.
The same considerations apply when a channel multiplier is used as a current amplifier. The amplification is linear only so long as the output current is less than about 1% of the standing current in the wall of the multiplier. For example, a channel of resistance $10^9\Omega$ operated at 1.5 kV cannot produce an output current of more than 1.5×10^{-8}A while maintaining a linear current-transfer characteristic.

RESISTANCE

The resistance of a channel electron multiplier is measured between input and output terminals at atmospheric pressure. i.e. at room temperature with no space current flow.

BACKGROUND OR SPONTANEOUS PULSE COUNT RATE

The background or spontaneous pulse count rate is the number of pulses detected per second above a specified equivalent threshold when the input end of the multiplier is closed. The equivalent threshold is the amount of charge produced by the multiplier which, when amplified, just appears above the threshold of the discriminator used for pulse counting. The count is made with a multiplier voltage and equivalent threshold as specified in the data sheets.

STARTING VOLTAGE

As the voltage applied to the channel is increased, the gain rises and the output pulses become larger. The pulses are not all the same size, but as the gain increases, more of them exceed the equivalent threshold. This process continues until all the pulses are above the threshold. The observed count rate is plotted against voltage in Fig. 3 and this graph shows a steeply rising portion followed by a plateau.

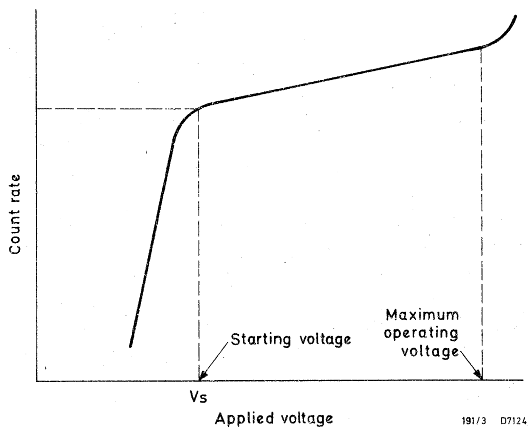


Fig. 3 Definition of starting voltage

The starting voltage is the voltage at which the pulse count rate is 90% of the plateau counting rate, where the plateau is defined as the region over which the count rate changes by less than 10% for each applied kilovolt.
For the purposes of determining the starting voltage, the plateau counting rate is taken at the midpoint of the plateau. The midpoint is either halfway between the lower and upper voltages or between the lower voltage and the maximum permissible operating voltage, whichever is the less.
The starting voltage is measured using an input source adjusted to give a fixed count rate at a high applied voltage. The count rate and voltage, together with the equivalent threshhold, are given in the data sheets.

GAIN

The output pulse corresponding to one input electron will show a statistical spread. Due to saturation effects in the multiplier this spread is approximately Gaussian and the gain is defined as its median value.
For a gain of 1.0×10^8 a single input electron will produce an output of 16 picocoulombs.

$$\text{Gain} = \frac{\text{Charge in the output pulse}}{\text{Input charge}}$$

The gain is constant up to a count rate of 1000 pulses per second. Above this the gain falls by approximately 3 dB per octave. In specifying gain, it is necessary to stipulate the applied voltage and the count rate. These are given in the data sheets.

OUTPUT

The output pulse corresponding to one input electron will consist of G electrons. The corresponding charge in the output pulse will thus be $G \times 1.6 \times 10^{-19}$ coulombs, where 1.6×10^{-19} coulombs is the electron charge. The charge in the output pulse raises the potential across the input capacitance of a pulse amplifier, and this voltage change is referred to as the pulse height (usually in millivolts).
This expression of output as a voltage is common practice, but the capacitance to be charged must also be known.
When a channel multiplier is used for direct current amplification, the output current must be collected at a separate electrode. If it is used for pulse counting, the output can be detected at the positive terminal of the multiplier; in this case, the multiplier is a two-terminal device.

PULSE HEIGHT DISTRIBUTION

The nominal gain of a channel multiplier will not be achieved every time an electron produces an output pulse: there is a variation in gain because of the statistical nature of the multiplication process. However, the spread is not usually very great at high values of gain, and it is expressed in terms of the resolution of the pulse height distribution.
A typical distribution showing pulse height as abscissa and the frequency of occurrence of that pulse height as ordinate is given in Fig. 4. The distribution is seen to be Gaussian. The resolution is defined as the ratio of the full width of the distribution at half maximum

PULSE HEIGHT DISTRIBUTION (Contd.)

frequency to the modal pulse height. The resolution depends on applied voltage and gain. Values for various multipliers are quoted in the data sheets.

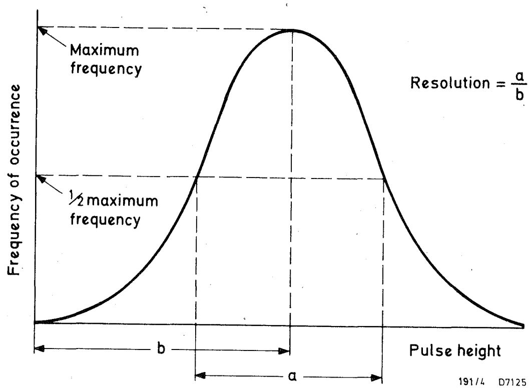


Fig. 4. Definition of resolution of pulse distribution height.

INPUT APERTURE

Larger input apertures can be achieved without increasing the overall dimensions of the multiplier by fitting a cone-shaped flared end. Because the response of a channel multiplier depends on the angle of incidence of the input flux, it is not practicable to quote dimensions of effective apertures which are valid in all situations. The effective aperture of standard multipliers is not necessarily the same as the geometrical aperture, but may be smaller.

MODE OF OPERATION

The multiplier is most commonly used with pulse counting circuits to detect individual particles or quanta. For this application closed end multipliers are recommended. A typical circuit is shown in Figure 5. The output pulse is capacitively coupled into a suitable charge sensitive pulse amplifier and discriminator. Under certain circumstances the multiplier may be used as a current amplifier. In this case an open-ended multiplier is necessary, the output being collected at a separate electrode as shown in Figure 6. The collector electrode is biased positively to ensure collection of all output electrons. For satisfactory linearity the multiplier should be operated with a gain of less than 10^5 and the output current should not exceed 1% of the standing current.

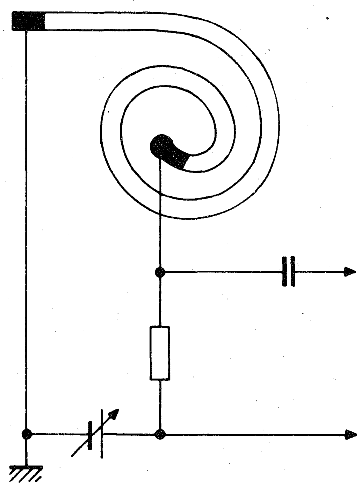


Fig. 5

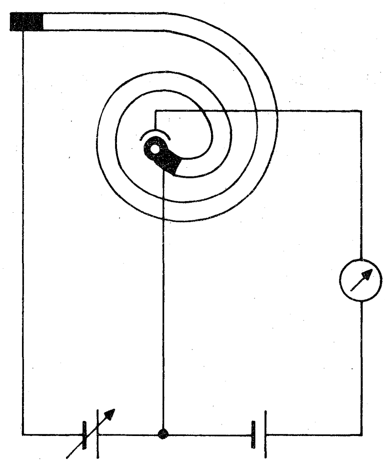


Fig. 6

OPERATIONAL NOTES

Mounting

It is recommended that, in general, the leads are not used for mounting the device as sustained vibration may result in fracture of the electrical connections.
The outer surface of the device is also a conductor, and supports applied to the glass must be insulated to avoid unwanted circuits.

Vacuum environment

Normal vacuum precautions should be observed. In particular gross contamination with hydrocarbon vapours will cause rapid loss of gain and should be avoided. If necessary the device may be cleaned in iso-propyl alcohol and air dried at a temperature not exceeding 70 ^{o}C.
The device is stable in air and may be vacuum cycled repeatedly without damage, but if it has to be stored in air for several months it is good practice to use a desiccator.

Baking conditions

The specified baking conditions apply when the device is under vacuum. The temperature must not exceed the specified maximum operating and storage temperature unless the pressure is less than 50 mN/m^2 (3.7×10^{-4} torr). No voltage should be applied to the device during bake-out.

OPERATIONAL NOTES (Contd.)

Thermal stability

Due to the negative temperature coefficient of resistance of the devices, thermal runaway is possible. Operation below the maximum voltage and temperature limits specified will ensure that this does not occur.

Choice of operating voltage

Use of an operating voltage approximately 500 volts greater than the starting voltage will ensure that all output pulses exceed the threshold and are recorded. If, as a result of prolonged use the median gain of the multiplier falls, the operating voltage may be in-reased in order to restore the gain to its original value.

To avoid contamination, these devices should be handled only with gloved hands or tweezers.

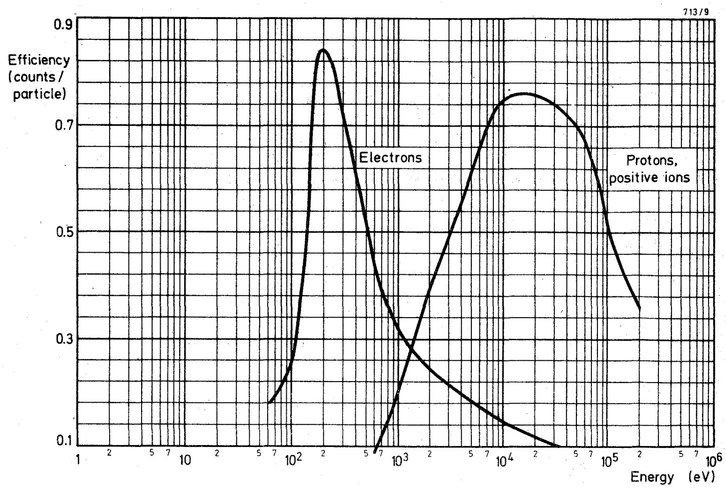


Fig. 7 Typical detection efficiencies for electrons, protons and positive ions*.

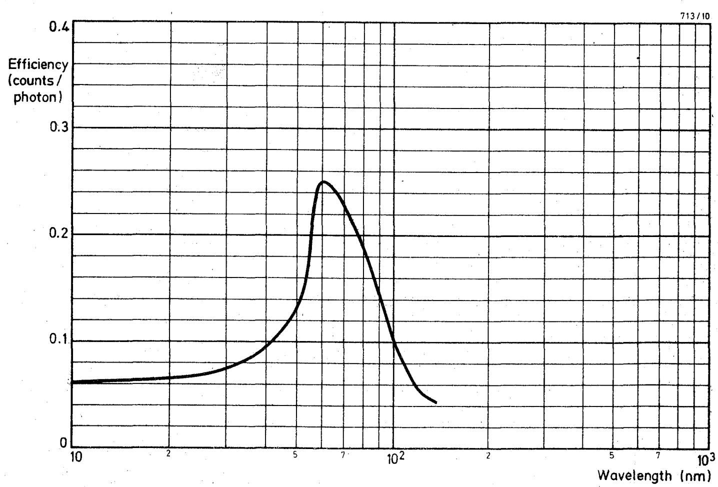


Fig. 8 Typical detection efficiency for ultraviolet radiation*.

*With acknowledgements to TIMOTHY, A. F., and TIMOTHY, J. G., 'Space applications of single channel electron multipliers', Acta Electronica, Vol. 14, No. 2 pp. 159 to 179, April 1971.

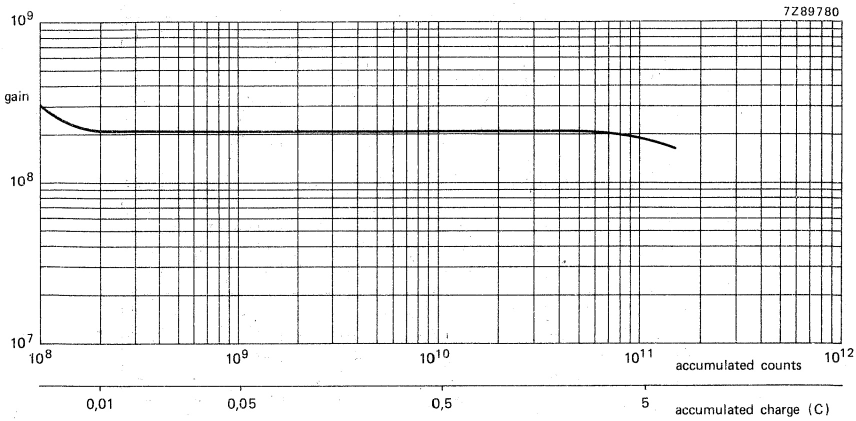


Fig. 9 Typical gain as a function of accumulated counts and accumulated charge for single channel electron multipliers of X900 series.
Operating voltage = 2,8 kV; ambient pressure = 0,013 mPa; count rate = 10^4 counts/s; source = electrons.

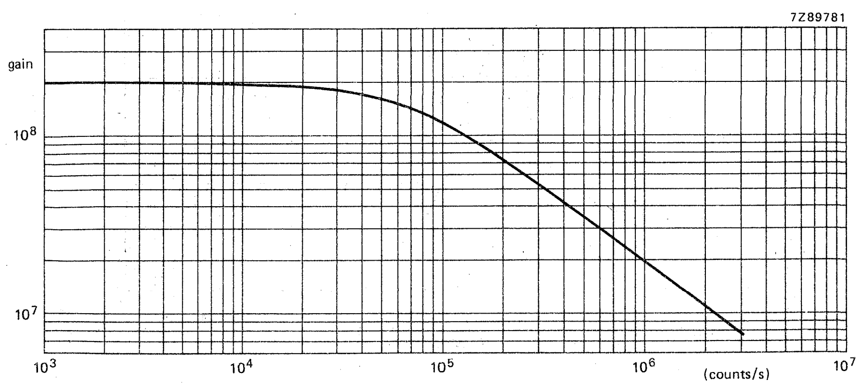


Fig. 10 Typical gain as a function of count rate for single channel electron multipliers of X900 series.
Operating voltage = 2,5 kV; threshold = 2,8 x 10^6 electrons.

CHANNEL ELECTRON MULTIPLIER

Channel electron multiplier in the form of a glass planar spiral tube.

QUICK REFERENCE DATA		
The B310AL/01 has an open-ended output.		
The B310BL/01 has a closed output.		
Typical gain at 3.0 kV	1.3×10^8	
Typical resistance	3.0×10^9	Ω
Maximum operating voltage	4.0	kV

Unless otherwise stated, data is applicable to both types

This data should be read in conjunction with
GENERAL EXPLANATORY NOTES - CHANNEL ELECTRON MULTIPLIERS

CHARACTERISTICS (measured at 3.0 kV and 1000 pulse/s where applicable)

	Min.	Typ.	Max.	
Resistance	2.0	3.0	5.0	$\times 10^9$ Ω
Gain, see note 1)	1.0	1.3	-	$\times 10^8$
Background above an equivalent threshold of 2.0×10^7 electrons	-	0.1	0.2	pulse/s
Starting voltage with an equivalent threshold of 2.0×10^7 electrons	2.0	2.5	2.6	kV
Resolution (F.W.H.M.) at a modal gain of 1.0×10^8	-	50	70	%
Effective input diameter	1.1	1.25	-	mm

LIMITING VALUES (Absolute max. rating system)

Operating voltage	max.	4.0	kV
Temperature, operating and storage	max.	70	°C
Bake temperatures, see note 2)	max.	400	°C
Ambient pressure with high voltage applied	max.	50	mN/m^2
		3.7×10^{-4}	torr

MASS 1.0 g

MOUNTING POSITION

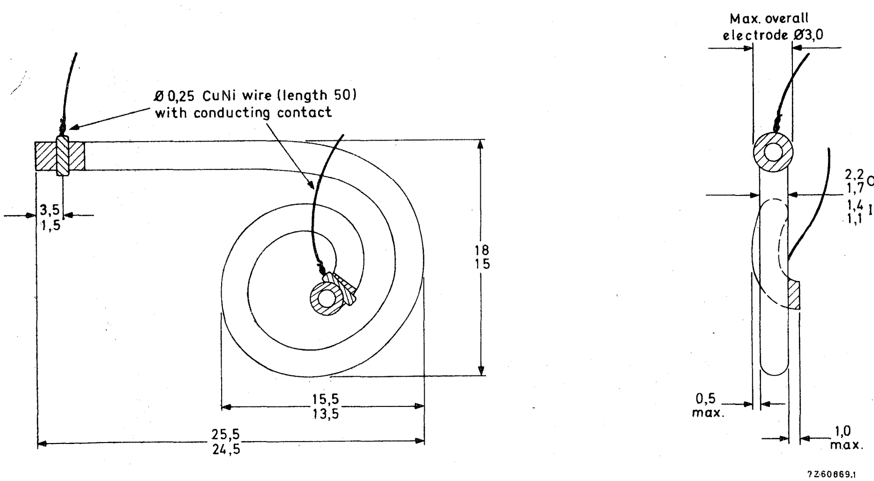
Any. In environments where vibration may be encountered the device should not be supported by the leads alone.

NOTES

1) The gain of a typical multiplier will increase by a factor of 2 for an increase of operating voltage of 500 V.

2) Baking will cause a permanent slight loss in gain and it is advisable to keep the baking time to a minimum, for example, baking for 16 hours at 400 °C will reduce gain by approximately a factor of 2.

DIMENSIONS AND CONNECTIONS Dimensions in mm



CHANNEL ELECTRON MULTIPLIER

Channel electron multiplier in the form of a glass planar spiral tube with a rectangular-section input cone 2.0 x 8.0 mm.

