



7102

MULTIPLIER PHOTOTUBE

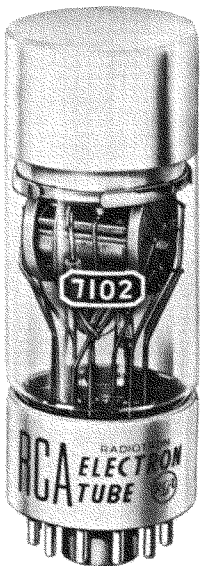
1.24" Dia. Flat
Semitransparent
Photocathode

10-Stage, Head-On Type
S-1 Response
Capable of Very Short Time-Resolution

4.57" Max. Length
1.56" Max. Diameter
Duodecal 12-Pin Base

TENTATIVE DATA

RCA-7102 is a head-on type of multiplier phototube intended for use in the detection and measurement of low-level red and near-infrared radiation. It is well suited for use in red and near-infrared spectrometry, infrared ranging, astronomical measurements involving near-infrared radiation, optical pyrometry, and in applications utilizing near-infrared radiation for communications.



The spectral response of the 7102 covers the range from about 4200 to 11000 angstroms as shown in Fig. 1. Maximum response occurs at approximately 8000 angstroms.

Design features of the 7102 include a semitransparent cathode having a minimum diameter of 1.24 inches on the

inner surface of the face end of the bulb and ten electrostatically focused dynode stages. The relatively large cathode permits efficient collection of the radiation from sources of scattered radiation.

The 7102 is capable of very short time-resolution. For an input pulse having a duration of 1 millimicrosecond or less, the time spread of the pulse at the anode is about 5 millimicroseconds measured at 50 per cent of the maximum pulse height. This time spread corresponds to an electron transit-time spread of about 4 millimicroseconds. The transit-time spread can be reduced to about 2 millimicroseconds by irradiating only a small central area of the photocathode.

DATA

General:

Spectral Response. S-1
Wavelength of Maximum Response 8000 $\pm$ 1000 angstroms
Cathode, Semitransparent:
Shape. Circular

Window:

Area	1.2	sq. in.
Minimum diameter	1.24	in.
Index of refraction.	1.51	

Direct Interelectrode Capacitances (Approx.):

Anode to dynode No. 10	4	μ f
Anode to all other electrodes.	7	μ f
Maximum Overall Length	4.57"	
Seated Length.	3.88" $\pm$ 0.19"	
Maximum Diameter	1.56"	
Bulb	T-12	
Base	Small-Shell Duodecal 12-Pin (JEDEC No. B12-43)	

Non-hygroscopic

Socket	Eby No. 160, or equivalent
Operating Position	Any
Weight (Approx.)	2 oz

Maximum Ratings, Absolute Values:

ANODE-SUPPLY VOLTAGE (DC or Peak AC)	1500 max.	volts
SUPPLY VOLTAGE BETWEEN DYNODE No. 10 AND ANODE (DC or Peak AC).	250 max.	volts
SUPPLY VOLTAGE BETWEEN CATHODE AND DYNODE No. 1 (DC or Peak AC).	400 max.	volts
AVERAGE ANODE CURRENT	10 max.	μ a
AMBIENT TEMPERATURE.	75 max.	$^{\circ}$ C

Characteristics Range Values for Equipment Design:

Under conditions with supply voltage (E) across voltage divider providing 1/6 of E between cathode and dynode No. 1; 1/12 of E for each succeeding dynode stage; and 1/12 of E between dynode No. 10 and anode.

With E = 1250 volts (except as noted)

	Min.	Median	Max.	
Sensitivity:				
Radiant, at 8000 angstroms	—	400	—	μ a/ μ w
Cathode Radiant, at 8000 angstroms .	—	0.0027	—	μ a/ μ w
Luminous: ●				
At 0 cps	1	4.5	30	amp/lumen
With dynode No. 10 as output electrode* . . .	—	2.7	—	amp/lumen
Cathode Luminous:				
With tungsten light source ▲	10	30	—	μ a/lumen
With infrared source (see Fig. 2) ●	0.012	0.036	—	μ a
Current Amplification	—	150000	—	
Equivalent Anode-Dark-Current Input ‡	—	3×10^{-7}	5×10^{-6}	lumen
	—	3.3×10^{-9}	5.5×10^{-8}	watt
Equivalent Noise Input* §	—	1.5×10^{-10}	7.5×10^{-10}	lumen
	—	1.7×10^{-12}	8.4×10^{-12}	watt

With E = 1500 volts (except as noted)

