Title
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Authors
Parker, Sherwood
Oliver, William
Rey, Charles.

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A PHOTOMULTIPLIER SHIELD AND BASE SYSTEM*

Sherwood Parker, William Oliver, and Charles Rey

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This note describes a phototube shield and base system with the following characteristics:

1. Simple construction, mostly from stock parts, to minimize machining.
2. Complete electrical shielding suitable for use near large spark chambers.
3. Quick access for changing either the tube, the base, or the scintillator.
4. Magnetic shield length optimized for axial fields. (Axial fields are the most difficult to shield. The optimum length turns out to be surprisingly short.)
5. A clamping arrangement that allows for minor variations in phototube dimensions without need for adjustments in the shield dimensions or light-pipe position.
6. A zener diode base that can be converted from a 56AVP to a 6810A configuration with the change of three soldered connections and that can provide anode currents of 10 mA.

An assembly drawing is shown in Fig. 1 and a photograph of the system showing both an assembled and an exploded view is shown in Fig. 2. The light pipe is held with three set screws, and the light seal to the shield is made with a turn of black tape.

The magnetic shield was designed as a reasonably light-weight double shield for service in fields of tens of gauss. For much higher field values, the addition of a third shield is generally better than a great increase in thickness of the second shield. An inner, 1.2-mm-thick mu metal shield is loosely held between the aluminum light pipe holder and the inner Bakelite ring. The outer shield is in two parts, a 20.3-cm-long tube of 1010 steel, usually with a 2.4-mm wall that covers most of the length of the phototube, and another tube of the same material that covers the bottom of the phototube and also clamps it in place. Magnetic field effects are most severe for axial fields and for low values of the photocathode-anode voltages. When a high voltage of 1.75 kV was used with the phototube in a 1.6-mm-thick outer shield, the output signal heights from a 56AVP and a 6810A dropped by 3% at axial fields of 40 gauss and 50 gauss, respectively. This value increased to 70 gauss for a 6810A in a 3.2-mm-thick outer shield. Once the shield extends about a diameter beyond the phototube, additional shield length results primarily in an increase in the amount of flux diverted into the shield and a consequently lowered external field at which the shield starts to saturate. We ran tests with a 6810A, using a high voltage of 2.5 kV and with 1.6-mm-thick outer shields that extended 3, 4, 5, and 6 in. beyond the photocathode. The field at which the output pulse height had dropped by 3% decreased from 109 gauss to 98, 91, and 82 gauss respectively.

The phototube is held against the light pipe by two felt rings, one on each side of its flange. These are compressed between two Bakelite rings when the steel clamping tube is slid in place and locked with thumb screws. The felt rings also make a lighttight seal. If an air or vacuum grease interface is used between the phototube and the light pipe, the tube and its base can be rotated without breaking either the optical joint or the lighttight seal. (56AVP's do not come with flanges, so a Bakelight ring, attached to it as shown in Figs. 1 and 2, serves as one.)

The electrical shield completely encloses the phototube. It consists of the aluminum foil around the light pipe, the aluminum light-pipe holder, the steel outer shield, the steel clamping tube, and the phototube base. The base is built with a section of thin-walled aluminum pipe and is locked to the clamping tube by a brass ring compressed by a thumb screw.

If negative high voltage is used, an inner electrostatic shield held at the photocathode potential and surrounded by an insulator (usually Mylar) is of course necessary.