QUICK REFERENCE DATA		
The B312AL/01 has an open-ended output.		
The B312BL/01 has a closed output.		
Typical gain at 3.0 kV	1.3×10^8	
Typical resistance	3.0×10^9	Ω
Maximum operating voltage	4.0	kV

Unless otherwise stated, data is applicable to both types

This data should be read in conjunction with
GENERAL EXPLANATORY NOTES - CHANNEL ELECTRON MULTIPLIERS

CHARACTERISTICS (measured at 3.0 kV and 1000 pulse/s where applicable)

	Min.	Typ.	Max.	
Resistance	2.0	3.0	5.0	$\times 10^9$ Ω
Gain, see note 1)	1.0	1.3	-	$\times 10^8$
Background above an equivalent threshold of 2.0×10^7 electrons	-	0.2	0.5	pulse/s
Starting voltage with an equivalent threshold of 2.0×10^7 electrons	2.0	2.5	2.6	kV
Resolution (F.W.H.M.) at a modal gain of 1.0×10^8	-	50	70	%
Effective input aperture	1.7 x 7.5	2.0 x 8.0	-	mm

LIMITING VALUES (Absolute max. rating system)

Operating voltage	max.	4.0	kV
Temperature, operating and storage	max.	70	°C
Bake temperatures, see note 2)	max.	400	°C
Ambient pressure with high voltage applied	max.	50	mN/m²
		3.7×10^{-4}	torr

MASS 1.0 g

MOUNTING POSITION

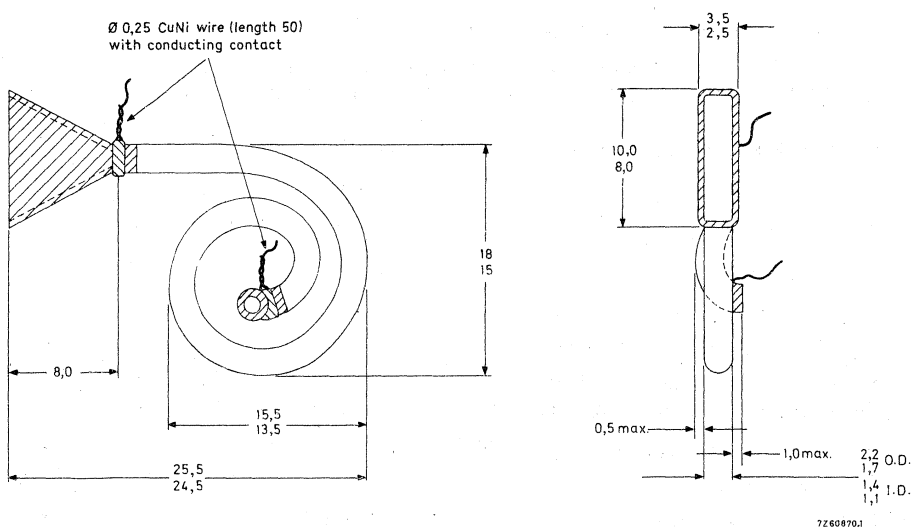
Any. In environments where vibration may be encountered the device should not be supported by the leads alone.

NOTES

1) The gain of a typical multiplier will increase by a factor of 2 for an increase of operating voltage of 500 V.

2) Baking will cause a permanent slight loss in gain and it is advisable to keep the baking time to a minimum, for example, baking for 16 hours at 400 °C will reduce gain by approximately a factor of 2.

DIMENSIONS AND CONNECTIONS Dimensions in mm



CHANNEL ELECTRON MULTIPLIER

Channel electron multiplier in the form of a glass planar spiral tube with a rectangular-section input cone 2.0 x 8.0 mm.

QUICK REFERENCE DATA	
The B314AL/01 has an open-ended output.	
The B314BL/01 has a closed output.	
Typical gain at 3.0 kV	1.3×10^8
Typical resistance	3.0×10^9 Ω
Maximum operating voltage	4.0 kV

Unless otherwise stated, data is applicable to both types

This data should be read in conjunction with
GENERAL EXPLANATORY NOTES - CHANNEL ELECTRON MULTIPLIERS

CHARACTERISTICS (measured at 3.0 kV and 1000 pulse/s where applicable)

	Min.	Typ.	Max.	
Resistance	2.0	3.0	5.0	$\times 10^9$ Ω
Gain, see note 1)	1.0	1.3	-	$\times 10^8$
Background above an equivalent threshold of 2.0×10^7 electrons	-	0.2	0.5	pulse/s
Starting voltage with an equivalent threshold of 2.0×10^7 electrons	2.0	2.5	2.6	kV
Resolution (F.W.H.M.) at a modal gain of 1.0×10^8	-	50	70	%
Effective input aperture	1.7 x 7.5	2.0 x 8.0	-	mm

LIMITING VALUES (Absolute max. rating system)

Operating voltage	max.	4.0	kV
Temperature, operating and storage	max.	70	°C
Bake temperatures, see note 2)	max.	400	°C
Ambient pressure with high voltage applied	max.	50	mN/m^2
		3.7×10^{-4}	torr

MASS 1,0 g

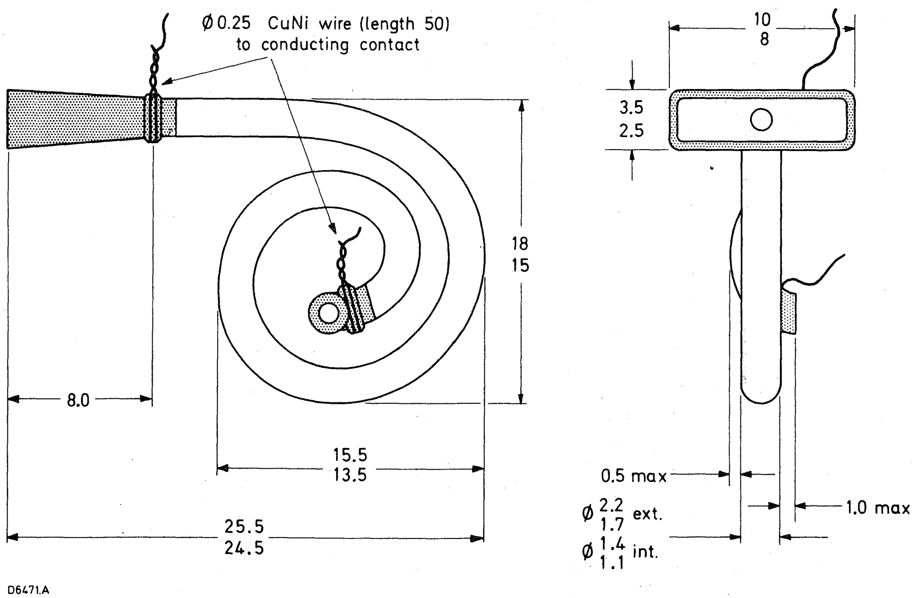
MOUNTING POSITION

Any. In environments where vibration may be encountered the device should not be supported by the leads alone.

NOTES

1. The gain of a typical multiplier will increase by a factor of 2 for an increase of operating voltage of 500 V.
2. Baking will cause a permanent slight loss in gain and it is advisable to keep the baking time to a minimum, for example, baking for 16 hours at 400 °C will reduce gain by approximately a factor of 2.

DIMENSIONS AND CONNECTIONS Dimensions in mm



CHANNEL ELECTRON MULTIPLIER

Channel electron multiplier in the form of a glass planar spiral tube with a 5.0 mm diameter input cone.

QUICK REFERENCE DATA		
The B318AL/01 has an open-ended output.		
The B318BL/01 has a closed output.		
Typical gain at 3,0 kV	1.3×10^8	
Typical resistance	3.0×10^9	Ω
Maximum operating voltage	4.0	kV

Unless otherwise stated, data is applicable to both types

This data should be read in conjunction with
GENERAL EXPLANATORY NOTES - CHANNEL ELECTRON MULTIPLIERS

CHARACTERISTICS (measured at 3.0 kV and 1000 pulse/s where applicable)

	Min.	Typ.	Max.	
Resistance	2.0	3.0	5.0	$\times 10^9$ Ω
Gain, see note 1)	1.0	1.3	–	$\times 10^8$
Background above an equivalent threshold of 2.0×10^7 electrons	–	0.25	0.5	pulse/s
Starting voltage with equivalent threshold of 2.0×10^7 electrons	2.0	2.5	2.6	kV
Resolution (F.W.H.M.) at a modal gain 1.0×10^8	–	50	70	%
Effective cone diameter	4.0	5.0	–	mm

LIMITING VALUES (Absolute max. rating system)

Operating voltage	max.	4.0	kV
Temperature, operating and storage	max.	70	°C
Bake temperatures, see note 2)	max.	400	°C
Ambient pressure with high voltage applied	max.	50	mN/m^2
		3.7×10^{-4}	torr

MASS 1.3 g

MOUNTING POSITION

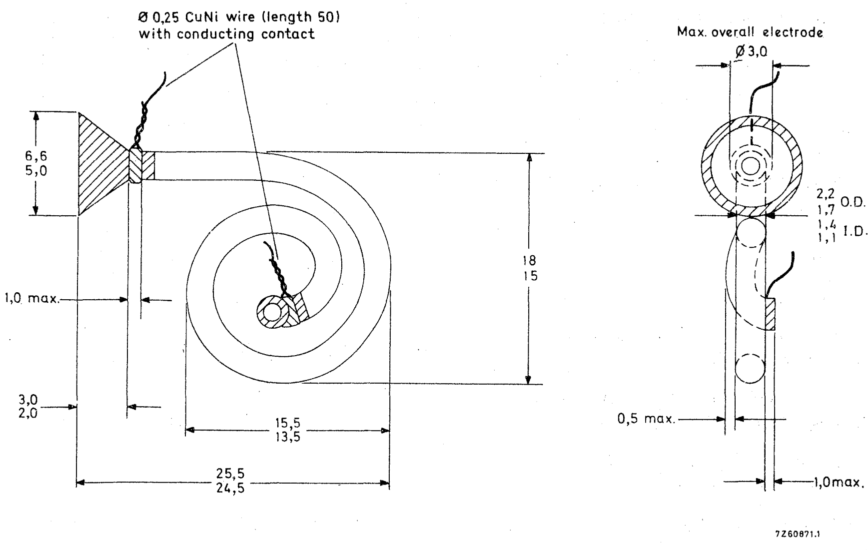
Any. In environments where vibration may be encountered the device should not be supported by the leads alone.

NOTES

1) The gain of a typical multiplier will increase by a factor of 2 for an increase of operating voltage of 500 V.

2) Baking will cause a permanent slight loss in gain and it is advisable to keep the baking time to a minimum, for example, baking for 16 hours at 400 °C will reduce gain by approximately a factor of 2.

DIMENSIONS AND CONNECTIONS Dimensions in mm



CHANNEL ELECTRON MULTIPLIER

Channel electron multiplier in the form of a glass C-shaped tube.

QUICK REFERENCE DATA		
The B330AL/01 has an open-ended output.		
The B330BL/01 has a closed output.		
Typical gain at 3.0 kV	1.5×10^8	
Typical resistance	3.0×10^9	Ω
Maximum operating voltage	4.0	kV

Unless otherwise stated, data is applicable to both types

This data should be read in conjunction with
GENERAL EXPLANATORY NOTES - CHANNEL ELECTRON MULTIPLIERS

CHARACTERISTICS (measured at 3.0 kV and 1000 pulse/s where applicable)

	Min.	Typ.	Max.	
Resistance	2.0	3.0	5.0	$\times 10^9$ Ω
Gain, see note 1)	1.0	1.5	-	$\times 10^8$
Background above an equivalent threshold of 2.0×10^7 electrons	-	0.1	0.2	pulse/s
Starting voltage with an equivalent threshold of 2.0×10^7 electrons	2.0	2.5	2.6	kV
Resolution (F.W.H.M.) at a modal gain of 1.0×10^8	-	50	70	%
Effective input diameter	1.1	1.25	-	mm

LIMITING VALUES (Absolute max. rating system)

Operating voltage	max.	4.0	kV
Temperature, operating and storage	max.	70	°C
Bake temperatures, see note 2)	max.	400	°C
Ambient pressure with high voltage applied	max.	50	mN/m²
		3.7×10^{-4}	torr

MASS 1,3 g

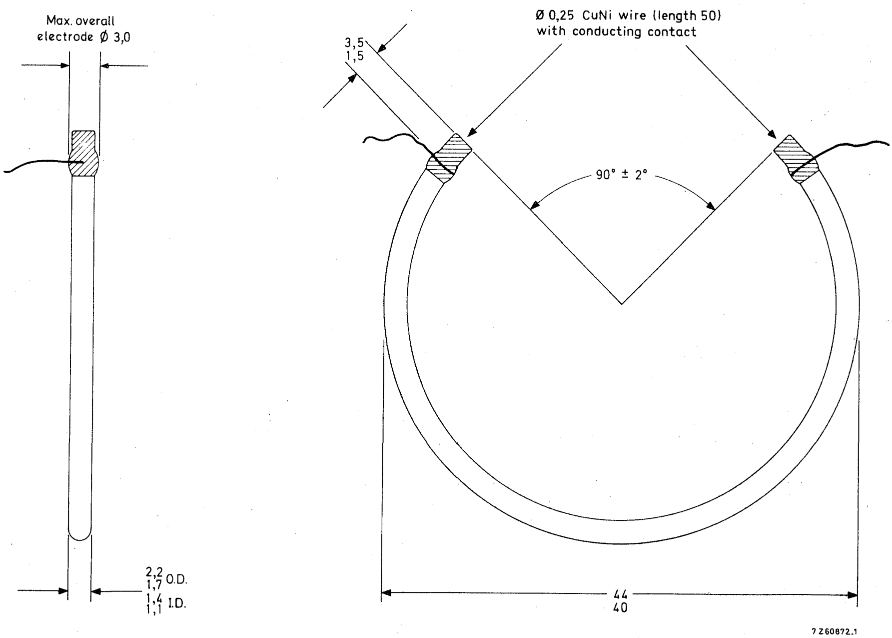
MOUNTING POSITION

Any. In environments where vibration may be encountered the device should not be supported by the leads alone.

NOTES

1. The gain of a typical multiplier will increase by a factor of 2 for an increase of operating voltage of 500 V.
2. Baking will cause a permanent slight loss in gain and it is advisable to keep the baking time to a minimum, for example, baking for 16 hours at 400 °C will reduce gain by approximately a factor of 2.

DIMENSIONS AND CONNECTIONS Dimensions in mm



CHANNEL ELECTRON MULTIPLIER

Channel electron multiplier in the form of a glass planar spiral tube with a 10 mm diameter input cone.

QUICK REFERENCE DATA		
The B419AL/01 has an open-ended output.		
The B419BL/01 has a closed output.		
Typical gain at 2.5 kV	1.7×10^8	
Typical resistance	3.0×10^9	Ω
Maximum operating voltage	3.5	kV

Unless otherwise stated, data is applicable to both types

This data should be read in conjunction with
GENERAL EXPLANATORY NOTES - CHANNEL ELECTRON MULTIPLIERS

CHARACTERISTICS (measured at 2.5 kV and 1000 pulse/s where applicable)

	Min.	Typ.	Max.	
Resistance	2.0	3.0	5.0	$\times 10^9$ Ω
Gain, see note 1)	1.0	1.7	–	$\times 10^8$
Background above an equivalent threshold of 2.0×10^7 electrons	–	0.25	0.5	pulse/s
Starting voltage with an equivalent threshold of 2.0×10^7 electrons	1.7	2.0	2.2	kV
Resolution (F.W.H.M.) at a modal gain of 1.0×10^8	–	50	70	%
Effective input diameter	9.0	10.0	–	mm

LIMITING VALUES (Absolute max. rating system)

Operating voltage	max.	3.5	kV
Temperature, operating and storage	max.	70	°C
Bake temperatures, see note 2)	max.	400	°C
Ambient pressure with high voltage applied	max.	50	mN/m^2
		3.7×10^{-4}	torr

MASS 4.0 g

MOUNTING POSITION

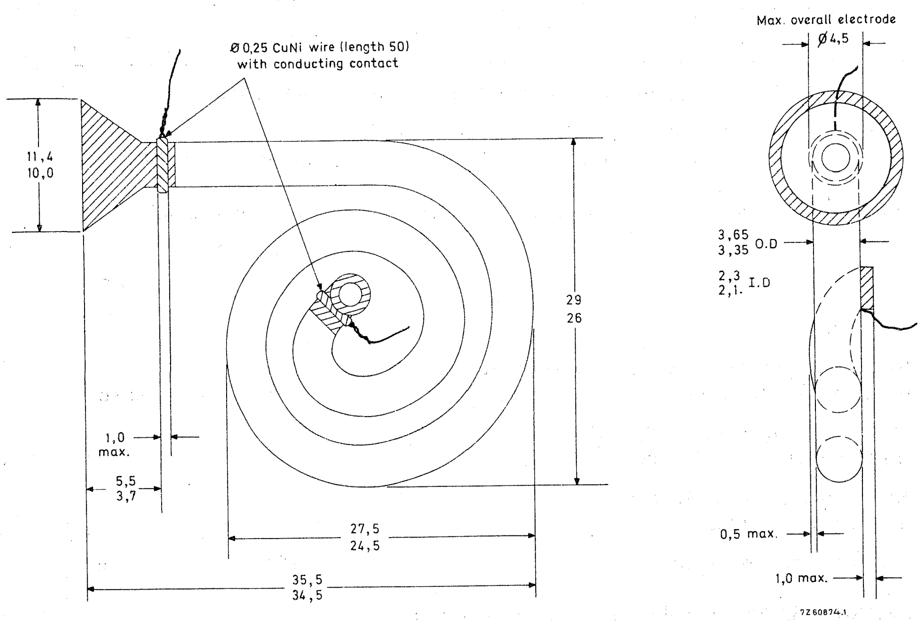
Any. In environments where vibration may be encountered the device should not be supported by the leads alone.

NOTES

1) The gain of a typical multiplier will increase by a factor of 2 for an increase of operating voltage of 500 V.

2) Baking will cause a permanent slight loss in gain and it is advisable to keep the baking time to a minimum, for example, baking for 16 hours at 400 °C will reduce gain by approximately a factor of 2.

DIMENSIONS AND CONNECTIONS Dimensions in mm



SINGLE CHANNEL ELECTRON MULTIPLIERS

Channel electron multipliers in the form of a glass planar spiral tube.
The X910AL has an open-ended output. To ensure efficient collection of electrons, a collector should be used, biased at 100 to 200 V positive with respect to the multiplier output.
The X910BL has a closed output.