	Min.	Median	Max.	
Sensitivity:				
Radiant, at 8000 angstroms . .	—	1250	—	μ a/ μ w
Cathode Radiant, at 8000 angstroms.	—	0.0027	—	μ a/ μ w
Luminous: ●				
At 0 cps	—	14	—	amp/lumen
With dynode No. 10 as output electrode*	—	8.4	—	amp/lumen



	Min.	Median	Max.
Cathode Luminous:			
With tungsten light source [▲]	10	30	- $\mu\text{a/lumen}$
With infrared source (See Fig. 2) [⊕]	0.012	0.036	- μa
Current Amplification	-	465000	-

- Averaged over any interval of 30 seconds maximum.
- ⬇ For conditions where the light source is a tungsten-filament lamp operated at a color temperature of 2870° K. A light input of 10 microlumens is used. The load resistance has a value of 0.01 megohm.
- * An output current of opposite polarity to that obtained at the anode may be provided by using dynode No. 10 as the output electrode. With this arrangement, the load is connected in the dynode-No. 10 circuit and the anode serves only as collector.
- ▲ For conditions the same as shown under (⬇) except that the value of light flux is 0.01 lumen and 150 volts are applied between cathode and all other electrodes connected together as anode.
- ⊕ Under the following conditions: 2870° K tungsten light source; light flux of 0.01 lumen incident on Corning No. 2540 Infrared Filter (Melt 1613, 2.61 mm thick, or equivalent); irradiated area of photocathode is 1.24 inch in diameter.
- † Measured at 8000 angstroms.
- ⊞ Measured at a tube temperature of 25° C and with the supply voltage (E) adjusted to give a luminous sensitivity of 4 amperes per lumen. Dark current caused by thermionic emission and ion feedback may be reduced by the use of a refrigerator.
- ★ Under the following conditions: Supply voltage (E) 1250 volts, 25° C tube temperature, ac-amplifier bandwidth of 1 cycle per second, tungsten light source at color temperature of 2870° K interrupted at a low audio frequency to produce incident radiation pulses alternating between zero and the value stated. The "on" period of the pulse is equal to the "off" period. The output current is measured through a filter which passes only the fundamental frequency of the pulses.

DEFINITIONS

Radiant Sensitivity. The quotient of output current by incident radiant power of a given wavelength, at constant electrode voltages.

Cathode Radiant Sensitivity. The quotient of current leaving the photocathode by incident radiant power of a given wavelength.

Luminous Sensitivity. The quotient of output current by incident luminous flux, at constant electrode voltages.

Cathode Luminous Sensitivity. The quotient of current leaving the photocathode by the incident luminous flux.

Current Amplification. Ratio of the output current to the photocathode current, at constant electrode voltages.

Equivalent Anode-Dark-Current Input. The quotient of the anode dark current by the luminous sensitivity or the radiant sensitivity.

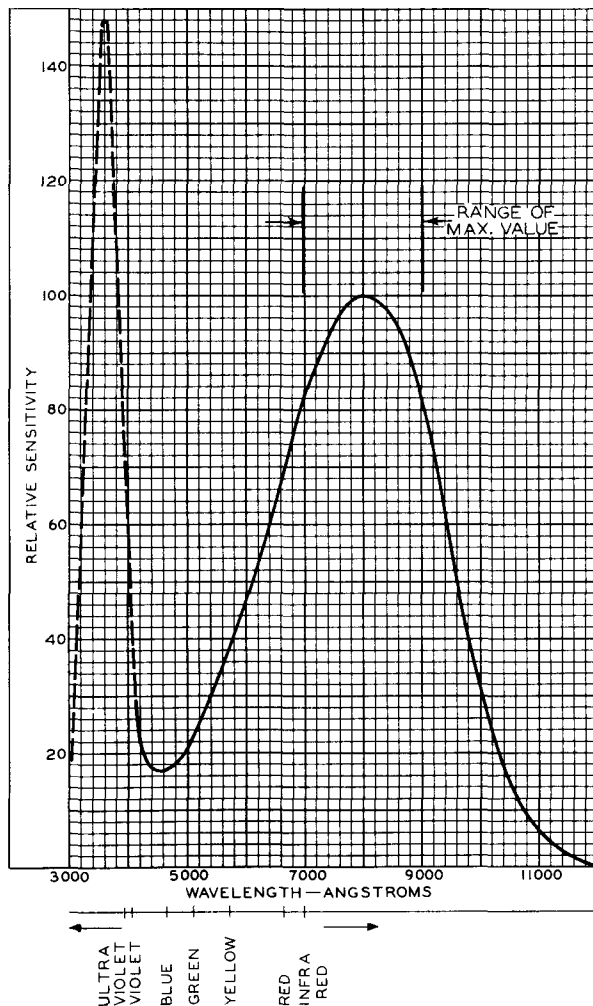
Equivalent Noise Input. That value of incident radiant flux which when modulated in a stated manner produces an rms output current equal to the rms noise current within a specified bandwidth.

