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A HIGH-RATE PHOTOTUBE BASE

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Introduction

Phototube bases designed for high-rate applications have generally made use of zener diodes or the so-called after-burner technique where additional power supplies are needed to supply "stiff" voltage to the last few dynodes of a phototube. Other techniques include the use of miniature, on-board Cockcroft-Walton power sources or large capacitor banks. All of these techniques may find use where they nicely solve a problem; in this note a new type of high-rate base will be discussed which doesn't have a high-current string and therefore works effectively from the present high voltage zener divider distribution panels available at Fermilab. This base is designed to minimize voltage changes in a phototube base that would cause gain instability.[1]

Circuit Design

Figure 1 is the schematic of a phototube base designed specifically for E288 and will serve well to demonstrate the design under discussion here. The concept will work for either high plus or high minus; high minus is shown. Stiff voltage sources for dynodes are provided by making use of emitter follower characteristics of high beta, high voltage, video transistors. This is a Smart power saving voltage divider: as the tube current increases, current is diverted from string to tube; instead of using a high string current, the transistors Beta provides an improvement factor as if the string current were more than 100X greater than it is. Over a group of transistors purchased there will be a spread of Betas. The high-Beta transistors (e.g. $\beta = 150$) were put in the later stages to get the best overall performance from the active voltage divider. The technique provides a lightweight, small size and simple base design not requiring voluminous energy-storage capacitors. The only capacitors needed are the usual ones for high-frequency bypassing. The diodes placed at the base-emitter junction of the transistors are to prevent over-voltaging the transistor junction in the inverse direction, an effect that does not normally happen but could occur under fault conditions or during the transient turn-on or turn-off periods. Various different tapers for the voltage division are possible at will; these are achieved by the proper choice of resistors at each stage in the resistor string shown in Fig. 1. If a particular interstage voltage is too high for one transistor, use two in series; Fig. 1 demonstrates (D_{11}-D_{12}) this principle, which can be extended at will to three, four, or ... transistors.

A feature of this base, not found in "zener" bases or "after-burner" systems, is worth mentioning. Suppose you wish to change the phototube voltage -- the voltage division "tracks" over the whole voltage range with a single voltage adjustment, just like an ordinary simple resistive divider. With a zener base, of course, the voltage on some tube elements stay constant, while others vary in some fashion as the supply voltage is adjusted. With afterburners, one has at least two separate power supplies to adjust, plus extra cables and connectors to contend with. Another point is the low cost; even if 10 transistors are used in each base, the cost is less than just the extra connector used with the afterburner, let alone the rest of the electronics used with such a design. (The transistors, MPS-U10, are $ 0. 67 each).

NPN vs PNP Transistors

The idea could be described as a solid-state, active voltage divider. The designer is faced with the choice of using either NPN or PNP transistors. One could make the base with either type, however, it appears that certain advantages favor the NPN. (When suitable FET's appear on the market, I will try them.)

1) The stiff voltage action of the NPN transistor only applies over a purposely limited current range. This helps prevent destruction of phototubes; a base capable of supplying unlimited current is a booby-trap because if a photomultiplier is accidentally exposed to an excessive amount of light, it may be damaged by the resultant high current. This current-limiting action carries the terminology "foldback current limiting", i. e. the voltage holds constant from zero current to some level; for greater current loading, the voltage sags.

This foldback protection is obtained "naturally" with the use of NPN's in this circuit, whereas PNP's turn "ON" harder with more load current, instead of turning "OFF".

2) One does not need a transistor for every dynode stage if NPN's are used, but one does need a transistor for every dynode if one uses PNP's. Typically, one saves 8 out of 14 transistors by going NPN with say a 56AVP phototube.

Disadvantages

Solid-state devices are used in the phototube base, hence radiation damage eventually will occur. So far this has not been a problem. In the course of time, we will doubtless accumulate more experience on this. If it becomes a problem, the transistors can be replaced at $ 0.67 each.