QUICK REFERENCE DATA

Typical gain at 2.5 kV		1.8×10^8	
Typical resistance		6.0×10^8	Ω
Operating voltage	max.	4.0	kV

Unless otherwise stated, data is applicable to both types.
This data should be read in conjunction with GENERAL EXPLANATORY NOTES – SINGLE CHANNEL ELECTRON MULTIPLIERS

CHARACTERISTICS (measured at 2.5 kV and 10 000 pulse/s where applicable)

	Min.	Typ.	Max.	
Resistance	4.0	6.0	8.0	$\times 10^8$ Ω
Gain (note 1)	1.0	1.8	–	$\times 10^8$
Background above an equivalent threshold of 2.0×10^7 electrons	–	0.15	0.5	pulse/s
Starting voltage with an equivalent threshold of 2.0×10^7 electrons	1.4	1.6	1.8	kV
Resolution (F.W.H.M.) at a modal gain of 2.0×10^8	–	50	70	%
Effective input diameter	2.0	2.2	–	mm

RATINGS

Limiting values in accordance with the Absolute Maximum System (IEC 134)

Operating voltage	max.	4.0	kV
Temperature, operating and storage	max.	70	°C
Bake temperature in vacuo (note 2)	max.	400	°C
Ambient pressure with high voltage applied	max.	50	mN/m^2
		3.7×10^{-4}	torr

MASS 4.0 g

MOUNTING POSITION

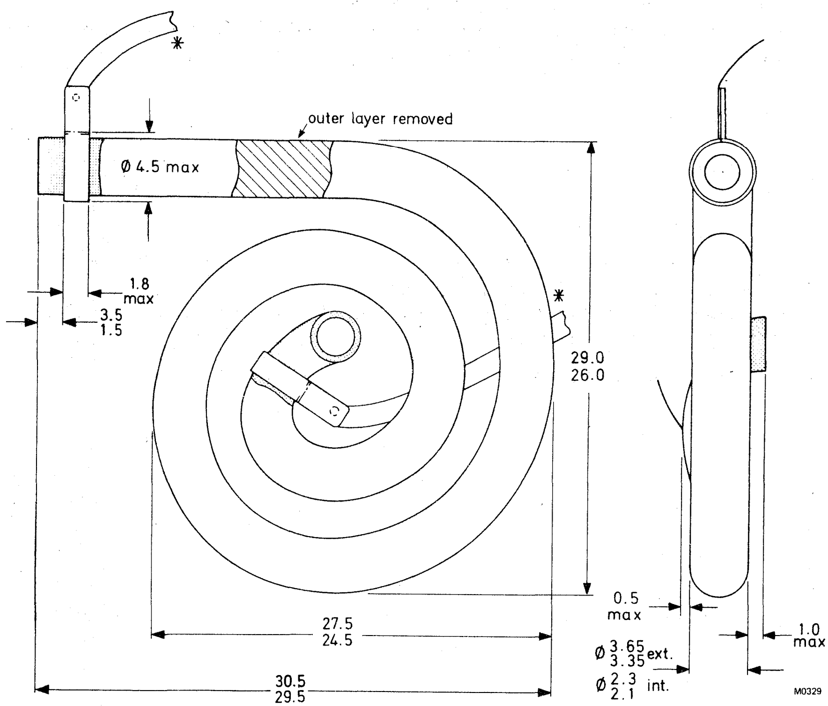
Any. In environments where vibration may be encountered, the device should not be supported by the leads alone.

NOTES

1. The gain of a typical multiplier will increase by a factor of approx. 2 for an increase of operating voltage of 500 V.
2. Baking will cause a permanent slight loss of gain and it is advisable to keep the baking time to a minimum, for example, baking for 16 hours at 400 °C could reduce the gain by approximately a factor of 2.

MECHANICAL DATA X910AL

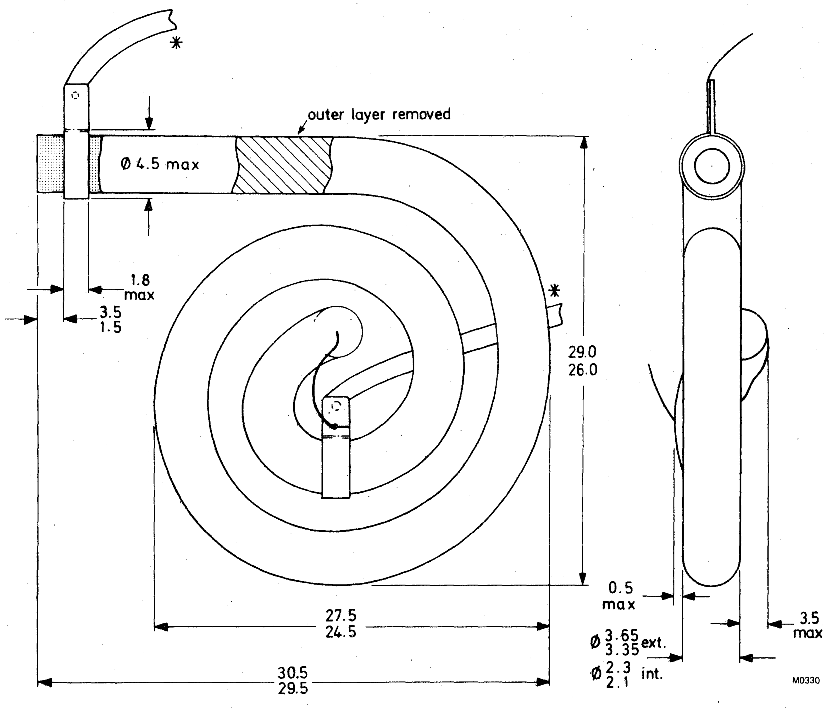
Dimensions in mm



* 1.0 x 0.1 Inconel strip (length 50).

MECHANICAL DATA X910BL

Dimensions in mm



* 1.0 x 0.1 Inconel strip (length 50).

SINGLE CHANNEL ELECTRON MULTIPLIERS

Channel electron multipliers in the form of a glass planar spiral tube with a rectangular section input cone 3.5 x 15.5 mm.
The X913AL has an open-ended output. To ensure efficient collection of electrons, a collector should be used, biased at 100 to 200 V positive with respect to the multiplier output.
The X913BL has a closed output.

QUICK REFERENCE DATA

Typical gain at 2.5 kV		2.0×10^8	
Typical resistance		6.0×10^8	Ω
Operating voltage	max.	4.0	kV

Unless otherwise stated, data is applicable to both types.
This data should be read in conjunction with GENERAL EXPLANATORY NOTES – SINGLE CHANNEL ELECTRON MULTIPLIERS

CHARACTERISTICS (measured at 2.5 kV and 10 000 pulse/s where applicable)

	Min.	Typ.	Max.	
Resistance	4.0	6.0	8.0	$\times 10^8$ Ω
Gain (note 1)	1.0	2.0	–	$\times 10^8$
Background above an equivalent threshold of 2.0×10^7 electrons	–	0.15	0.5	pulse/s
Starting voltage with an equivalent threshold of 2.0×10^7 electrons	1.4	1.6	1.8	kV
Resolution (F.W.H.M.) at a modal gain of 2.0×10^8	–	50	70	%
Effective input aperture	3.0 x 14.5	3.5 x 15.5	5 x 17	mm

RATINGS

Limiting values in accordance with the Absolute Maximum System (IEC 134)

Operating voltage	max.	4.0	kV
Temperature, operating and storage	max.	70	°C
Bake temperature in vacuo (note 2)	max.	400	°C
Ambient pressure with high voltage applied	max.	50	mN/m^2
		3.7×10^{-4}	torr

MASS

MASS	4.0	g

MOUNTING POSITION

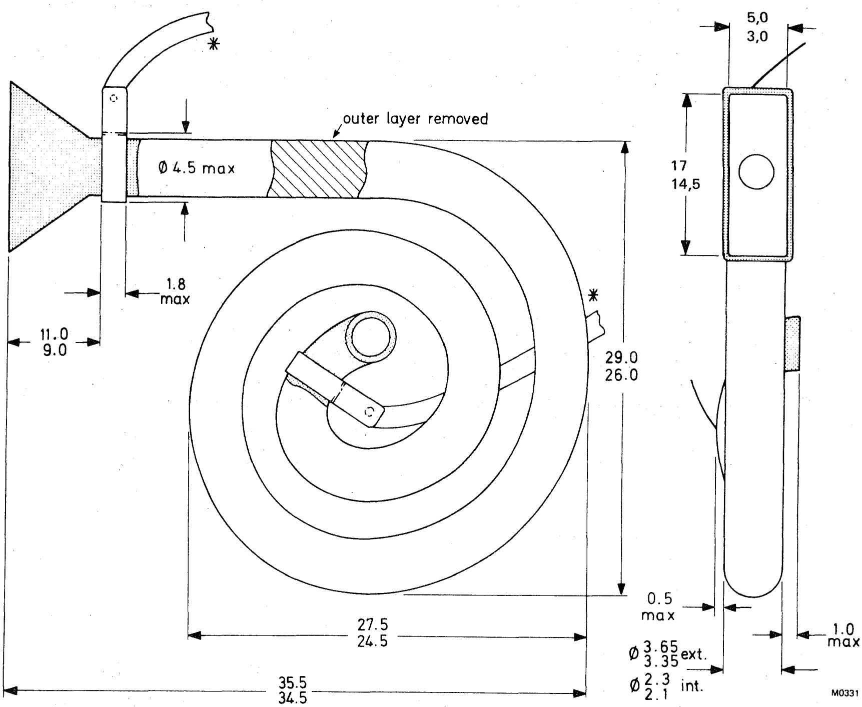
Any. In environments where vibration may be encountered, the device should not be supported by the leads alone.

NOTES

1. The gain of a typical multiplier will increase by a factor of approx. 2 for an increase of operating voltage of 500 V.
2. Baking will cause a permanent slight loss of gain and it is advisable to keep the baking time to a minimum, for example, baking for 16 hours at 400 °C could reduce the gain by approximately a factor of 2.

MECHANICAL DATA X913AL

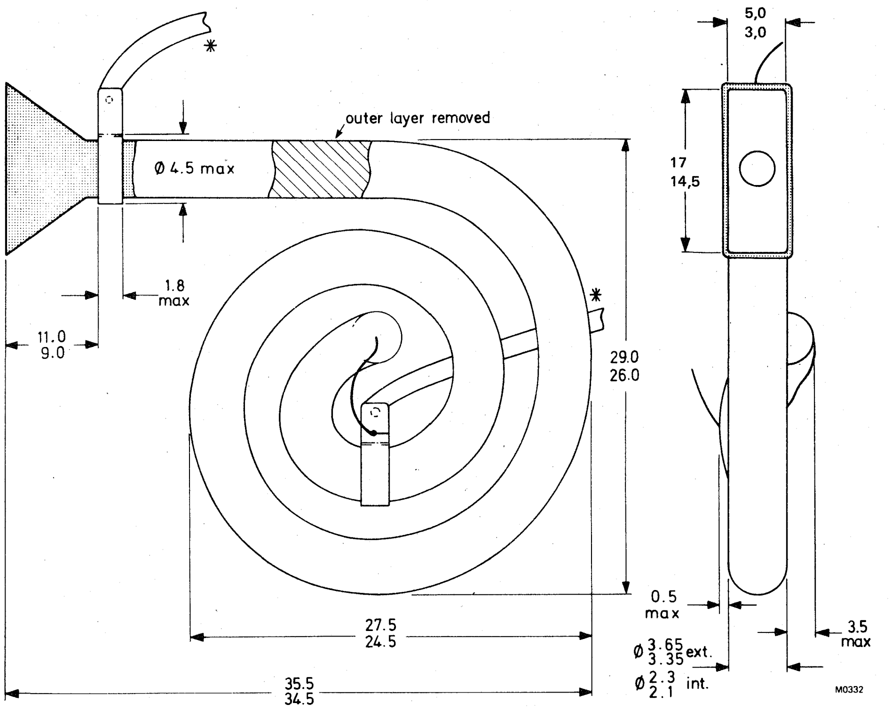
Dimensions in mm



* 1.0 x 0.1 Inconel strip (length 50).

MECHANICAL DATA X913BL

Dimensions in mm



* 1.0 x 0.1 Inconel strip (length 50).

SINGLE CHANNEL ELECTRON MULTIPLIERS

Channel electron multipliers in the form of a glass planar spiral tube with a rectangular section input cone 3.5 x 15.5 mm.
The X914AL has an open-ended output. To ensure efficient collection of electrons, a collector should be used, biased at 100 to 200 V positive with respect to the multiplier output.
The X914BL has a closed output.

QUICK REFERENCE DATA

Typical gain at 2.5 kV		2.0×10^8	
Typical resistance		6.0×10^8	Ω
Operating voltage	max.	4.0	kV

Unless otherwise stated, data is applicable to both types.
This data should be read in conjunction with GENERAL EXPLANATORY NOTES – SINGLE CHANNEL ELECTRON MULTIPLIERS

CHARACTERISTICS (measured at 2.5 kV and 10 000 pulse/s where applicable)

	Min.	Typ.	Max.	
Resistance	4.0	6.0	8.0	$\times 10^8$ Ω
Gain (note 1)	1.0	2.0	–	$\times 10^8$
Background above an equivalent threshold of 2.0×10^7 electrons	–	0.15	0.5	pulse/s
Starting voltage with an equivalent threshold of 2.0×10^7 electrons	1.4	1.6	1.8	kV
Resolution (F.W.H.M.) at a modal gain of 2.0×10^8	–	50	70	%
Effective input	3 x 14.5	3.5 x 15.5	5 x 17	mm

RATINGS

Limiting values in accordance with the Absolute Maximum System (IEC 134)

Operating voltage	max.	4.0	kV
Temperature, operating and storage	max.	70	°C
Bake temperature in vacuo (note 2)	max.	400	°C
Ambient pressure with high voltage applied	max.	50	mN/m²
		3.7×10^{-4}	torr

MASS

	4.0	g

MOUNTING POSITION

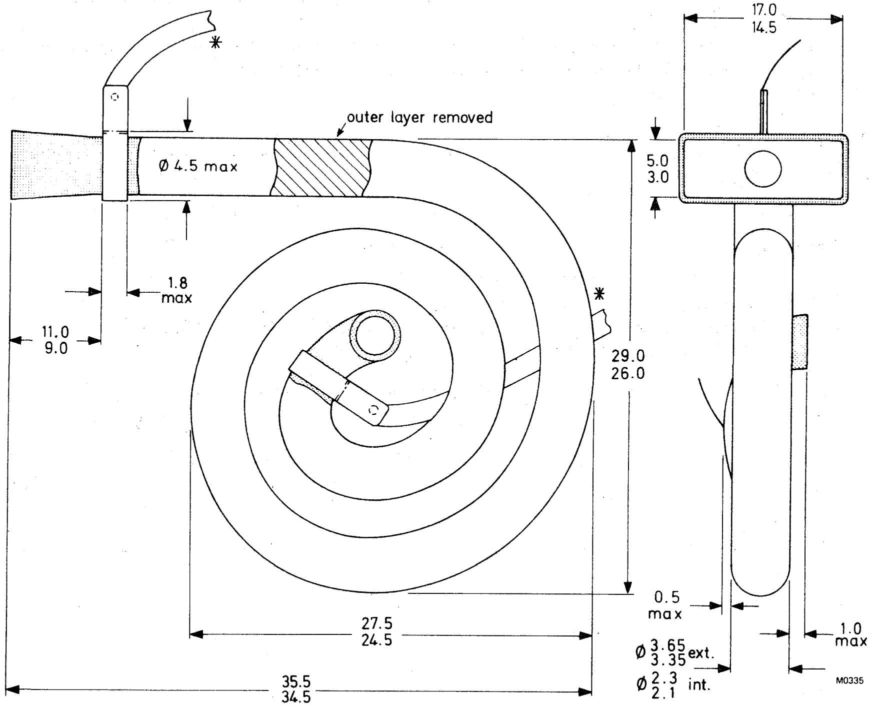
Any. In environments where vibration may be encountered, the device should not be supported by the leads alone.

NOTES

1. The gain of a typical multiplier will increase by a factor of approx. 2 for an increase of operating voltage of 500 V.
2. Baking will cause a permanent slight loss of gain and it is advisable to keep the baking time to a minimum, for example, baking for 16 hours at 400 °C could reduce the gain by approximately a factor of 2.

MECHANICAL DATA X914AL

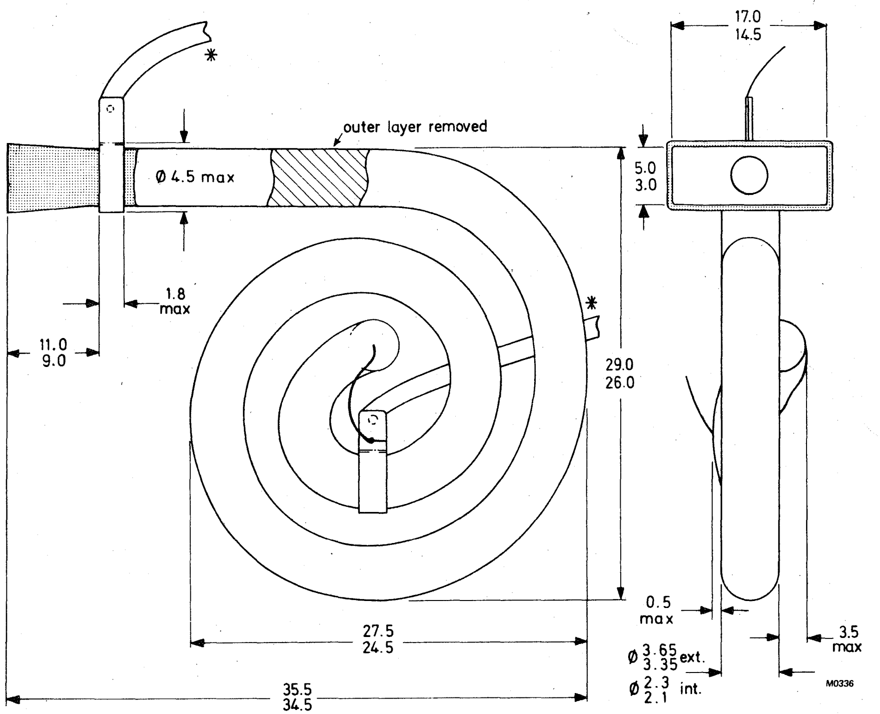
Dimensions in mm



* 1.0 x 0.1 Inconel strip (length 50).