Transit-Time Spread. The increase in width of the output pulse over that of the input pulse. Pulse width is measured at 50% of the pulse height.

GENERAL CONSIDERATIONS

The 7102 is a phototube incorporating an electron multiplier. An electron multiplier utilizes the phenomenon of secondary emission to amplify signals composed of electron streams. In the 7102 multiplier phototube, represented in Fig. 4, the electrons emitted from the irradiated cathode are directed by fixed electrostatic fields to the first dynode (secondary emitter). The electrons impinging on the dynode surface produce many other electrons, the number depending on the energy of the impinging electrons. These

secondary electrons are then directed by fixed-electrostatic fields along curved paths to the second dynode where they produce more new electrons. This multiplying process is repeated in each successive stage, with an ever-increasing



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Fig. 1—Spectral Sensitivity Characteristic of Type 7102 which has S-1 Response. Curve is shown for Equal Values of Radiant Flux of All Wavelengths.

stream of electrons, until those emitted from the last dynode (dynode No. 10) are collected by the anode and constitute the current utilized in the output circuit.

Dynode No. 10 is so shaped as to enclose partially the anode and to serve as a shield for it in order to prevent the fluctuating potential of the anode from interfering with electron focusing in the interdynode region. Actually the anode consists of a grating which allows the electrons from dynode No. 9 to pass through it to dynode No. 10. Spacing between dynode No. 10 and



anode creates a collecting field such that all the electrons emitted by dynode No.10 are collected by the anode. Hence, the output current is substantially independent of the instantaneous positive anode potential over a wide range. As a result of this characteristic, the 7102 can be coupled to any practical load impedance.

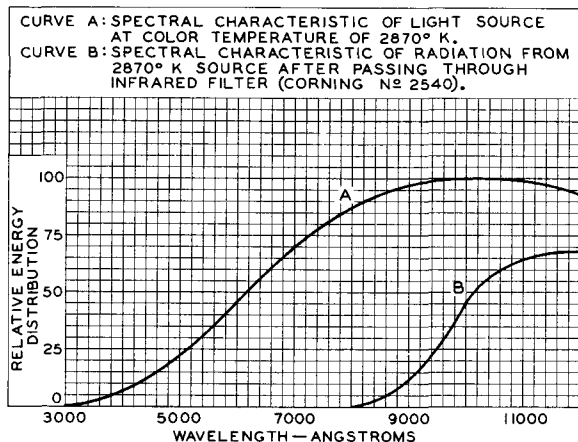


Fig.2 - Spectral Characteristic of 2870° K Light Source, and Spectral Characteristic of Radiation from 2870° K Source after Passing Through Indicated Filter.

The metallic coating on the inner side wall of the glass bulb is connected to the cathode, and serves to direct the electrons from the cathode toward dynode No.1. The grill through which the electrons reach dynode No.1, is connected to dynode No.1 and serves along with the accelerating electrode as an electrostatic shield for the open side of the electrode structure.

INSTALLATION and APPLICATION

The maximum ratings in the tabulated data are limiting values above which the serviceability of the 7102 may be impaired from the viewpoint of life and satisfactory performance. Therefore, in order not to exceed these absolute ratings, the equipment designer has the responsibility of determining an average design value below each absolute rating by an amount such that the absolute values will never be exceeded under any usual condition of supply-voltage variation, load variation, or manufacturing variation in the equipment itself.

The maximum ambient temperature as shown in the tabulated data is a tube rating which is to be observed in the same manner as other ratings. This rating should not be exceeded because too high a bulb temperature may cause the volatile cathode surface and dynode surfaces to evaporate with consequent decrease in the life and sensitivity of the tube.

The base pins of the 7102 fit the duodecal 12-contact socket. The socket should be made of high-grade, low-leakage material, and should be installed so that the incident radiation falls on the face end of the tube. It is to be noted that the basing arrangement is such that the voltage between anode pin and adjacent pins is not more than twice the voltage per stage. As a result, external leakage between anode pin and adjacent pins is kept low.

In general, the operating voltages for the 7102 are as follows. The cathode-to-dynode-No.1 potential is about twice the potential applied between the successive dynodes. The steps for the successive stages are generally chosen as 100 to 125 volts. The voltage between dynode No.10 and anode should be kept as low as will permit operation with anode-current saturation. Referring to the anode characteristic curves, shown in Fig.5, it will be seen that saturation occurs in the approximate range of 50 to 100 volts. Low operating voltage between dynode No.10 and anode reduces the dark current. To obtain the indicated operating voltage between dynode No.10 and anode, it will be necessary to increase the supply voltage between these electrodes above the operating voltage by an amount to allow for the signal-output voltage desired.