A Parting Thought

I have the nagging feeling that if one goes back ten or twenty years and looks, this idea was already around. Suffice it to say that, if so, it is time we put it to use, and that is what I intend with this memo.

Reference

[1] C. R. Kerns, Proceedings of the Calorimeter Workshop, Fermilab, Batavia, Illinois, May 1975, p. 143.

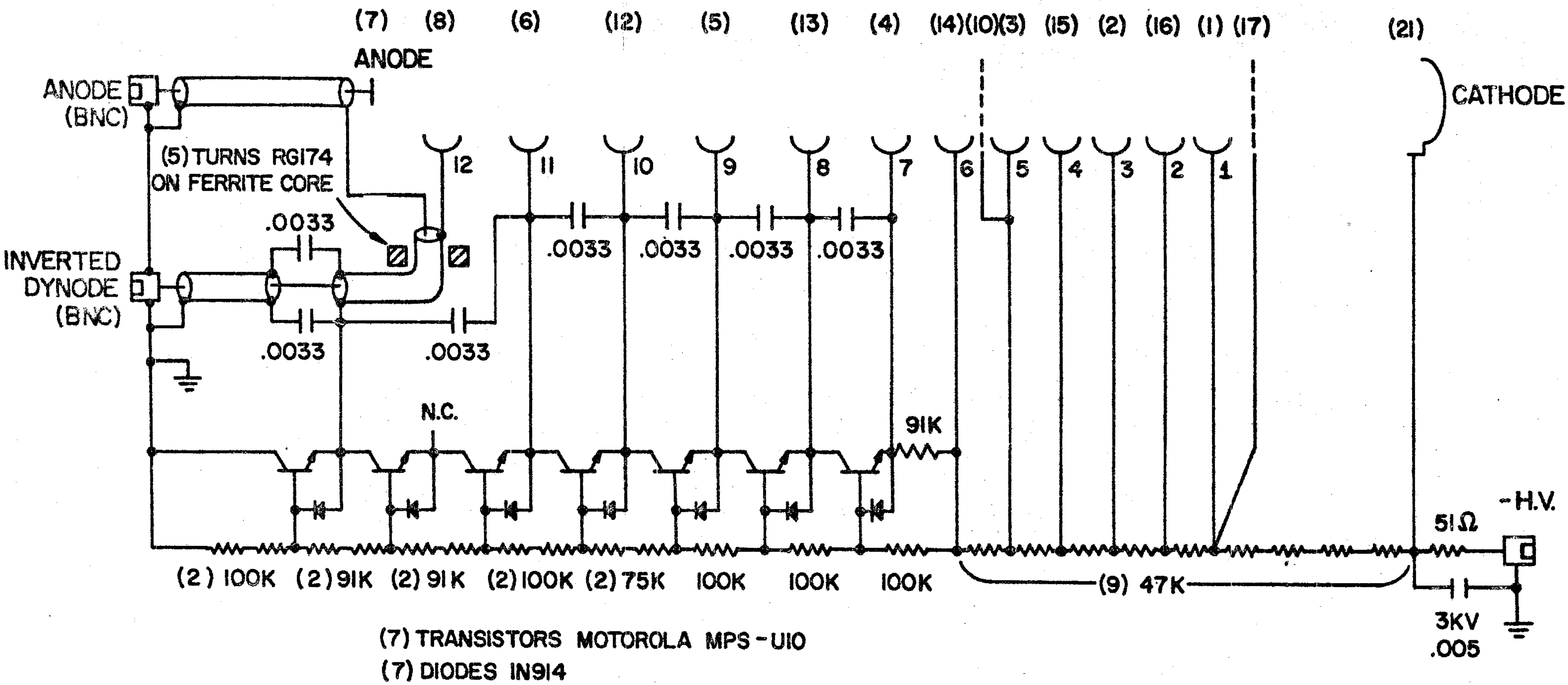

FIGURE 1 E-288 HIGH RATE PHOTOTUBE BASE