MECHANICAL DATA X914BL

Dimensions in mm



* 1.0 x 0.1 Inconel strip (length 50).

SINGLE CHANNEL ELECTRON MULTIPLIERS

Channel electron multipliers in the form of a glass planar spiral tube with a 10 mm diameter input cone. The X919AL has an open-ended output. To ensure efficient collection of electrons, a collector should be used, biased at 100 to 200 V positive with respect to the multiplier output.
The X919BL has a closed output.

QUICK REFERENCE DATA

Typical gain at 2.5 kV		2.0×10^8	
Typical resistance		6.0×10^8	Ω
Operating voltage	max.	4.0	kV

Unless otherwise stated, data is applicable to both types.
This data should be read in conjunction with GENERAL EXPLANATORY NOTES – CHANNEL ELECTRON MULTIPLIERS.

CHARACTERISTICS (measured at 2.5 kV and 10 000 pulse/s where applicable)

	Min.	Typ.	Max.	
Resistance	4.0	6.0	8.0	$\times 10^8$ Ω
Gain (note 1)	1.0	2.0	–	$\times 10^8$
Background above an equivalent threshold of 2.0×10^7 electrons	–	0.15	0.5	pulse/s
Starting voltage with an equivalent threshold of 2.0×10^7 electrons	1.4	1.6	1.8	kV
Resolution (F.W.H.M.) at a modal gain of 2.0×10^8	–	50	70	%
Effective input diameter	9.0	10	–	mm

RATINGS

Limiting values in accordance with the Absolute Maximum System (IEC 134)

Operating voltage	max.	4.0	kV
Temperature, operating and storage	max.	70	°C
Bake temperature in vacuo (note 2)	max.	400	°C
Ambient pressure with high voltage applied	max.	50	mN/m^2
		3.7×10^{-4}	torr

MASS 4.0 g

MOUNTING POSITION

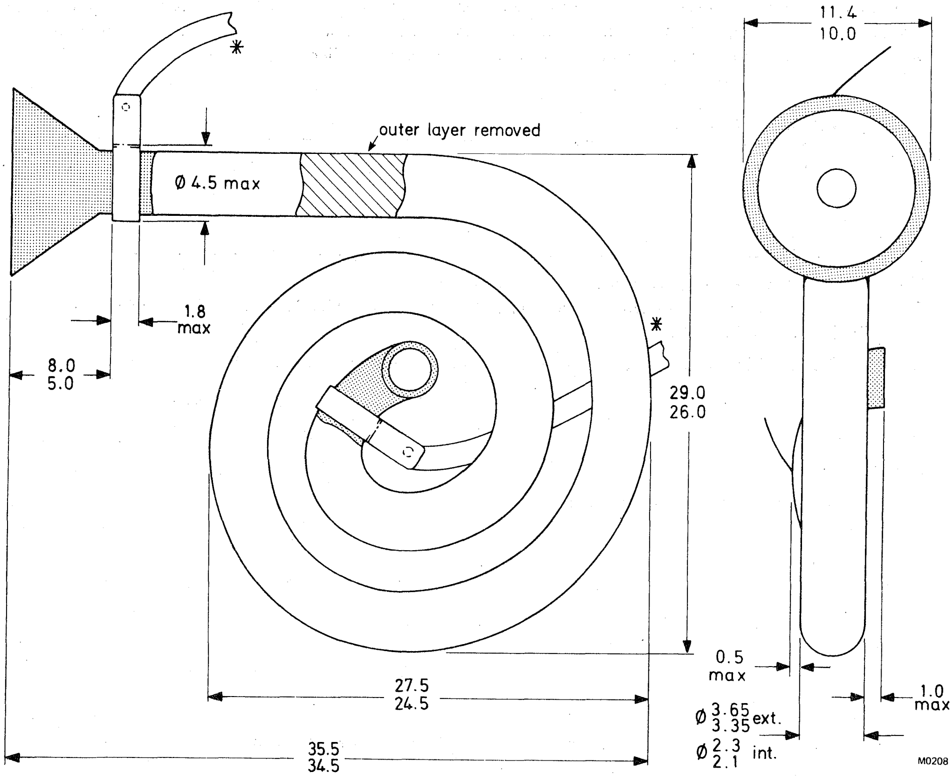
Any. In environments where vibration may be encountered, the device should not be supported by the leads alone.

NOTES

1. The gain of a typical multiplier will increase by a factor of approx. 2 for an increase of operating voltage of 500 V.
2. Baking will cause a permanent slight loss of gain and it is advisable to keep the baking time to a minimum, for example, baking for 16 hours at 400 °C could reduce the gain by approximately a factor of 2.

MECHANICAL DATA X919AL

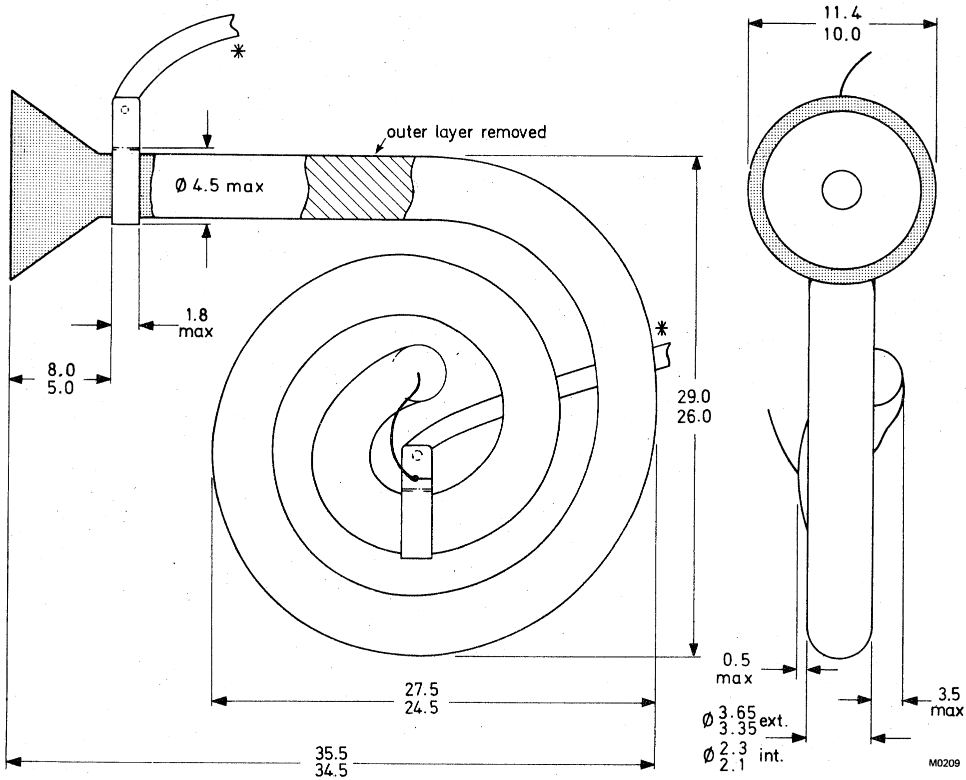
Dimensions in mm



* 1.0 x 0.1 Inconel strip (length 50).

MECHANICAL DATA X919BL

Dimensions in mm



* 1.0 x 0.1 Inconel strip (length 50).

SINGLE CHANNEL ELECTRON MULTIPLIERS

Channel electron multipliers in the form of a glass planar spiral tube with a 15 mm diameter input cone. The X959AL has an open-ended output. To ensure efficient collection of electrons, a collector should be used, biased at 100 to 200 V positive with respect to the multiplier output.
The X959BL has a closed output.

QUICK REFERENCE DATA

Typical gain at 2.5 kV		2.0×10^8	
Typical resistance		6.0×10^8	Ω
Operating voltage	max.	4.0	kV

Unless otherwise stated, data is applicable to both types.
This data should be read in conjunction with GENERAL EXPLANATORY NOTES – SINGLE CHANNEL ELECTRON MULTIPLIERS

CHARACTERISTICS (measured at 2.5 kV and 10 000 pulse/s where applicable)

	Min.	Typ.	Max.	
Resistance	4.0	6.0	8.0	$\times 10^8$ Ω
Gain (note 1)	1.0	2.0	–	$\times 10^8$
Background above an equivalent threshold of 2.0×10^7 electrons	–	0.15	0.5	pulse/s
Starting voltage with an equivalent threshold of 2.0×10^7 electrons	1.4	1.6	1.8	kV
Resolution (F.W.H.M.) at a modal gain of 2.0×10^8	–	50	70	%
Effective input diameter	14	15	–	mm

RATINGS

Limiting values in accordance with the Absolute Maximum System (IEC 134)

Operating voltage	max.	4.0	kV
Temperature, operating and storage	max.	70	°C
Bake temperature in vacuo (note 2)	max.	400	°C
Ambient pressure with high voltage applied	max.	50	mN/m^2
		3.7×10^{-4}	torr

MASS

MASS	4.0	g

MOUNTING POSITION

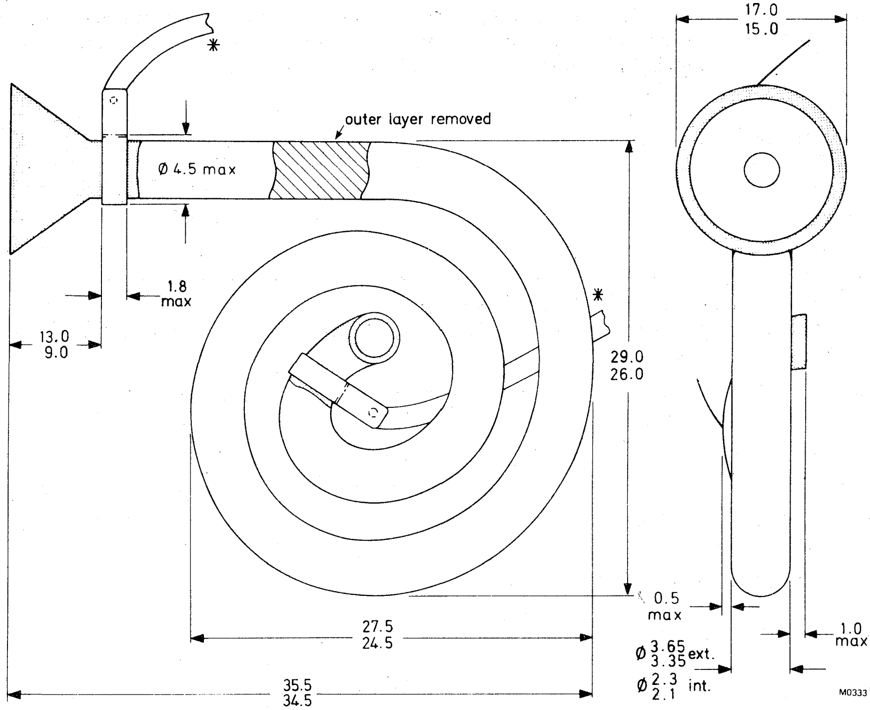
Any. In environments where vibration may be encountered, the device should not be supported by the leads alone.

NOTES

1. The gain of a typical multiplier will increase by a factor of approx. 2 for an increase of operating voltage of 500 V.
2. Baking will cause a permanent slight loss of gain and it is advisable to keep the baking time to a minimum, for example, baking for 16 hours at 400 °C could reduce the gain by approximately a factor of 2.

MECHANICAL DATA X959AL

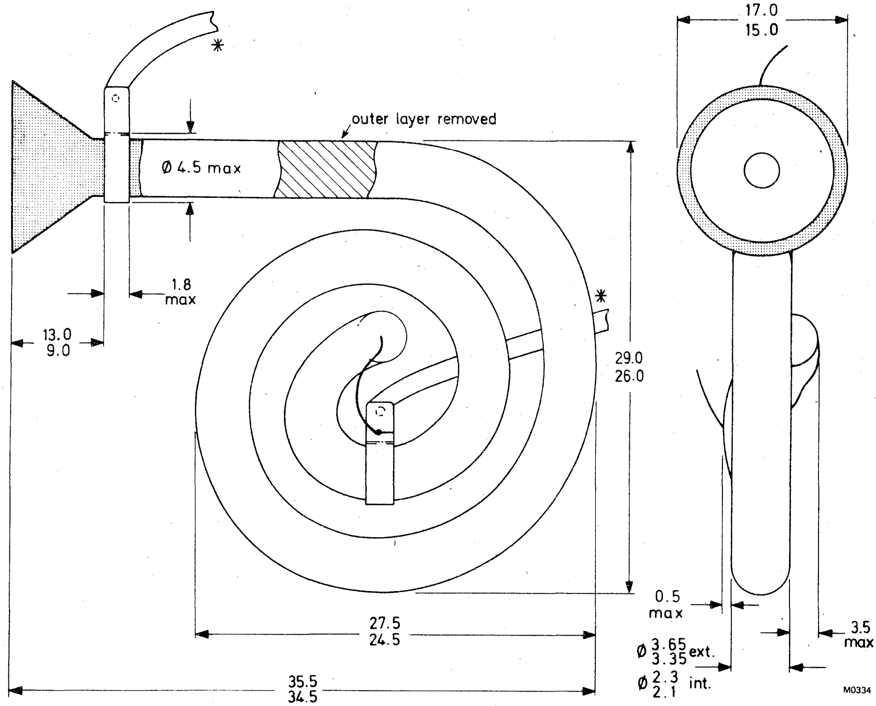
Dimensions in mm



* 1.0 x 0.1 Inconel strip (length 50).

MECHANICAL DATA X959BL

Dimensions in mm



* 1.0 x 0.1 Inconel strip (length 50).

CHANNEL ELECTRON MULTIPLIER PLATES

SURVEY OF TYPES

type*	status	plate dimensions mm	channel diameter μm	channel angle degree
G12-25SE	N	φ 25	12,5	13
G12-25SE/A	N	φ 25	12,5	13
G12-36	N	φ 36	12,5	13
G12-36/A	N	φ 36	12,5	13
G12-36DT/0	N	φ 36	12,5	0
G12-36DT/13	N	φ 36	12,5	13
G12-46	N	φ 46	12,5	13
G12-46/A	N	φ 46	12,5	13
G12-46DT/0	N	φ 46	12,5	0
G12-46DT/13	N	φ 46	12,5	13
G25-20x50	N	20 x 50	25	13
G25-25x90	N	25 x 90	25	13
G25-25	D	φ 25	25	13
G25-25/A	D	φ 25	25	13
G25-50	M	φ 50	25	13
G25-50/A	M	φ 50	25	13
G25-70	M	φ 70	25	13
G25-70/A	M	φ 70	25	13

* SE = solid edge, DT = double thickness, A = matched pair of plates.

Status code

N = **New design type.** Recommended for new equipment design; production quantities available *after date of publication.*

D = **Design type.** Recommended for equipment design; production quantities available *at date of publication.*

M = **Maintenance type.** No longer recommended for equipment production; available for maintenance of existing equipment.

EXPLANATORY NOTES

PRINCIPLES OF OPERATION

Multi-channel plates depend on the same physical phenomenon as single channel electron multipliers. They comprise a plate of special glass through which pass a large number of channels. The walls of the holes are specially processed to coat them with a high resistance material which also has a coefficient of secondary emission greater than 1. If a potential is applied between opposite faces of the plate each channel becomes a continuous dynode analogous to the separate dynodes of a photomultiplier together with its resistive chain.

As with single channel multipliers, the channel plate operates in a vacuum. It is important that the vacuum should be better than 13,3 mPa (1 x 10^{-4} torr). An electron entering the low voltage end of one of the channels will generate secondary electrons on striking the wall. These in turn will be accelerated by the axial field and will again strike the wall, producing a further increase in the number of secondaries and so on. The avalanching process produces a large burst of electrons at the output end of the channel, corresponding to each input electron. As illustrated in Fig. 1 there is a statistical variation in pulse size depending on several factors. The channels are set an angle to the face of the plate to ensure that electrons approaching the plate normally will not fail to strike the wall. The output contains about 10^3 electrons for each input electron. The gain is a steep function of applied voltage and the supply should be well regulated for stability of operation.

The multiplier is usually used to amplify the electrons emitted from a photocathode placed close to the input face, and excites a phosphor screen placed close to the output, preserving the spatial resolution and making an amplified image of the information on the photocathode. The input of the channel is also sensitive to ions, beta particles, X-rays, or any radiation of a suitable energy and this extends its use to many other applications. Since the resistive path is continuous, many electron paths are possible and the number of stages of amplification is indeterminate. The electron trajectories are scaled in proportion to the dimensions of the channel for a given applied voltage. Thus if the length to diameter ratio is kept constant the gain per channel remains constant, irrespective of the absolute length of the channel. For most applications the spatial resolution is important and in order to achieve the highest resolutions the channel diameters and the walls between channels are kept as small as possible.

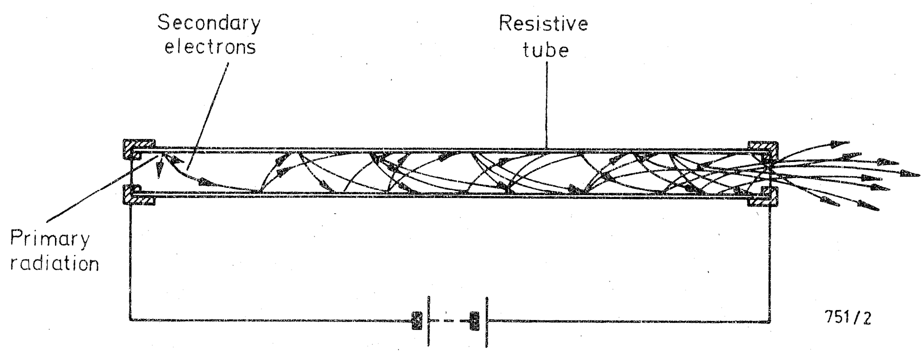


Fig. 1.