In applications where it is desired to keep the statistical fluctuations to a minimum, e.g., as in astronomical measurements, the potential

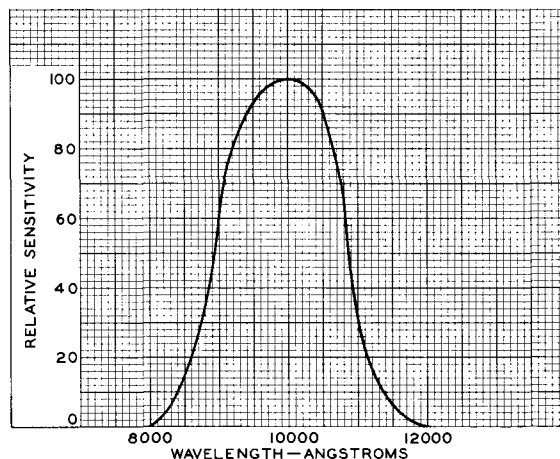


Fig.3 - Spectral Characteristic of Type 7102 when Irradiated with Infrared Flux Obtained by Passing Radiant Flux from a 2870° K Tungsten Source Through Infrared Filter (Corning No. 2540).

between cathode and dynode No.1 may be increased to the rated maximum value of 400 volts.

Dark current observed when voltage is applied to the electrodes of the 7102 in complete darkness is caused primarily by electrons thermionically released from the cathode and establishes a limit below which the incident radiation on

the cathode can not be detected. The dark current can be substantially reduced by cooling the photocathode. Dark current is reduced by about 50 per cent for each 6° reduction in temperature beginning at 25° C.

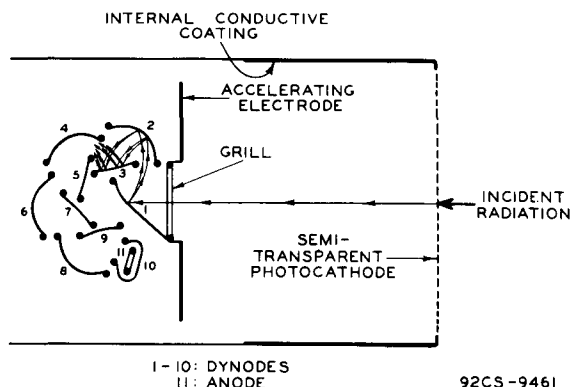


Fig. 4 - Schematic Arrangement of Type 7102 Structure.

When the application utilizes *continuous luminous excitation and dc anode current* and it is desired to have a high ratio of signal output to dark current, it is recommended that the operating supply voltage (E) be determined with reference to the curve in Fig. 6 which shows the equivalent anode-dark-current input as a function of luminous sensitivity for the 7201, and the curves in Fig. 7 which show luminous sensitivity as a function of the supply voltage.

In applications involving *pulsed excitation and ac coupling at the anode*, the best signal-to-noise ratio is obtained with a supply voltage (E) in the range from 1000 to 1250 volts. Within this range, the noise at the anode is produced primarily by the statistical release of thermal electrons, and the noise power spectrum is essentially flat up to about 50 megacycles per second. At voltages above 1250 volts, regenerative phenomena usually contribute to the noise.

The noise spectrum of the 7201 is such that the threshold of pulse detection depends on the associated circuitry. The bandpass filter should be designed to pass only the frequency range of the exciting signal in order to eliminate as much noise as possible.

In either dc or ac applications where maximum gain with unusually low dark current is required, the use of a refrigerant, such as dry ice, to cool the bulb of the 7201 is recommended. The refrigerant reduces the thermionic emission, and thereby lowers the detection threshold to give improved operation. The curves in Fig. 8 show the equivalent noise input as a function of the temperature of the 7201.

When stability of operation is important, the use of an average anode current well below

the maximum rated value of 10 microamperes is recommended. This maximum rating should never be exceeded because operation at higher average output currents may cause a permanent decrease in infrared sensitivity and a consequent decrease in the tube life.

A small temporary loss of infrared sensitivity may be observed after long periods of operation. The sensitivity recovers during idle periods but only very slowly at temperatures below 25° C.