The base circuit diagram is shown in Fig. 3. It uses a standard high-gain resistor string. Tests on a large number of 56AVP's and 6810A's showed that it was not necessary to adjust any resistor values when tubes were changed if about 5% reduction in gain could be tolerated. Turning the high voltage on or off produces no detectable transient signal output at the millivolt level, a useful feature if the electronics input stages are easily damaged. The zener diodes are used in the standard manner, allowing operation at an anode current of 10 mA while keeping low the amount of current run down the entire string. (Note, however, that the average anode current limitation on both tube types is 2 mA.) The high standing current in the last two stages allows operation at high rates (typically 10 to 100 MHz). The low dynamic impedance of the zener diodes allows operation either at high rates or at high gain before the abrupt onset of an effect first described by Stump and Talley:[1]

Suppose an increase occurs in the anode current, I, of magnitude ΔI; this causes a decrease in the external current and hence a decrease $Z\Delta I$ in voltage between the last dynode and the anode, where Z is the dynamic impedance of the base circuit elements between them. Since the photocathode-anode voltage is held constant, the photocathode-last-dynode voltage, V, increases by the same amount, $Z\Delta I$, causing an increase in tube gain and a consequent increase in anode current,

$$\Delta I' = \frac{dI}{dV} \Delta V = \frac{dI}{dV} Z\Delta I.$$

If

$$\frac{\Delta I'}{\Delta I} = Z \frac{dI}{dV} > 1,$$

this process continues until the current is limited by space-charge saturation between the last dynode and the anode. The levels are usually high enough to ruin the tube if continued for long. Since the effect may occur when the voltage is raised, it is often mistaken for a high-voltage breakdown. Note that large capacitors on the last stages will lower Z only for short times and will not help if the original ΔI came from an increase in the high voltage.

We would like to thank Louis Lavoie who, late one night on a cyclotron run at the University of Chicago with two of the present authors, mistakenly put in an extra felt ring on an earlier type of shield, and so gave rise, the following morning, to an important element of the present system.

Footnotes and References

*Work done under auspices of the U. S. Atomic Energy Commission.

1. Robert Stump and Harry Talley, Rev. Sci. Instr. 25, 1132 (1954).

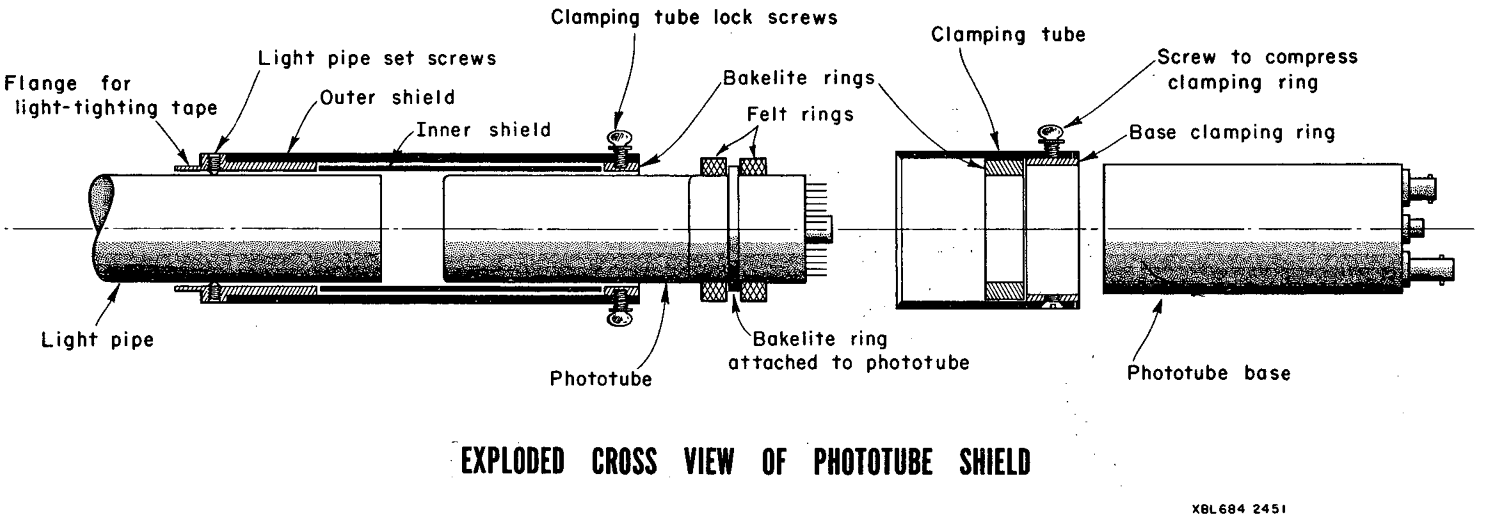

Fig. 1. Assembly drawing of the shield, phototube, and base.