IONIC FEEDBACK

The electron cloud at the output of the plate is sufficiently intense to generate an appreciable number of ions and these drift towards the input of the channel and on striking the wall can produce a further burst of secondary electrons. This pulse, starting near the output, will be smaller than the first pulse, but may also generate ions which will drift backwards, so that a train of pulses is generated. This train of pulses alters the charge on the wall, which reduces the gain. This effect limits the voltage that can be applied to the plate and thus the gain that can be achieved. By placing two plates in cascade with the channels angled in opposite directions, ions fed back from the output plate cannot enter the input plate and high gain can be achieved without excessive ion feedback and consequent loss of linearity.

SATURATION DUE TO SPACE CHARGE

If the charge in the output pulse reaches about 10^8 electrons the gain cannot increase further. The space charge in the output end of the channel repels secondary electrons, causing them to return to the wall without generating further electrons. When this occurs with an imaging application it will cause poor highlights and loss of detail. Imaging plates usually operate at gains of around 10^3.

SATURATION DUE TO FIELD DISTORTION

When the current in the output averages more than 10% of the total current, the voltage gradient in the wall is no longer linear and the gain falls so that there is a loss of linearity between input and output currents and a loss of highlights in the image.

SATURATION DUE TO FIELD EMISSION

It is important to keep channel plates scrupulously clean. Particles lodging in a channel can give rise to field emission which is multiplied in the channel and produces a permanently saturated condition. This is known as a switched on channel and is a condition extremely difficult to correct.

RESISTANCE

The resistance of a channel plate is the value measured in vacuum between electrodes applied to the input and output faces.

DARK CURRENT

Dark current is generally very low, much less than 1 count/s/cm^2 of plate area.

OPEN AREA

Open area is the total cross-section of all the channels in the plate expressed as a percentage of the total area of the plate.

GAIN

Gain in the linear region of operation is defined as the output current divided by the input current. This is always better than 1000 for 1000 volt applied to the plate and increases one order for each 200 V increase in applied voltage. The recommended operating voltage is 800 to 1200 V. Outside these limits spatial non-uniformity can become a problem.

MOUNTING

The opposite faces of channel plates are ground flat and parallel during manufacture. As the devices are fragile, care must be taken to ensure that they are not stressed unduly when mounting them in systems. It is recommended that they are placed between perfectly flat polished stainless steel rings spring loaded only sufficiently to ensure reliable connections to the metallized faces of the plate. A loading of 3 N per cm of periphery has been found adequate. Care must be taken to minimize the possibility of leakage or other currents between the contact rings when the working voltage is applied.

OPERATING TEMPERATURE AND OUTGASSING

The devices can be operated up to a maximum of 70 ^{o}C and degassed up to a maximum of 300 ^{o}C. Further evolution of gas may take place during operation. The pressure should never be allowed to rise above 13,3 mPa (1 x 10^{-4} torr) whilst the operating voltage is applied, but exposure to atmosphere for a few hours at a time does not cause any loss of performance. It is prudent to store devices in a well desiccated container if they have to be removed from the vacuum environment for longer periods. The devices may be damaged permanently if exposed to gross contamination by hydrocarbon vapours.

If the output is to be detected by means of a phosphor screen it is desirable to place it as close to the channel plate as can be arranged, commensurate with voltage and mechanical considerations. The electrons leave the outputs over a very wide angle, and detail can be lost if the spacing is excessive. For similar reasons a photocathode input source should be placed close to the input face.

A suitable distance for the channel plate/screen gap is 1 mm, with a potential between screen and channel plate output of about 5 kV. Either the screen distance or the screen potential may be adjusted in order to optimize the resolution of the system.

SOLID EDGE CHANNEL ELECTRON MULTIPLIER PLATES

Each plate consists of an array of channel electron multipliers fused into the shape of a disc with a solid edge. The multipliers are electrically connected in parallel by means of nickel-chromium electrodes evaporated on to the faces of the disc.

SPECIFICATION

Disc diameter		$25^{+0}_{-0.1}$	mm
Useful diameter	min.	19	mm
Disc thickness		0.5 ± 0.02	mm
Channel diameter	nom.	12.5	μm
Channel pitch	nom.	15.0	μm
Open area	approx.	60	%
Electrode material		nickel-chromium	
Electrical resistance between electrodes	approx.	250 to 750	MΩ
Current gain at 1.0 kV (see fig.1)	>	1000	

For a linear relationship between input and output, the output current must not exceed 0.1 of the standing current.
The plates are cut such that the channel electron multipliers form an angle of 13° to the perpendicular axis of the plate.

APPLICATIONS

These devices must operate in a vacuum and may be used to detect electrons, ions, soft X-rays and ultra-violet photons falling on the input face of the disc by producing electron pulses from the output face of the corresponding channel.
Such applications are fully discussed by P. Lecomte and V. Perez-Mendez in I.E.E.E. Transactions on Nuclear Science, Vol. NS-25, No. 2 April 1978 – 'Channel Electron Multipliers: Properties, Development and Applications'.
For space experiments, the environmental vacuum is adequate for their operation and they have considerable potential in the field of X-ray and ultra-violet astronomy from rockets and satellites. In laboratory use they must be incorporated in a vacuum chamber, where they will have important applications in field ion microscopy, electron microscopy and allied areas of research.

RATINGS

Limiting values in accordance with the Absolute Maximum System (IEC134)

Operating voltage	max.	2.0	kV
Temperature** (operating and storage)	max.	70	°C
Bake temperature	max.	300	°C
Ambient pressure with high voltage applied	max.	13.3 (1.0 x 10^{-4} torr)	mN/m^2

* The suffix /A denotes a matched pair of G12–25SE plates which are resistance matched for applications requiring two plates in cascade, (see fig.2).
** The plate should be stored in a dry or vacuum environment.

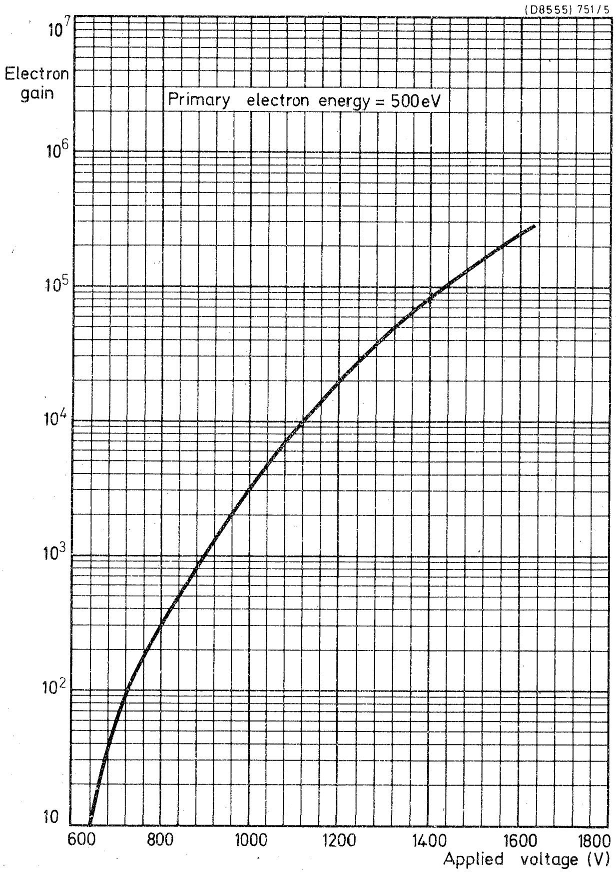


Fig.1 Typical current gain as a function of applied voltage.

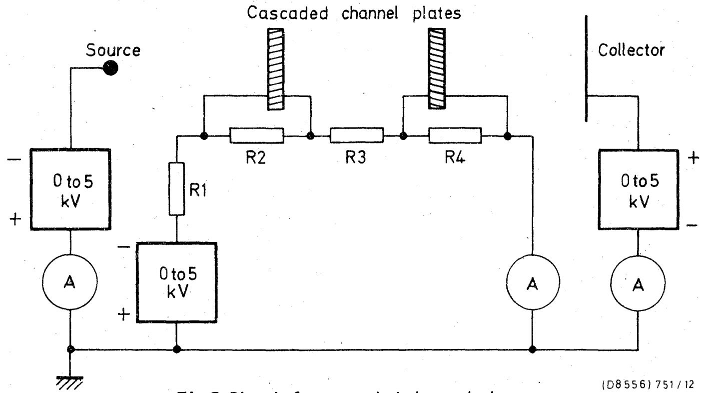


Fig.2 Circuit for cascaded channel plates

MOUNTING

Channel plates are fragile and great care must be taken to ensure that they are not unduly stressed when mounted in the vacuum system. It is recommended that the plates are mounted between clean polished brass or stainless steel rings, giving noise-free electrical contacts. The device will withstand a contact pressure of at least 10^4 N/m^2 (corresponding to a load of ~1g per mm^2) applied via screws pushing against small helical springs. Polished brass annular shims, about 1.5 mm wide and 50 μm thick, are recommended for insertion between plates operating in cascade.

DEVELOPMENT SAMPLE DATA

CHANNEL ELECTRON MULTIPLIER PLATES

Each plate consists of an array of channel electron multipliers fused into the shape of a disc. The multipliers are electrically connected in parallel by means of nickel-chromium electrodes evaporated on to the faces of the disc.

SPECIFICATION

Disc diameter		$36^{+0}_{-0.1}$	mm
Useful diameter	min.	32.5	mm
Disc thickness		0.5 ± 0.02	mm
Channel diameter	nom.	12.5	µm
Channel pitch	nom.	15	µm
Open area	approx.	60	%
Electrode material		nickel-chromium	
Electrical resistance between electrodes	approx.	65	MΩ
Current gain at 1.0 kV (see fig.1)	>	1000	

For a linear relationship between input and output, the output current must not exceed 0.1 of the standing current.
The plates are cut such that the channel electron multipliers form an angle of 13° to the perpendicular axis of the plate.

APPLICATIONS

These devices must operate in a vacuum and may be used to detect electrons, ions, soft X-rays and ultra-violet photons falling on the input face of the plate, by producing electron pulses from the output face of the corresponding channel.
Such applications are fully discussed by P. Lecomte and V. Perez-Mendez in I.E.E.E. Transactions on Nuclear Science, Vol. NS–25, No.2 April 1978 – 'Channel Electron Multipliers: Properties, Development and Applications'.
For space experiments, the environmental vacuum is adequate for their operation and they have considerable potential in the field of X-ray and ultra-violet astronomy from rockets and satellites. In laboratory use they must be incorporated in a vacuum chamber, where they will have important applications in field ion microscopy, electron microscopy and allied areas of research.

RATINGS

Limiting values in accordance with the Absolute Maximum System (IEC134)

Operating voltage	max.	2.0	kV
Temperature** (operating and storage)	max.	70	°C
Bake temperature	max.	300	°C
Ambient pressure with high voltage applied	max.	13.3 (1.0×10^{-4} torr)	mN/m^2
Plate clamping rings internal diameter	max.	33	mm

* The suffix /A denotes a matched pair of G12–36 plates which are resistance matched for applications requiring two plates in cascade, (see fig.2).
** The plate should be stored in a dry or vacuum environment.

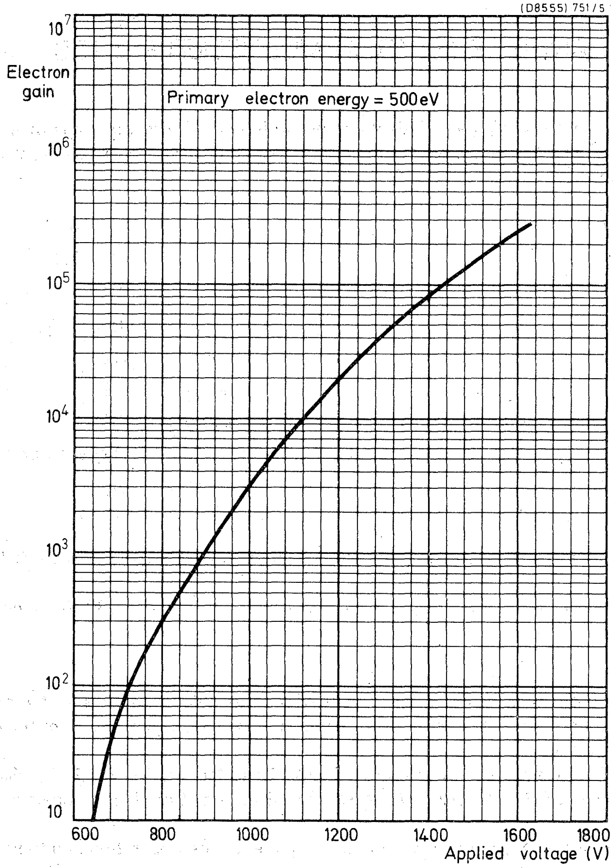


Fig. 1 Typical current gain as a function of applied voltage.

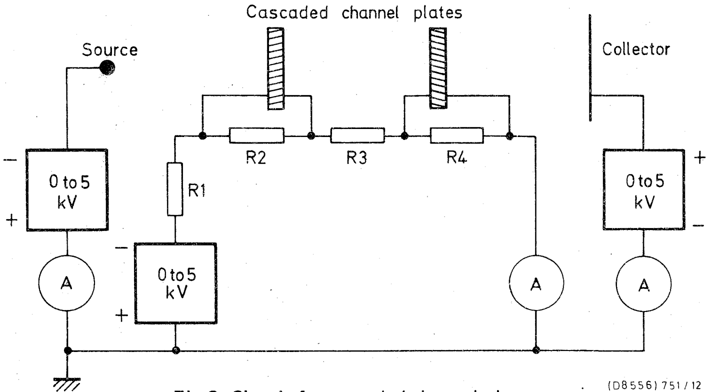


Fig.2 Circuit for cascaded channel plates

MOUNTING

Channel plates are fragile and great care must be taken to ensure that they are not unduly stressed when mounted in the vacuum system. It is recommended that the plates are mounted between clean polished brass or stainless steel rings, giving noise-free electrical contacts. The devices will withstand a contact pressure of at least 10^4 N/m^2 (corresponding to a load of ~1g per mm^2) applied via screws pushing against small helical springs. Polished brass annular shims, about 1.5 mm wide and 50 μm thick, are recommended for insertion between plates operating in cascade.

DEVELOPMENT SAMPLE DATA

CHANNEL ELECTRON MULTIPLIER PLATES

Each plate consists of an array of channel electron multipliers fused into the shape of a disc. The multipliers are electrically connected in parallel by means of nickel-chromium electrodes evaporated on to the faces of the disc. These plates have been specially developed for use in pairs in the pulse detection mode for X-rays and other types of radiation. The suffix DT indicates double thickness. The G12-36DT/0 is cut so that the channels form an angle of 0 degrees to the perpendicular axis; in the G12-36DT/13 the channels form an angle of 13° to the perpendicular axis.

SPECIFICATION

Disc diameter		$36^{+0}_{-0.1}$	mm
Useful diameter	min.	32.5	mm
Disc thickness		1.0 ± 0.02	mm
Channel diameter	nom.	12.5	μm
Channel pitch	nom.	15.0	μm
Open area	approx.	60	%
Electrode material		nickel-chromium	
Electrical resistance between electrodes	approx.	125	MΩ
Length to diameter ratio		80:1	
Gain (pair of plates at 1.2 kV/plate)	nom.	$>10^6$	

APPLICATIONS

These devices must operate in a vacuum and may be used to detect electrons, ions, soft X-rays and ultra-violet photons falling on the input face of the disc, by producing electron pulses from the output face of the corresponding channel.
Such applications are fully discussed by P. Lecomte and V. Perez-Mendez in I.E.E.E. Transactions on Nuclear Science, Vol. NS–25, No. 2 April 1978 – 'Channel Electron Multipliers: Properties, Development and Applications'.
For space experiments, the environmental vacuum is adequate for their operation and they have considerable potential in the field of X-ray and ultra-violet astronomy from rockets and satellites. In laboratory use they must be incorporated in a vacuum chamber, where they will have important applications in field ion microscopy, electron microscopy and allied areas of research.

RATINGS

Limiting values in accordance with the Absolute Maximum System (IEC134)

Operating voltage (pair of plates)	max.	6.0	kV
Operating voltage (single plate)	max.	3.0	kV
Temperature* (operating and storage)	max.	70	°C
Bake temperature	max.	300	°C
Ambient pressure with high voltage applied	max.	13.3 (1.0 x 10^{-4} torr)	mN/m²
Plate clamping rings internal diameter	max.	33	mm

* The plate should be stored in a dry or vacuum environment.