The range of sensitivity values is dependent on the respective amplification of each dynode stage. Hence large variations in sensitivity can be expected between individual tubes of a

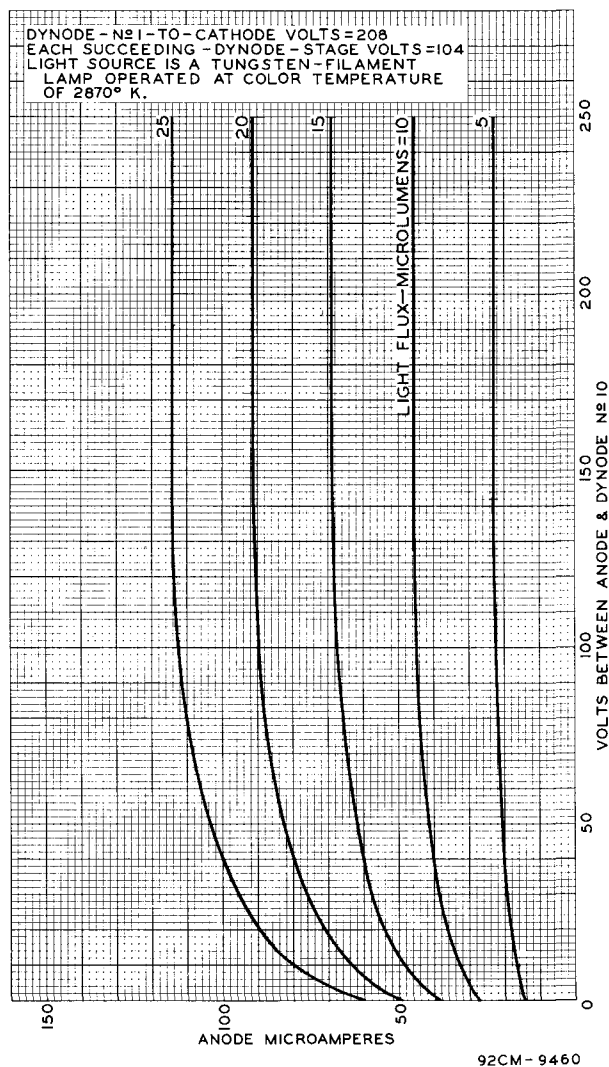


Fig. 5 - Average Anode Characteristics of Type 7102.

given type. The overall amplification of a multiplier phototube is equal to the average amplification per stage raised to the n th power, where n is the number of stages. Thus, very



small variations in amplification per stage produce very large changes in overall tube amplification.

Because these overall changes are very large, it is advisable for designers to provide adequate adjustment of the supply voltage per stage so as to be able to adjust the amplification of indi-

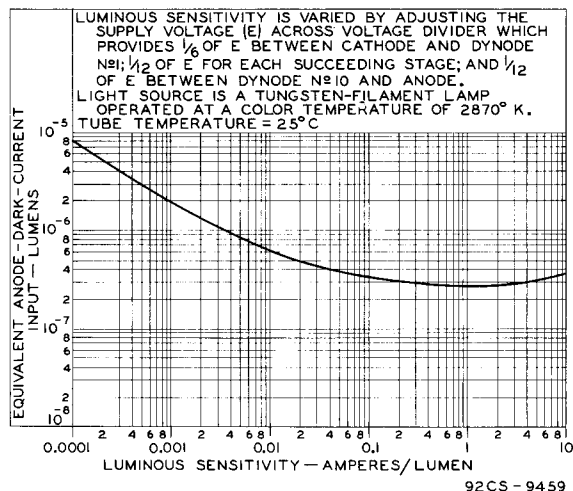


Fig. 6 - Typical Anode-Dark-Current Characteristic of Type 7102.

vidual tubes to the desired design value. The voltage-adjustment range required to take care of variations between individual tubes may be determined from Fig. 7. For example, if a sensitivity of 1 ampere per lumen is desired, it will be observed that this value on the "minimum" sensitivity curve corresponds to a supply voltage of about 1250 volts, and on the "maximum" sensitivity curve to a supply voltage of 910 volts. Therefore, provision should be made to adjust the supply voltage over the range from 910 to 1250 volts.

Electrostatic and/or magnetic shielding of the 7102 may be necessary. The metallic coating on the inner side wall of the glass bulb acts as an electrostatic shield to prevent the coated portion of the bulb wall from charging to a positive potential. However, the uncoated area of the bulb wall tends to charge to a potential near that of the anode, especially when the 7102 is operated at voltages near the maximum, with the result that an internal discharge phenomenon may occur and cause an increase in noise. To prevent this possibility, it is suggested that a shield be closely fitted over the uncoated area and be connected as a safety precaution (see below), through a high impedance in the order of 10 megohms to a potential near that of the cathode. The shield may consist of a conductive coating painted on the clear portion of the bulb above the base, or metallic foil wrapped around the clear area.

With certain orientations of the 7102, it will be observed that the earth's magnetic field is sufficient to cause a noticeable decrease in the response of the tube. The curve in Fig. 9 shows the effect on anode current of variation in magnetic-field strength under the conditions indicated. With increase in voltage above 100 volts between cathode and dynode No. 1, the effect of the magnetic field will cause less decrease in anode current.