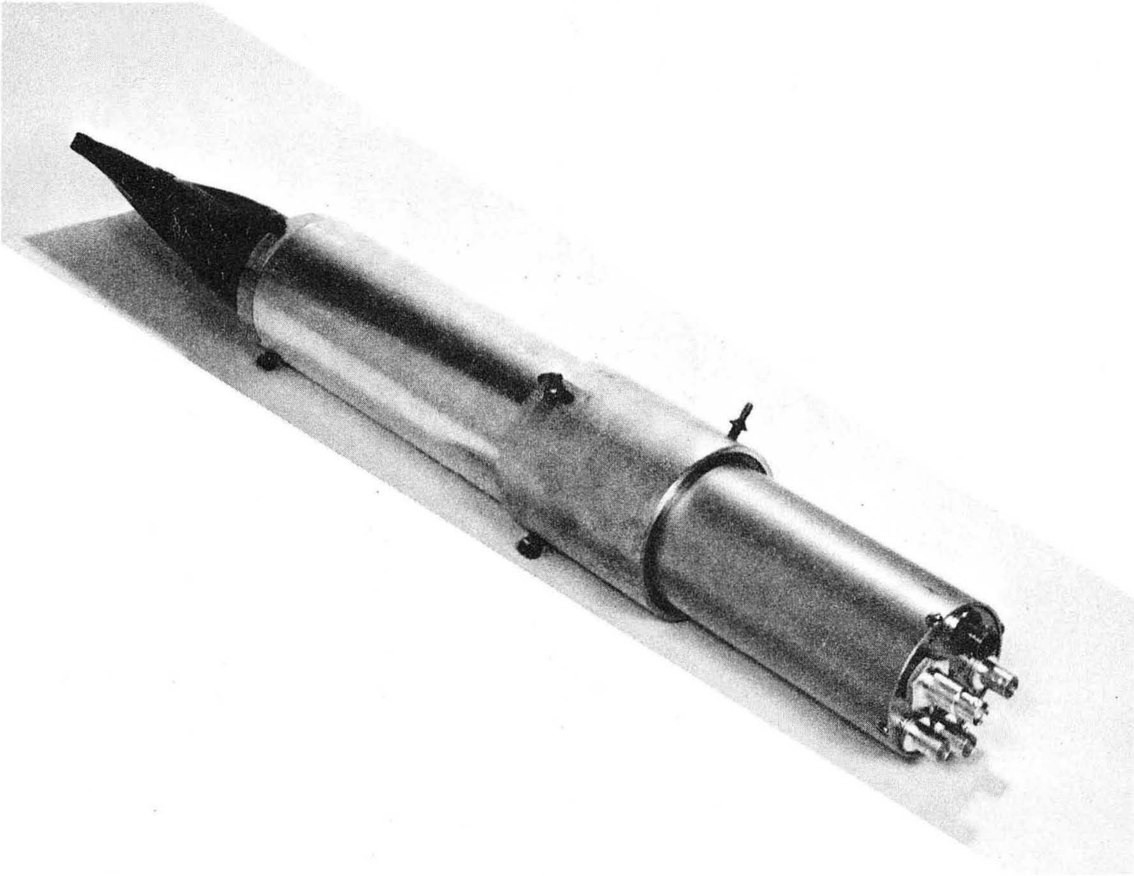

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Fig. 2a. Photograph of assembled system.