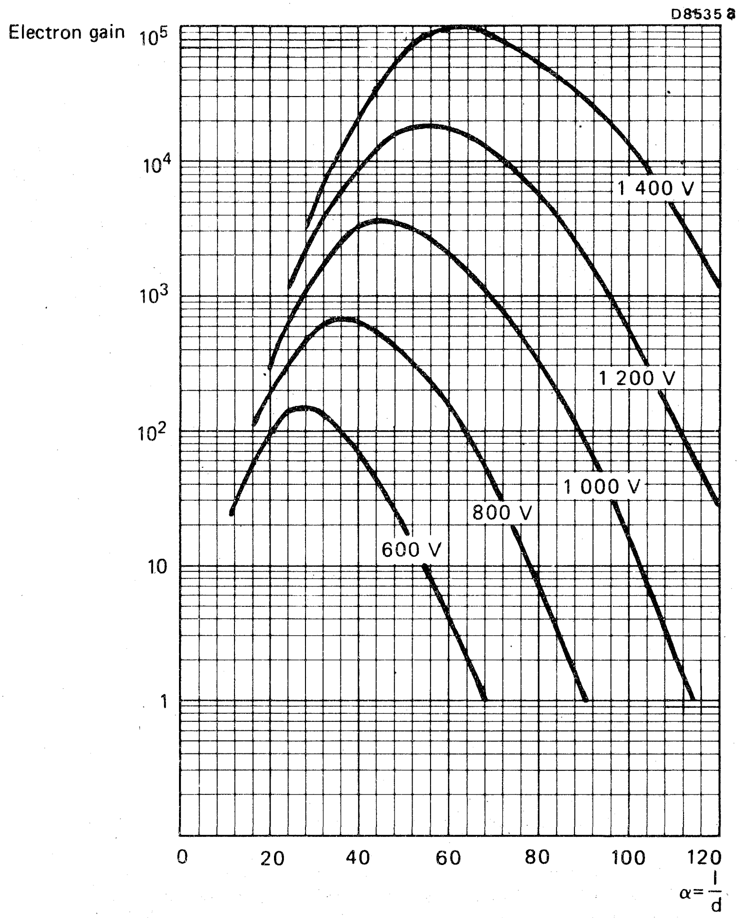


Fig. 1 Typical universal gain curves

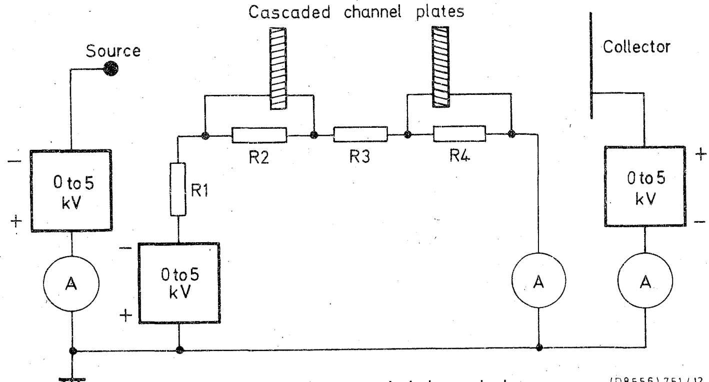


Fig.2 Circuit for cascaded channel plates

MOUNTING

Channel plates are fragile and great care must be taken to ensure that they are not unduly stressed when mounted in the vacuum system. It is recommended that the plates are mounted between clean polished brass or stainless steel rings, giving noise-free electrical contacts. The devices will withstand a contact pressure of at least 10^4 N/m^2 (corresponding to a load of ~1g per mm^2) applied via screws pushing against small helical springs. Polished brass annular shims, about 1.5 mm wide and 50 μm thick, are recommended for insertion between plates operating in cascade.

DEVELOPMENT SAMPLE DATA

CHANNEL ELECTRON MULTIPLIER PLATES

Each plate consists of an array of channel electron multipliers fused into the shape of a disc .
The multipliers are electrically connected in parallel by means of nickel-chromium electrodes evaporated on to the faces of the disc.

SPECIFICATION

Disc diameter		$46^{+0}_{-0.1}$	mm
Useful diameter	min.	42	mm
Disc thickness		0.5 ± 0.02	mm
Channel diameter	nom.	12.5	μm
Channel pitch	nom.	15.0	μm
Open area	approx.	60	%
Electrode material		nickel-chromium	
Electrical resistance between electrodes	approx.	45	MΩ
Current gain at 1.0 kV (see fig.1)	>	1000	

For a linear relationship between input and output, the output current must not exceed 0.1 of the standing current.
The plates are cut such that the channel electron multipliers form an angle of 13^{o} to the perpendicular axis of the plate.

APPLICATIONS

These devices must operate in a vacuum and may be used to detect electrons, ions, soft X-rays and ultra-violet photons falling on the input face of the disc, by producing electron pulses from the output face of the corresponding channel.
Such applications are fully discussed by P. Lecomte and V. Perez-Mendez in I.E.E.E. Transactions on Nuclear Science, Vol. NS-25, No.2 April 1978 – 'Channel Electron Multipliers: Properties, Development and Applications'.
For space experiments, the environmental vacuum is adequate for their operation and they have considerable potential in the field of X-ray and ultra-violet astronomy from rockets and satellites. In laboratory use they must be incorporated in a vacuum chamber, where they will have important applications in field ion microscopy, electron microscopy and allied areas of research.

RATINGS

Limiting values in accordance with the Absolute Maximum System (IEC134)

Operating voltage	max.	1.5	kV
Temperature** (operating and storage)	max.	70	^{o}C
Bake temperature	max.	300	^{o}C
Ambient pressure with high voltage applied		13.3 (1.0×10^{-4}) torr	mN/m^2
Plate clamping rings internal diameter	max.	42.5	mm

* The suffix/A denotes a matched pair of G12–46 plates which are resistance matched for applications requiring two plates in cascade, (see fig.2)
** The plate should be stored in a dry vacuum environment.

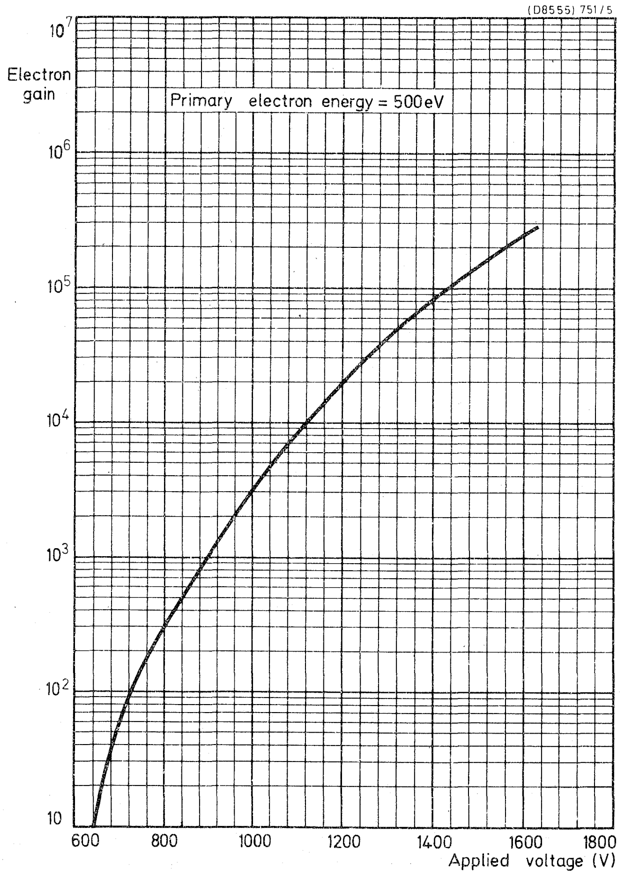


Fig. 1 Typical current gain as a function of applied voltage

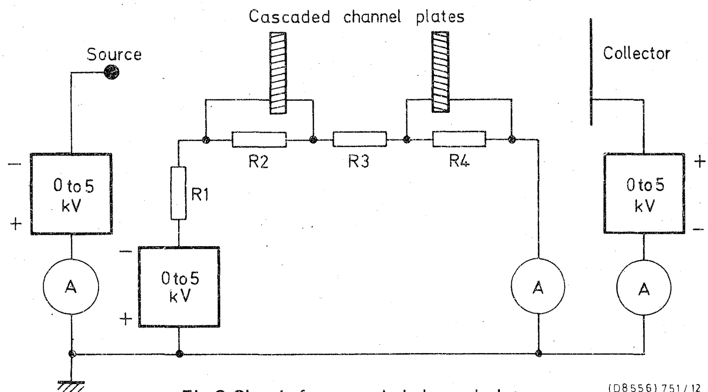


Fig.2 Circuit for cascaded channel plates

MOUNTING

Channel plates are fragile and great care must be taken to ensure that they are not unduly stressed when mounted in the vacuum system. It is recommended that the plates are mounted between clean polished brass or stainless steel rings, giving noise-free electrical contacts. The devices will withstand a contact pressure of at least 10^4 N/m^2 (corresponding to a load of ~1g per mm^2) applied via screws pushing against small helical springs. Polished brass annular shims, about 1.5 mm wide and 50 μm thick, are recommended for insertion between plates operating in cascade.

CHANNEL ELECTRON MULTIPLIER PLATES

Each plate consists of an array of channel electron multipliers fused into the shape of a disc. The multipliers are electrically connected in parallel by means of nickel-chromium electrodes evaporated on to the faces of the disc. These plates have been specially developed for use in pairs in the pulse detection mode for X-rays and other types of radiation. The suffix DT indicates double thickness. The G12-46DT/0 is cut so that the channels form an angle of 0 degrees to the perpendicular axis; in the G12-46DT/13 the channels form an angle of 13° to the perpendicular axis.

SPECIFICATION

Disc diameter		$46^{+0}_{-0.1}$	mm
Useful diameter	min.	42	mm
Disc thickness		1.0 ± 0.02	mm
Channel diameter	nom.	12.5	μm
Channel pitch	nom.	15.0	μm
Open area	approx.	60	%
Electrode material		nickel-chromium	
Electrical resistance between electrodes	approx.	75	MΩ
Length to diameter ratio		80:1	
Gain (pair of plates at 1.2 kV/plate)	nom.	$>10^6$	

APPLICATIONS

These devices must operate in a vacuum and may be used to detect electrons, ions, soft X-rays and ultra-violet photons falling on the input face of the disc, by producing electron pulses from the output face of the corresponding channel.
Such applications are fully discussed by P. Lecomte and V. Perez-Mendez in I.E.E.E. Transactions on Nuclear Science, Vol. NS—25, No.2 April 1978 — 'Channel Electron Multipliers: Properties, Development and Applications'.
For space experiments, the environmental vacuum is adequate for their operation and they have considerable potential in the field of X-ray and ultra-violet astronomy from rockets and satellites. In laboratory use they must be incorporated in a vacuum chamber, where they will have important applications in field ion microscopy, electron microscopy and allied areas of research.

RATINGS

Limiting values in accordance with the Absolute Maximum System (IEC134)

Operating voltage (pair of plates)	max.	6.0	kV
Operating voltage (single plate)	max.	3.0	kV
Temperature* (operating and storage)	max.	70	°C
Bake temperature	max.	300	°C
Ambient pressure with high voltage applied	max.	13.3 (1.0×10^{-4} torr)	mN/m^2
Plate clamping rings internal diameter	max.	42.5	mm

* The plate should be stored in a dry or vacuum environment.

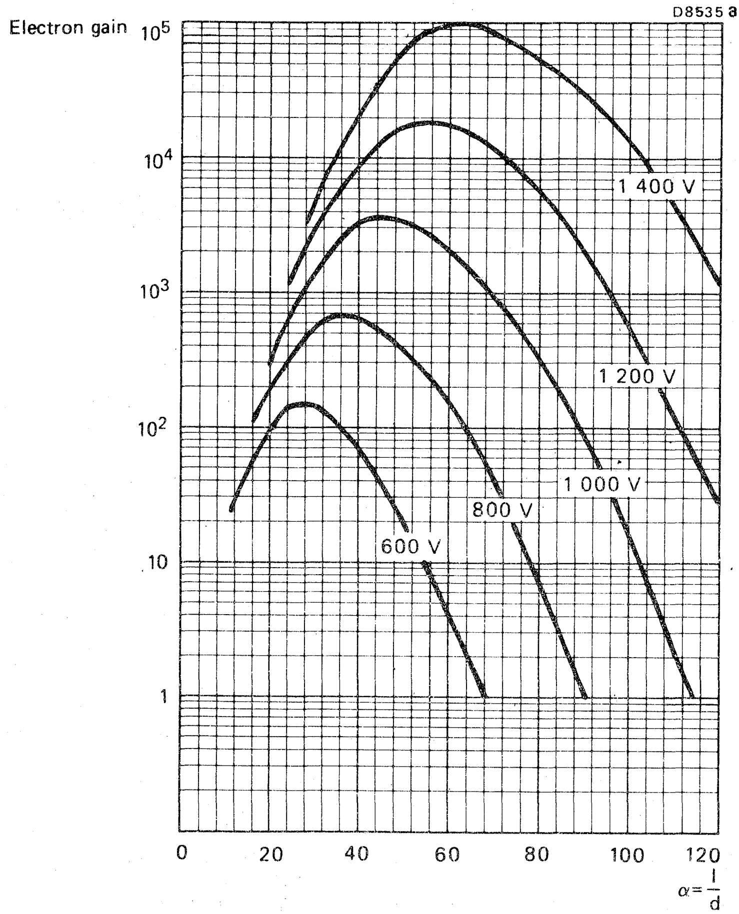


Fig. 1 Typical universal gain curves

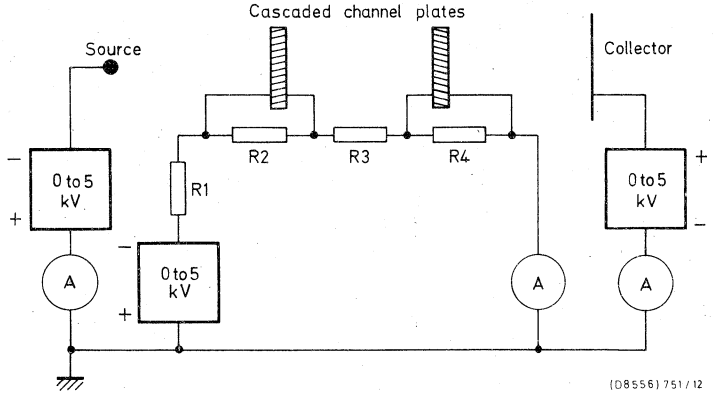


Fig.2 Circuit for cascaded channel plates

MOUNTING

Channel plates are fragile and great care must be taken to ensure that they are not unduly stressed when mounted in the vacuum system. It is recommended that the plates are mounted between clean polished brass or stainless steel rings, giving noise-free electrical contacts. The devices will withstand a contact pressure of at least 10^4 N/m^2 (corresponding to a load of ~1g per mm^2) applied via screws pushing against small helical springs. Polished brass annular shims, about 1.5 mm wide and 50 μm thick, are recommended for insertion between plates operating in cascade.

DEVELOPMENT SAMPLE DATA

CHANNEL ELECTRON MULTIPLIER PLATE

An array of channel electron multipliers fused into the shape of a rectangular plate. The multipliers are electrically connected in parallel by means of nickel-chromium electrodes evaporated on to the faces of the plate.

SPECIFICATION

Area of plate		$20^{+0}_{-0,2} \times 50^{+0}_{-0,2}$	mm^2
Useful area	min.	18,8 x 48,8	mm^2
Thickness of plate		1 ± 0,1	mm
Channel diameter		25	µm
Channel pitch		31	µm
Open area	approx.	60	%
Electrode material	nickel-chromium		
Electrical resistance between electrodes	approx.	35	MΩ
Current gain at 1,0 kV	min.	1000	
Maximum output current at 1,0 kV		0,2	µA
Angle of channel to perpendicular axis of plate		13°	

For linear relationship between input and output, the output current must not exceed 0,1 of the standing current.

APPLICATIONS

These devices must operate in a vacuum and may be used to detect electrons, ions, soft X-rays and ultraviolet photons falling on the input face of the plate, by producing electron pulses from the output face of the corresponding channel.

For space experiments the environmental vacuum is adequate for their operation.

In laboratory use they must be incorporated in a vacuum chamber, where they will have important applications in the field of ion microscopy, electron microscopy and allied areas of work.

LIMITING VALUES (Absolute maximum rating system)

Operating voltage	max.	2	kV
Operating temperature	max.	70	°C
Storage temperature*	max.	70	°C
Bake temperature	max.	300	°C
Ambient pressure with high voltage applied	max.	13,3 (1×10^{-4} torr)	mPa

* The plate should be stored in a dry or vacuum environment.

CHANNEL ELECTRON MULTIPLIER PLATE

An array of channel electron multipliers fused into the shape of a rectangle. The multipliers are electrically connected in paralled by means of nickel-chromium electrodes evaporated on to the faces of the plate.

SPECIFICATION

Area of plate		$25^{+0}_{-0.2} \times 90^{+0}_{-0.2}$	mm^2
Useful area	min.	23.8 x 88.8	mm^2
Plate thickness		1 ± 0.1	mm
Channel diameter		25	μm
Channel pitch		31	μm
Open area	approx.	60	%
Electrode material		nickel-chromium	
Electrical resistance between electrodes	nom.	10	MΩ
Current gain at 1.0 kV	min.	10^3	
Angle of channel to perpendicular axis of plate		13	degrees

APPLICATIONS

These devices must operate in a vacuum and may be used to detect electrons, ions, soft X-rays and ultra-violet photons falling on the input face of the plate, by producing electron pulses from the output face of the corresponding channel.
For space experiments, the environmental vacuum is adequate for their operation and they have considerable potential in the field of X-ray and ultra-violet astronomy from rockets and satellites. In laboratory use they must be incorporated in a vacuum chamber, where they will have important applications in field ion microscopy, electron microscopy and allied areas of research.

RATINGS

Limiting values in accordance with the Absolute Maximum System (IEC134)

Operating voltage	max.	2.0	kV
Temperature* (operating and storage)	max.	70	°C
Bake temperature (in vacuo)	max.	300	°C
Ambient pressure with high voltage applied	max.	13.3 1.0×10^{-4}	mPa torr

*The plate should be stored in a dry or vacuum environment.

CHANNEL ELECTRON MULTIPLIER PLATE

An array of channel electron multipliers fused into the shape of a disc. The multipliers are electrically connected in parallel by means of nickel-chromium electrodes evaporated on to the faces of the disc.

SPECIFICATION

Diameter of disc		27,1 ± 0,1	mm
Useful diameter	min.	26,5	mm
Thickness of disc		1,0 ± 0,1	mm
Channel diameter		25	µm
Channel pitch		31	µm
Open area	approx.	60	%
Electrode material		nickel-chromium	
Electrical resistance between electrodes	approx.	50	MΩ
Current gain at 1 kV	min.	1000	

For linear relationship between input and output the output current must not exceed 0,1 of the standing current.

The plates are cut such that the channel electron multipliers form an angle of 13° to the perpendicular axis of the plate.

APPLICATIONS

These devices must operate in a vacuum, and may be used to detect electrons, ions, soft X-rays and ultra-violet photons falling on the input face of the disc, by producing electron pulses from the output face of the corresponding channel.

For space experiments the environmental vacuum is adequate for their operation.

In laboratory use they must be incorporated in a vacuum chamber, where they will have important applications in field ion microscopy, electron microscopy and allied areas of work.