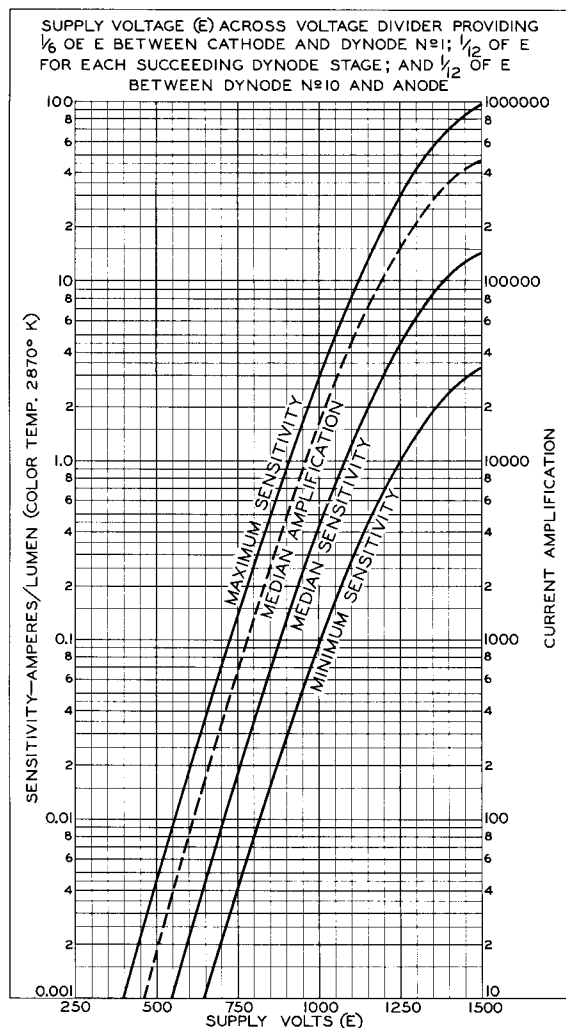


Fig. 7 - Characteristics of Type 7102.

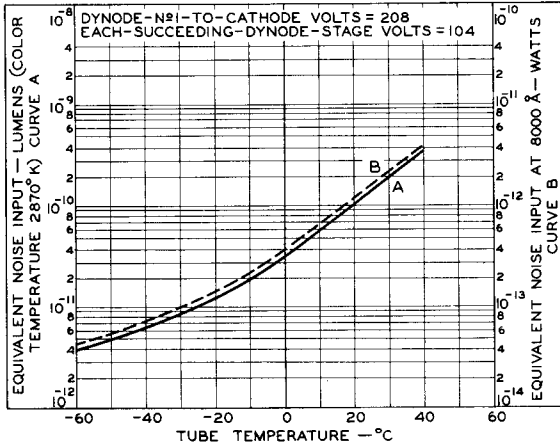
To prevent such decrease in response of the tube, magnetic shielding should be provided. When connected to cathode potential, this shielding may closely fit the bulb and serves the dual purpose of providing both magnetic and electrostatic shielding. When connected to anode potential, this shielding should be spaced at least 1/2 inch from the bulb wall to prevent the internal discharge phenomenon described above.

It is to be noted that the use of an external magnetic and/or electrostatic shield at high

negative potential presents a safety hazard unless the shield is connected through a high impedance in the order of 10 megohms to the potential. If the shield is not so connected, *extreme*

be short so as to minimize capacitance shunting of the phototube load.

The *dc supply voltages* for the electrodes can be obtained conveniently from a high-voltage, vacuum-tube rectifier. The voltage for each dynode and for the anode can be supplied by spaced taps on a voltage divider across the rectified power supply. The current through the voltage

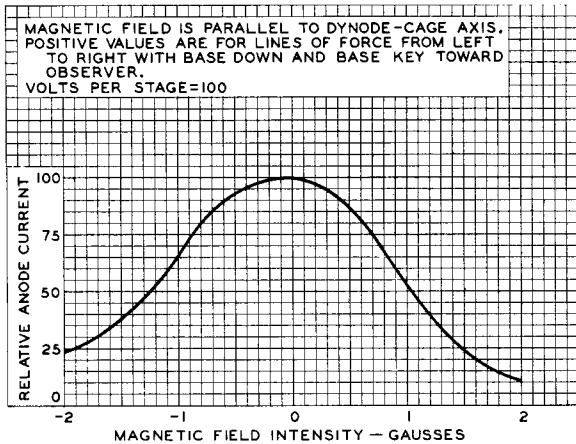


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Fig. 8 - Equivalent Noise-Input Characteristics of Type 7102.

care should be observed in providing adequate safeguards to prevent personnel from coming in contact with the high potential of the shield.