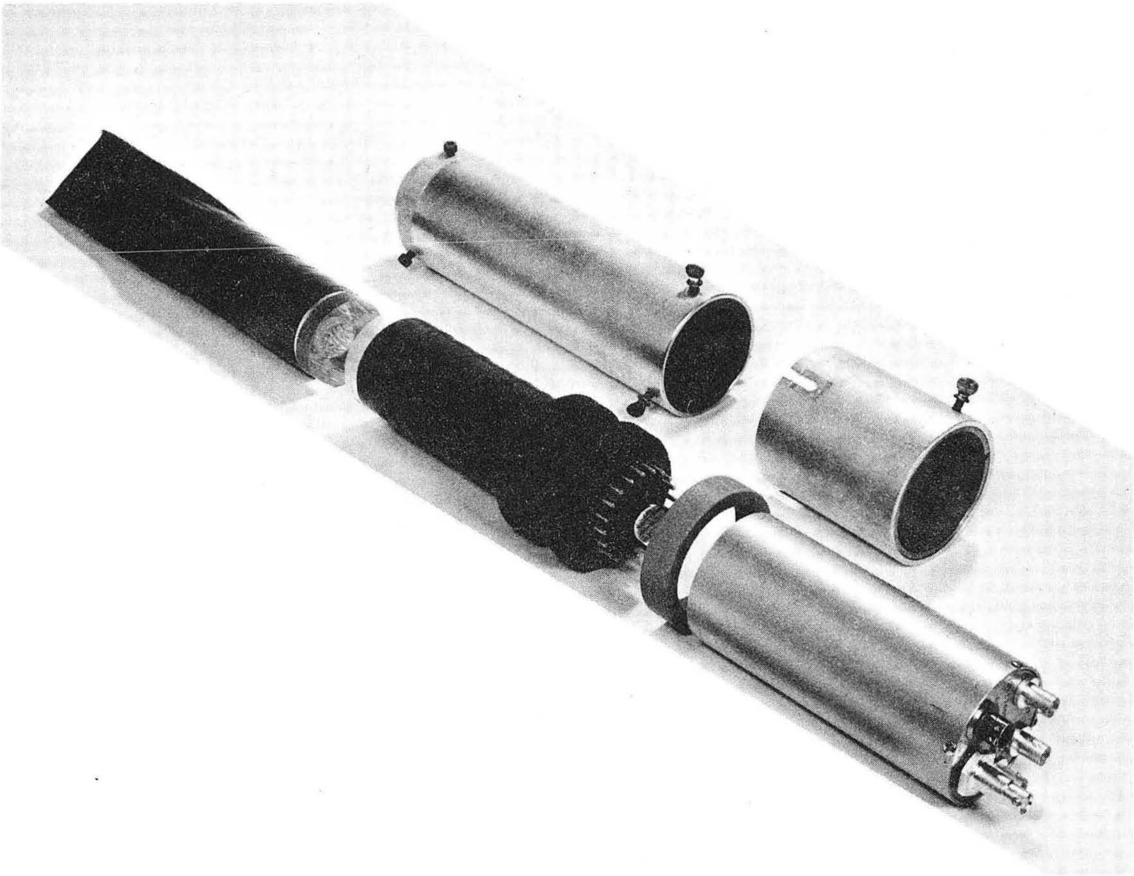

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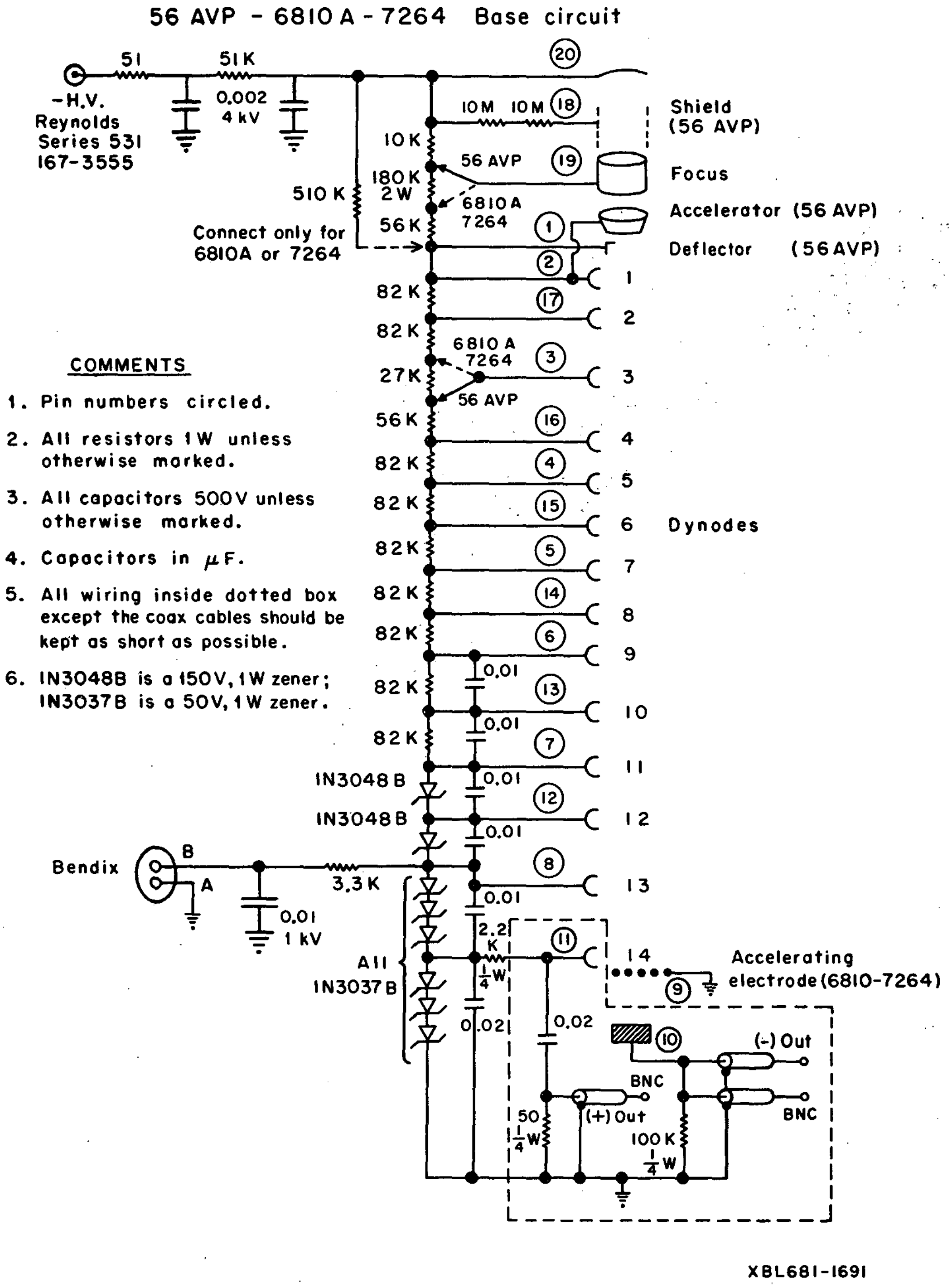
Fig. 2b. Photograph of disassembled system.



56 AVP - 6810 A - 7264 Base circuit

COMMENTS

1. Pin numbers circled.
2. All resistors 1W unless otherwise marked.
3. All capacitors 500V unless otherwise marked.
4. Capacitors in μF.
5. All wiring inside dotted box except the coax cables should be kept as short as possible.
6. IN3048B is a 150V, 1W zener; IN3037B is a 50V, 1W zener.

Fig. 3. Base circuit diagram.

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