* The "/A" suffix denotes a matched pair of G25-25 plates which are resistance matched for applications requiring two plates in cascade.

LIMITING VALUES (Absolute max. rating system)

Operating voltage	max.	2	kV
Temperature, operating and storage [1])	max.	70	°C
Bake temperature	max.	300	°C
Ambient pressure with high voltage applied	max.	13,3	mPa
		(10^{-4}	torr)
Diameter of plate clamping rings	max.	26,6	mm

[1]) The plate should be stored in a dry or vacuum environment.

CHANNEL ELECTRON MULTIPLIER PLATE

An array of channel electron multipliers fused into the shape of a disc. The multipliers are electrically connected in parallel by means of nickel-chromium electrodes evaporated on to the faces of the disc.

SPECIFICATION

Diameter of disc		$53,0\,^{+0}_{-0,2}$	mm
Useful diameter	min.	51,8	mm
Thickness of disc		1,0 ± 0,1	mm
Channel diameter		25	µm
Channel pitch		31	µm
Open area	approx.	60	%
Electrode material		nickel-chromium	
Electrical resistance between electrodes	approx.	10	MΩ
Current gain at 1 kV	min.	1000	

For linear relationship between input and output the output current must not exceed 0,1 of the standing current.

The plates are cut such that the channel electron multipliers form an angle of 13° to the perpendicular axis of the plate.

APPLICATIONS

These devices must operate in a vacuum, and may be used to detect electrons, ions, soft X-rays and ultra-violet photons falling on the input face of the disc, by producing electron pulses from the output face of the corresponding channel.

For space experiments the environmental vacuum is adequate for their operation.

In laboratory use they must be incorporated in a vacuum chamber, where they will have important applications in field ion microscopy, electron microscopy and allied areas of work.

* The "/A" suffix denotes a matched pair of G25-50 plates which are resistance matched for applications requiring two plates in cascade.

LIMITING VALUES (Absolute max. rating system)

Operating voltage	max.	2	kV
Temperature, operating and storage [1])	max.	70	^oC
Bake temperature	max.	300	^oC
Ambient pressure with high voltage applied	max.	13,3	mPa
		(10^{-4} torr)	
Diameter of plate clamping rings	max.	52,4	mm

[1]) The plate should be stored in a dry or vacuum enviroment.

CHANNEL ELECTRON MULTIPLIER PLATE

An array of channel electron multipliers fused into the shape of a disc. The multipliers are electrically connected in parallel by means of nickel-chromium electrodes evaporated on to the faces of the disc.

SPECIFICATION

Diameter of disc		$70,0\ ^{+0}_{-0,2}$	mm
Useful diameter	min.	68	mm
Thickness of disc		1,0 ± 0,1	mm
Channel diameter		25	µm
Channel pitch		31	µm
Open area	approx.	60	%
Electrode material		nickel-chromium	
Electrical resistance between electrodes	approx.	5	MΩ
Current gain at 1 kV	min.	1000	

For linear relationship between input and output the output current must not exceed 0,1 of the standing current.

The plates are cut such that the channel electron multipliers form an angle of 13° to the perpendicular axis of the plate.

APPLICATIONS

These devices must operate in a vacuum, and may be used to detect electrons, ions, soft X-rays and ultra-violet photons falling on the input face of the disc, by producing electron pulses from the output face of the corresponding channel.

For space experiments the environmental vacuum is adequate for their operation.

In laboratory use they must be incorporated in a vacuum chamber, where they will have important applications in field ion microscopy, electron microscopy and allied areas of work.

* The "/A" suffix denotes a matched pair of G25-70 plates which are resistance matched for applications requiring two plates in cascade.

LIMITING VALUES (Absolute max. rating system)

Operating voltage	max.	2	kV
Temperature, operating and storage [1])	max.	70	°C
Bake temperature	max.	300	°C
Ambient pressure with high voltage applied	max.	13,3	mPa
		(10^{-4} torr)	
Diameter of plate clamping rings	max.	68,5	mm

[1]) The plate should be stored in a dry or vacuum environment.

ASSOCIATED ACCESSORIES

SOCKET

DESCRIPTION

This socket consists of a plastic moulding with 12 gold-plated contacts. The connections to the socket can be made by means of wire soldering. Mounting is done with two M3 screws.

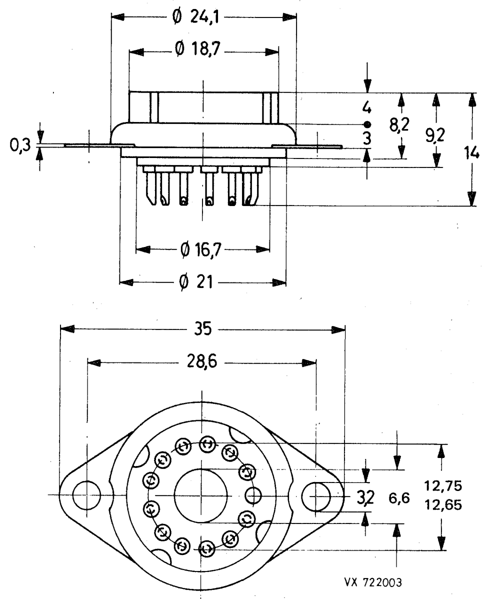
ELECTRICAL DATA

Maximum working voltage between two adjacent contacts		2000 V
Insulation resistance between two adjacent contacts (at 500 V)	>	10^{13} Ω
Contact resistance	<	10 mΩ
Capacitance		
between two adjacent contacts		0,8 pF
one contact to all		1,3 pF
Temperature range		−55 to + 100 °C

MECHANICAL DATA

Outlines

Dimensions in mm



Mass	7 g
Mounting hole diameter	22,5 mm

The use of flexibie connecting wires is strongiy recommended.

DUODECAL SOCKET

DESCRIPTION

This socket consists of an epoxy moulding with 12 tin-plated phosphor-bronze contacts, spigot keyway in the centre hole and separate cadmium-plated saddle. The socket pins are suitable for either wire soldering, or soldering into a printed-wiring board. The socket can be mounted with or without the separate mounting ring by means of two M3 screws.

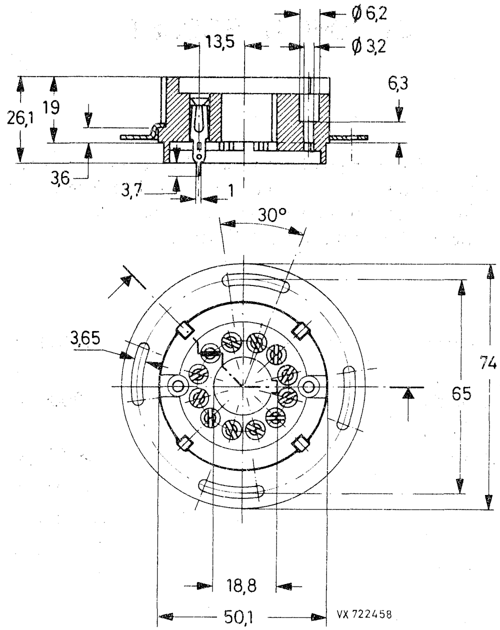
ELECTRICAL DATA

Maximum working voltage between two adjacent contacts		2000 V
Maximum working voltage between any contact and saddle		3000 V
Insulation resistance between two adjacent contacts (at 500 V)	>	10^{13} Ω
Contact resistance	<	50 mΩ
Temperature	max.	80 °C

MECHANICAL DATA

Dimensions in mm

Outlines



Mass

socket	50 g
mounting ring	15 g

DIHEPTAL SOCKET

DESCRIPTION

This socket consists of an epoxy moulding with 14 tin-plated phosphor-bronze contacts, spigot keyway in the centre hole and separate cadmium-plated saddle. The socket pins are suitable for either wire soldering, or soldering into a printed-wiring board. The socket can be mounted with or without the separate mounting ring by means of two M3 screws.

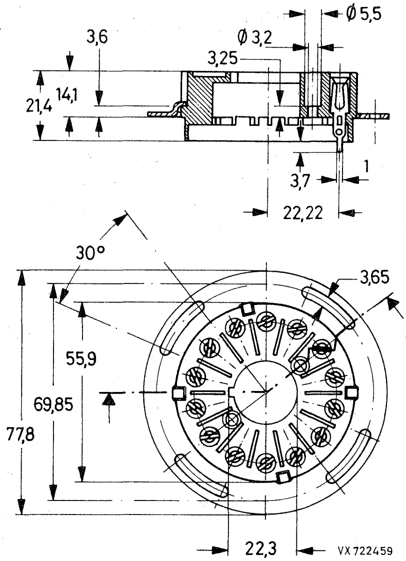
ELECTRICAL DATA

Maximum working voltage between two adjacent contacts		2000 V
Maximum working voltage between any contact and saddle		3000 V
Insulation resistance between two adjacent contacts (at 500 V)		$> 10^{13}$ Ω
Contact resistance		$<$ 50 mΩ
Temperature	max.	80 °C

MECHANICAL DATA

Dimensions in mm

Outlines



Mass

socket	45 g
mounting ring	15 g

BIDECAL SOCKET

DESCRIPTION

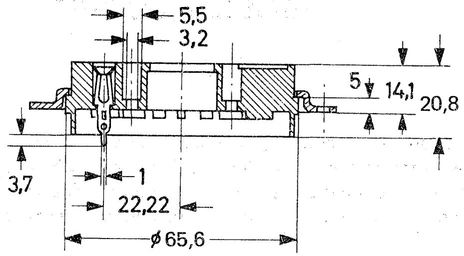
This socket consists of an epoxy moulding with 20 tin-plated phosphor-bronze contacts, spigot keyway in the centre hole and separate cadmium-plated saddle. The socket pins are suitable for either wire soldering, or soldering into a printed-wiring board. The socket can be mounted with or without the separate mounting ring by means of three M4 or three M3 screws respectively.

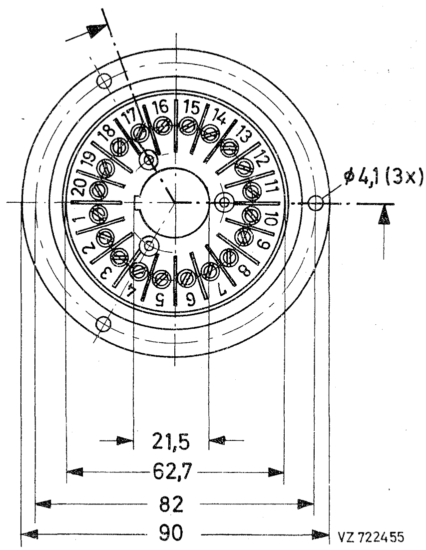
ELECTRICAL DATA

Maximum working voltage between two adjacent contacts		2000 V
Maximum working voltage between any contact and saddle		4000 V
Insulation resistance between two adjacent contacts (at 500 V)		$> 10^{13}$ Ω
Contact resistance		$<$ 50 mΩ
Temperature	max.	80 °C

MECHANICAL DATA Dimensions in mm

Outlines





Mass

socket	64 g
mounting ring	44 g

SOCKET

DESCRIPTION

This socket has a plastic moulding with 12 tin-plated printed-wiring contacts.

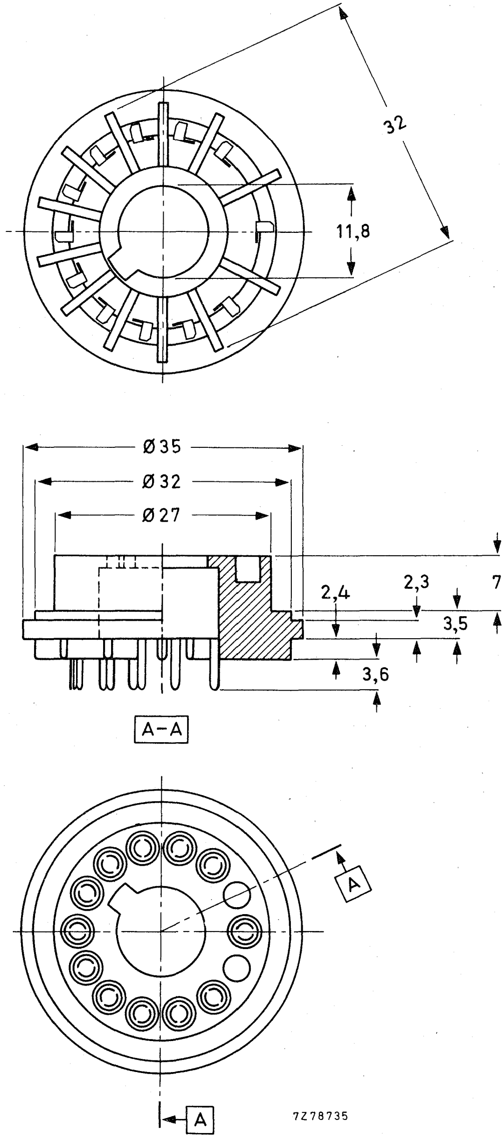
ELECTRICAL DATA

Maximum working voltage between two adjacent contacts		2000	V
Insulation resistance between two adjacent contacts (at 500 V)	>	10^{13}	Ω
Contact resistance	<	10	mΩ
Temperature	max.	80	°C

MECHANICAL DATA

Outlines

Dimensions in mm



Mass 7 g

SOCKET

DESCRIPTION

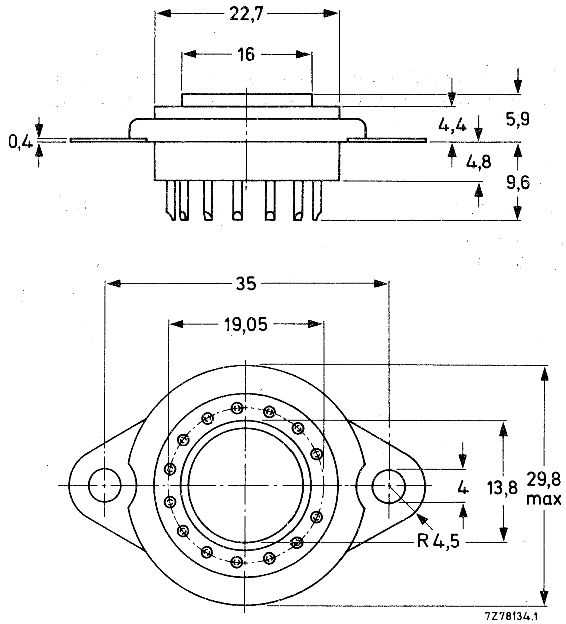
This socket consists of a plastic moulding with 14 gold-plated contacts. The connections to the socket can be made by means of wire soldering. Mounting is done with two M3 screws.

ELECTRICAL DATA

Maximum working voltage between two adjacent contacts		2000	V
Insulation resistance between two adjacent contacts (at 500 V)	>	10^{13}	Ω
Contact resistance	<	10	mΩ
Temperature	max.	80	°C

MECHANICAL DATA Dimensions in mm

Outlines



SOCKET

DESCRIPTION

This socket consists of a polytetrafluoraethylene moulding with 19 tin-plated phosphor-bronze contacts and a separate cadmium-plated saddle. The socket pins are suitable for either wire soldering, or soldering into a printed-wiring board. The socket can be mounted with the separate mounting ring by means of two M3 screws.

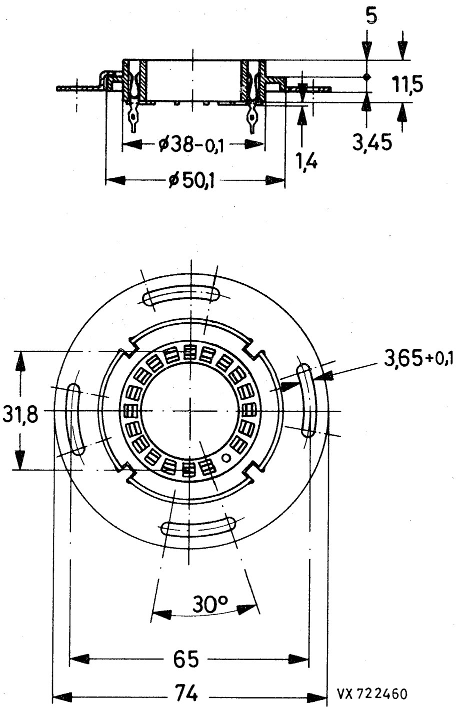
ELECTRICAL DATA

Maximum working voltage between two adjacent contacts		2000 V
Maximum working voltage between any contact and saddle		3000 V
Insulation resistance between two adjacent contacts (at 500 V)	>	10^{13} Ω
Contact resistance	<	50 mΩ
Temperature	max.	80 °C

MECHANICAL DATA

Outlines

Dimensions in mm



Mass

socket	18 g
mounting ring	15 g

SOCKET

DESCRIPTION

This socket consists of a polytetrafluoraethylene moulding with 21 tin-plated phosphor-bronze contacts and a separate cadmium-plated saddle. The socket pins are suitable for either wire soldering, or soldering into a printed-wiring board. The socket can be mounted with the separate mounting ring by means of two M3 screws.

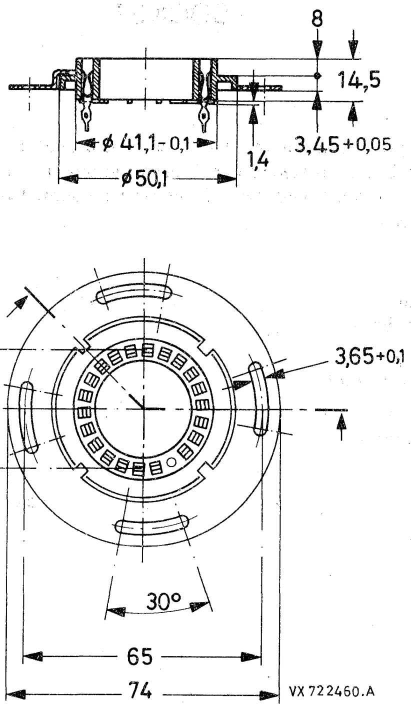
ELECTRICAL DATA

Maximum working voltage between two adjacent contacts		2000	V
Maximum working voltage between any contact and saddle		3000	V
Insulation resistance between two adjacent contacts (at 500 V)	>	10^{13}	Ω
Contact resistance	<	50	mΩ
Temperature	max.	80	°C

MECHANICAL DATA

Dimensions in mm

Outlines



Mass

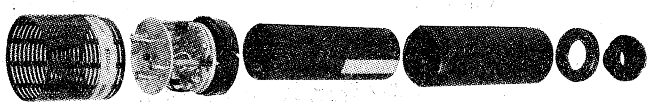
socket	35 g
mounting ring	15 g

PHOTOMULTIPLIER BASE ASSEMBLY

This base assembly is for tubes used to detect very brief low-intensity light pulses in physics experiments using coincidence measurements, Cerenkov light, high-speed scintillators, or the counting of single photoelectrons.