Adequate *light and infrared-radiation shielding* should be provided to prevent extraneous radiation from reaching any part of the 7102. Although the metallic coating on the inner side

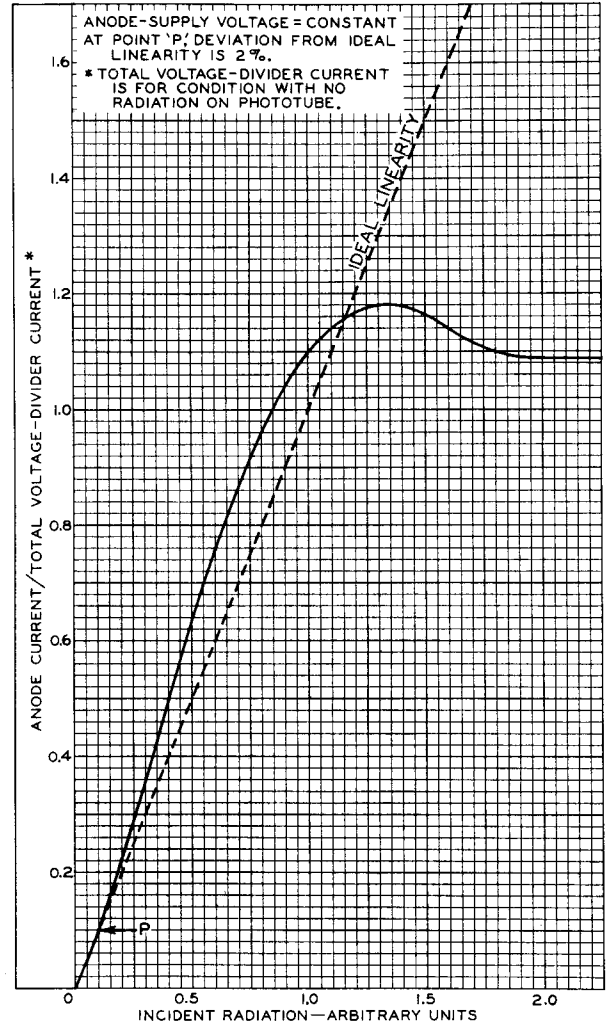


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Fig. 9 - Effect of Magnetic Field on Anode Current of Type 7102.

wall of the glass bulb serves to reduce the amount of extraneous radiation reaching the electrodes, it is inadequate to shield completely the entire structure from extraneous radiation.

Whenever frequency response is important, the leads from the 7102 to the amplifier should



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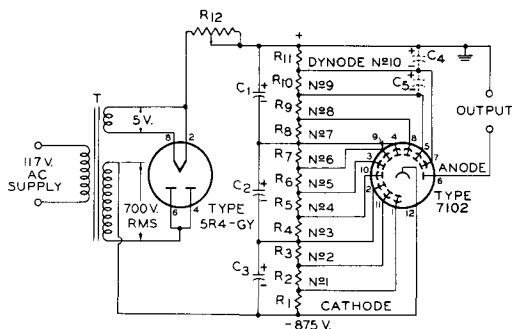
Fig. 10 - Linearity Characteristic of Type 7102 as Affected by Ratio of Anode Current to Total Divider Current.

divider will depend on the voltage regulation, required by the application. In general, the current in the divider should be about 10 times the maximum value of total dynode current flowing through the divider. Such a value will prevent variations of the dynode potentials by the signal current. Because of the relatively large divider current required for good regulation, the use of a rectifier of the full-wave type is



recommended. Sufficient filtering will ordinarily be provided by a well-designed, two-section filter of the capacitor-input type. A choke-input filter may be desirable for certain applications to provide better regulation. Due to critical dependence of the gain of the 7102 on volt-

The high voltages at which the 7102 is operated are very dangerous. Care should be taken in the design of apparatus to prevent the operator from coming in contact with these high voltages. Precautions should include the enclosure of high-potential terminals and the use of interlock