QUICK REFERENCE DATA

H.T. supply	see data sheet of relevant photomultiplier tube
Maximum current consumption	0,6 mA/kV
Outputs	anode output, 50 Ω, BNC dynode output, 50 Ω, BNC



The base assembly S5632 consists of two parts that screw together:

S5632/AV shielding part for fast photomultiplier tubes with a useful diameter of 44 mm;

S563 voltage divider part for fast photomultiplier tubes with a useful diameter of 44 mm or 110 mm, and a 20-pin plastic base.

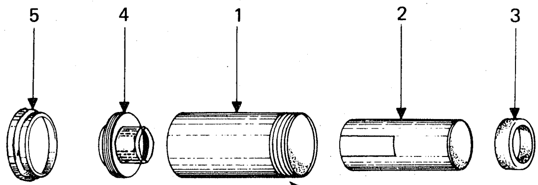
The parts can also be used separately; see table below.

photomultiplier tube		shielding + voltage divider	shielding	voltage divider
useful diameter of photocathode	type			
44 mm	XP2020(Q) XP2230B XP2232B XP2262B XP2233B PM2254B 56AVP family	S5632	S5632/AV	S563
110 mm	XP2040(Q) XP2041(Q)	information on request		S563

MECHANICAL DATA

Outlines

S5632/AV



1 = Soft iron shield
2 = Mumetal shield
3 = Foam plastic ring
4 = Fastening ring for light guide
5 = Lock ring

S563

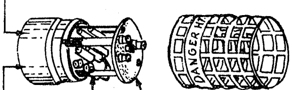


Fig. 1 S5632 = S5632/AV + S563.

assembly	overall length mm	overall diameter mm	mass g
S5632	334	90	4490
S5632/AV	240	80	4000
S563	108	90	490

ELECTRICAL DATA

Maximum supply voltage	–3 kV
Maximum current consumption	0,6 mA/kV

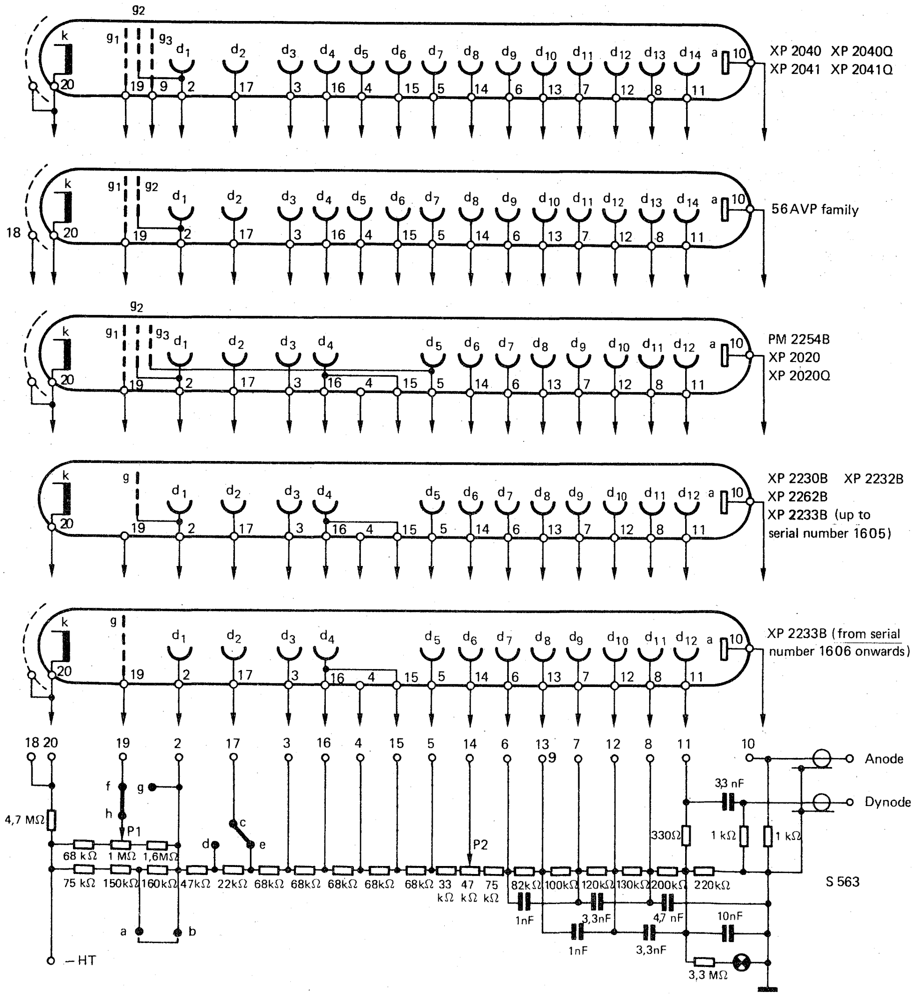


Fig. 2.

The voltage divider is wired for 12-stage and 14-stage tubes (see Fig. 2); in 12-stage tubes two of the resistors are short-circuited by the internal connection of dynode d_4 to pins 15 and 16.

The divider can be used as-is with any of the listed 44 mm tubes except the XP2233B. For use with the XP2233B, remove jumper f-h and connect a new jumper f-g. (Tubes with serial numbers up to 1605 have this connection provided internally.)

For use with 110 mm tubes XP2040(Q) and XP2041(Q), remove jumpers a-b and c-e and connect a new jumper c-d.

Potentiometer P1 is for adjusting the input optics; P2 is for gain adjustment. CAUTION: Beware of high voltage when adjusting either of these potentiometers.

The resistors of the last three stages (* in Fig. 3) may be replaced by zener diodes with 100 kΩ protection resistors in parallel.

Observe the limiting values given in the data sheet of the tube used.

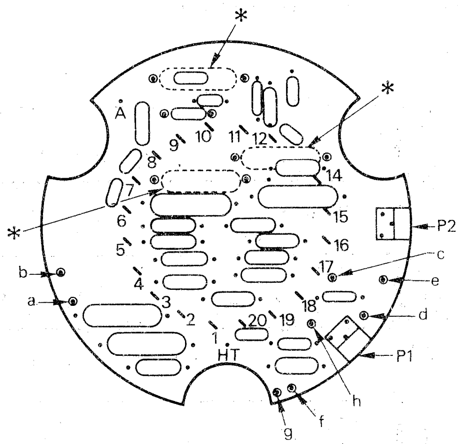


Fig. 3.

CONNECTIONS

A: anode output, 50 Ω BNC
B: dynode output, 50 Ω BNC (to be terminated with 50 Ω if not used)
C: H.T. supply input (socket SHV R 317580; mating connector R 317005**)
D: high-voltage indicator
E: housing lock

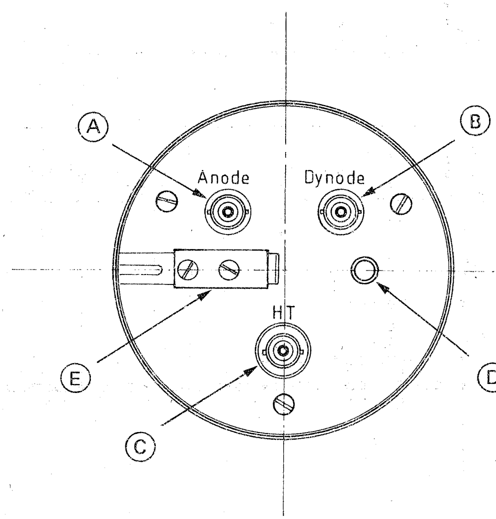


Fig. 4.

** Not supplied by the manufacturer of the base assembly.

ELECTRICAL PERFORMANCE

Pulse response

Figure 5 shows the anode pulse due to a very brief light pulse at the cathode. The peak amplitude into a 50 Ω load is 200 mA; 10% – 90% rise time, t_r, and full width at half maximum, t_W, are tabulated below.

Gain

The voltage divider is of the semi-progressive type, similar to type B′ for tubes XP2020(Q), XP2040(Q), XP2041(Q), XP2230B, PM2254B, and 56AVP family, type B for tubes XP2232B, XP2233B and XP2262B. It combines very fast response with a good compromise between gain and pulse linearity. Supply voltages for a gain of 10^7 are tabulated below.

Pulse response

tube	supply voltage V	t_r ns	t_W ns
XP2020(Q)	2800	1,6	2,5
XP2040(Q)	2200	2,4	3,3
XP2041(Q)	2200	2,4	3,3
XP2230B	2700	1,8	2,6
XP2232B	2100	2,1	3,1
XP2233B	2100	2,1	3,1
XP2262B	2100	2,1	3,1
PM2254B	2800	1,6	2,5
56DVP	2400	2,1	3,5

Gain

tube	supply voltage for $G = 10^7$ (V)
XP2020(Q)	2230
XP2040(Q)	2150
XP2041(Q)	2350
XP2230B	2330
XP2232B	2050
XP2233B	2200
XP2262B	1950
PM2254B	2350
56DVP	2060

DEVELOPMENT SAMPLE DATA

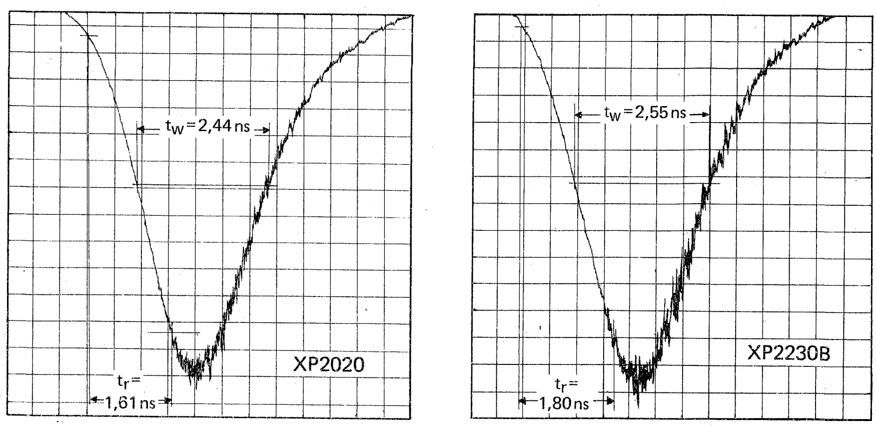
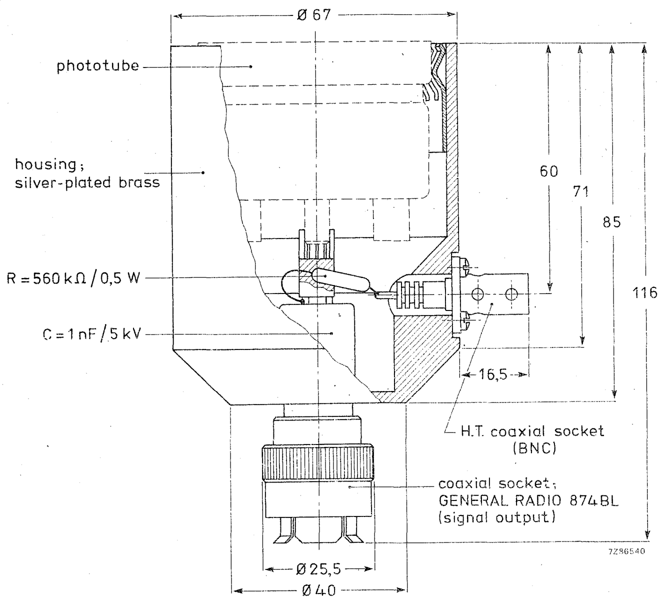
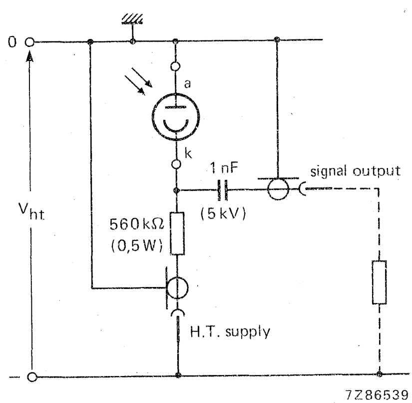


Fig. 5.

COAXIAL SOCKET FOR PHOTOTUBE TVHC40

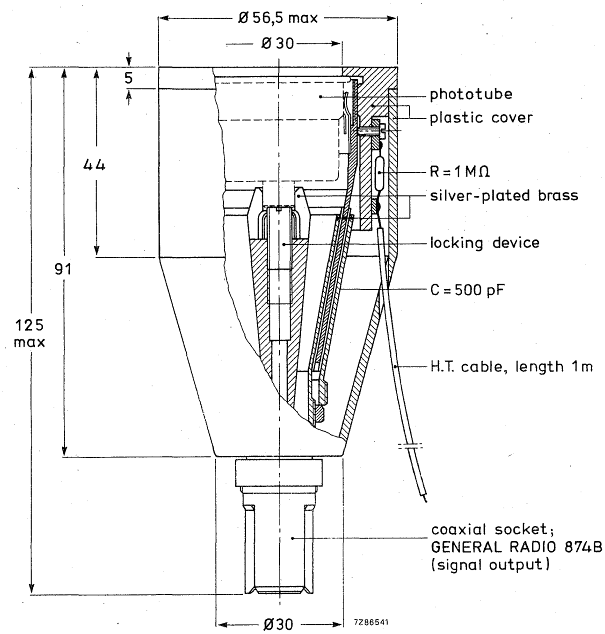
Dimensions in mm

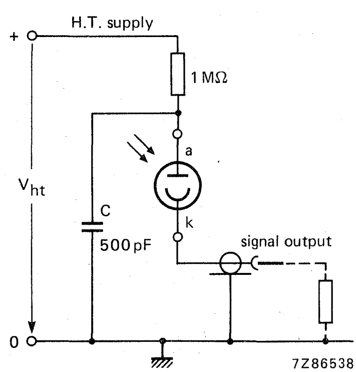




COAXIAL SOCKET FOR PHOTOTUBES XA1002 AND XA1003

Dimensions in mm





REPLACEMENT LIST AND INDEX

Development types
Maintenance types
Obsolete types

OBSOLETE TYPES

type number	replaced by
PM1980	XP2972
PM1982	PM2982
XP1000	XP2202B
XP1001	XP2202B
XP1002	XP2203B
XP1003	PM2254B
XP1004	–
XP1006	XP2202B
XP1010	XP2012B
XP1011	–
XP1016	XP2013B
XP1020	XP2020
XP1021	XP2020
XP1023	XP2020Q
XP1030	PM2412B or PM2312B
XP1031	PM2412B or PM2312B
XP1034	PM2412B or PM2312B
XP1040	XP2041
XP1041	XP2041
XP1110	PM1911
XP1113	XP1920
XP1116	–
XP1143*	–

type number	replaced by
XP1180	XP2972
XP1910	PM1911
XP2000	PM2102B
XP2000UB	PM2102
XP2030	PM2412B
XP2030UB	PM2412
XP2232	XP2262
XP2232B	XP2262B
54AVP	XP2050
54DVP	XP2050
54UVP	–
56AVP	XP2262B
56CVP	–
56DUVP	XP2020Q
56DVP	XP2262B
56TUVP	PM2254B
56TVP	XP2233B
56UVP	XP2020Q
58AVP	XP2041
58DVP	XP2041
58UVP	XP2041Q
60AVP	–
60DVP	–

* Information available on request.

DEVELOPMENT TYPES

type number	replaces
AV29	–
G12-25SE	–
G12-25SE/A	–
G12-36	–
G12-36/A	–
G12-36DT/0	–
G12-36DT/13	–
G12-46	–
G12-46/A	–
G12-46DT/0	–
G12-46DT/13	–
G25-20x50	–
G25-25x90	–
PM1911	XP1910
PM2018B	150UVP
PM2102	XP2000UB
PM2102B	XP2000
PM2242B	–
PM2254B	56TUVP
PM2312	–
PM2312B	–
PM2402	–
PM2402B	–
PM2412	XP2030UB
PM2412B	XP2030
PM2422	–
PM2422B	–
PM2432	–
PM2432B	–
PM2442	–
PM2442B	–
PM2962	–
PM2982	PM1982
XP2203B	XP1002
XP2262	XP2232
XP2262B	XP2232B
XP2972	PM1980

MAINTENANCE TYPES

type number	replaced by
AVHC201	–
B310AL/01	–
B310BL/01	–
B312AL/01	–
B312BL/01	–
B314AL/01	–
B314BL/01	–
B318AL/01	–
B318BL/01	–
B330AL/01	–
B330BL/01	–
B419AL/01	X919AL
B419BL/01	X919BL
G25-50	–
G25-50/A	–
G25-70	–
G25-70/A	–
TVHC40	–
XP1017	–
XP1117	–
XP1920	–
XP2010	XP2012B
XP2040	XP2041
XP2040Q	XP2041Q
150CVP	–

INDEX OF TYPE NUMBERS

type number	description
XP2013B	photomultiplier tube
XP2020	
XP2020Q	
XP2040	
XP2040Q	
XP2041	
XP2041Q	
XP2050	
XP2060	
XP2060B	
XP2202	
XP2202B	
XP2203B	
XP2212	
XP2212B	
XP2230	
XP2230B	

type number	description
XP2233B	photomultiplier tube
XP2262	
XP2262B	
XP2972	
56AVP	
56CVP	
56DUVP	
56DVP	
56TUVP	
56TVP	
90CG	phototube
90CV	
92AG	
92AV	
150AV	
150CVP	photomultiplier tube
56041	coaxial socket

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