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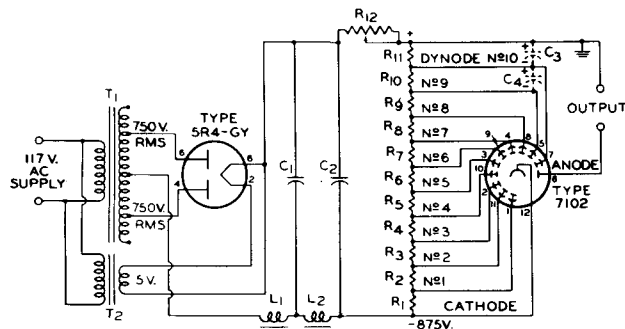
C1 C2 C3: 16 μ f, electrolytic, 450 volts (dc working)
C4 C5: 8 μ f, electrolytic, 150 volts (dc working)
Required only if high peak currents are drawn.
R1: 100000 ohms, 1/2 watt
R2 R3 R4 R5 R6 R7 R8 R9 R10: 50000 ohms, 1/2 watt
R11: 33000 ohms, 1/2 watt
R12: 100000 ohms, 1 watt, adjustable, Centralab A122, or equivalent
T: United Transformer Corp. No. R-2, or equivalent

Fig. 11 - Simple Half-Wave Rectifier Power-Supply Circuit with Voltage Divider for Supplying DC Voltages to Type 7102.

age, rapid changes in the voltage resulting from insufficient filtering of the power supply will introduce hum modulation; and slow shifts in the line voltage due to poor regulation will cause a change in the level of the output. When the dc supply voltage is provided by means of a rectifier, satisfactory regulation can be obtained by the use of a vacuum-tube regulator circuit of the mu-bridge type.

The relationship between the ratio of anode current-to-voltage-divider current and incident radiation is shown in Fig. 10. For operation along the *ideal linearity* curve of Fig. 10, the anode current-to-voltage-divider current ratio should be less than 0.1.

In most applications, it is recommended that the positive high-voltage terminal be grounded in order that the output signal will be produced between anode and ground. This method prevents power-supply fluctuations from being coupled directly into the signal-output circuit.



92CM-7815

C1 C2: 2 μ f, 1000 volts (dc working)
C3 C4: 8 μ f, electrolytic, 150 volts (dc working).
Required only if high peak currents are drawn.
L1 L2: United Transformer Corp. No. R-17, or equivalent
R1: 39000 ohms, 2 watts
R2 R3 R4 R5 R6 R7 R8 R9 R10: 18000 ohms, 1 watt
R11: 12000 ohms, 1 watt
R12: 200000 ohms, 12 watts, adjustable, General Radio Type 471-A, or equivalent
T1: United Transformer Corp. No. S-45, or equivalent
T2: United Transformer Corp. No. FT-6, or equivalent

Fig. 12 - Full-Wave Rectifier Power-Supply Circuit with Voltage Divider for Supplying DC Voltages to Type 7102 in Applications Critical as to Hum Modulation.

switches to break the primary circuit of the high-voltage power supply when access to the apparatus is required.

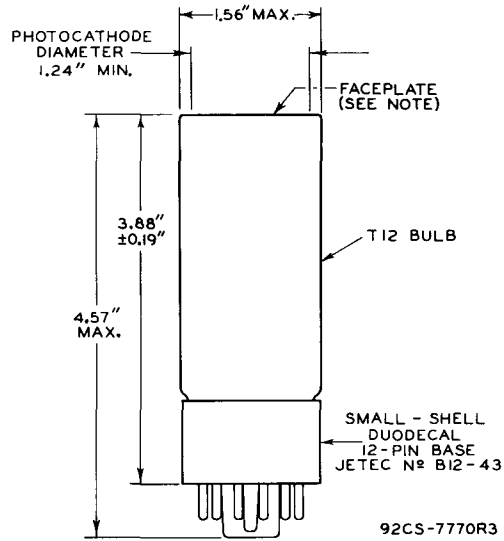
In the use of the 7102, as with other tubes requiring high voltages, it should always be remembered that these high voltages may appear at points in the circuit which are normally at low potential, because of defective circuit parts or incorrect circuit connections. Therefore, before any part of the circuit is touched, the power-supply switch should be turned off and both terminals of any capacitors grounded.

Typical power-supply circuits for the 7012 are shown in Fig. 11 and 12. The circuit in Fig. 11 utilizes a half-wave rectifier to provide the dc power for the 7102. In applications where better regulation and minimum hum modulation are essential, the circuit of Fig. 12 may be used.

Devices and arrangements shown or described herein may use patents of RCA or others. Information contained herein is furnished without responsibility by RCA for its use and without prejudice to RCA's patent rights.



DIMENSIONAL OUTLINE



NOTE: WITHIN 1.24" DIAMETER, DEVIATION FROM FLATNESS OF EXTERNAL SURFACE OF FACEPLATE WILL NOT EXCEED 0.010" FROM PEAK TO VALLEY.

Ø OF BULB WILL NOT DEVIATE MORE THAN 2° IN ANY DIRECTION FROM THE PERPENDICULAR ERRECTED AT THE CENTER OF BOTTOM OF THE BASE.

SOCKET CONNECTIONS

Bottom View

