RB-126

# AN EXPERIMENTAL CODING TUBE

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# AN EXPERIMENTAL CODING TUBE

This bulletin describes an experimental coding or quantizing tube* providing ten output channels in which two electron multipliers, to obtain greater output current, are arranged in such a way that sharp separation between adjacent channels is maintained. In the tube, a 6-microampere electron beam from a conventional electron gun is electrostatically deflected into one or the other of the multipliers, the output appearing on one of ten collector electrodes. This output is essentially constant at 2 milliamperes for all deflection signals within 95 percent of each channel width. Long specially-shaped deflection plates provide a deflection factor of 5 volts per channel.

## Introduction

Several investigators have made switching tubes of various forms for many specific systems applications [1-8]. They have been variously called switching, commutator or coding tubes depending upon their use. All have essentially the same objectives; (a) many-channel output; (b) rapid, low-voltage switching across all the channels; (c) no spaces between channels; (d) low signal crosstalk between channels; (e) high output current; and (f) a flat output characteristic over as large a portion of the channel width as possible. This last is conveniently expressed as the *channel ratio*, the ratio of the respective switching or deflection voltages for that portion of the channel width for which the output is constant to that portion for which the output varies.

Requirements a, b, e, and f are interrelated by the physics of the formation and deflection of electron beams. The product of (a) the number of channels, and (f) the channel ratio is very closely the number of spot sizes per target diameter, and is to be recognized as the quantity called *resolution* in other types of cathode-ray tubes.

The experimental tubes described in this bulletin were made in an effort to determine how much the performance of coding tubes could be improved with respect to the characteristics listed above, particularly the obtaining of a high channel ratio and low adjacent channel crosstalk.

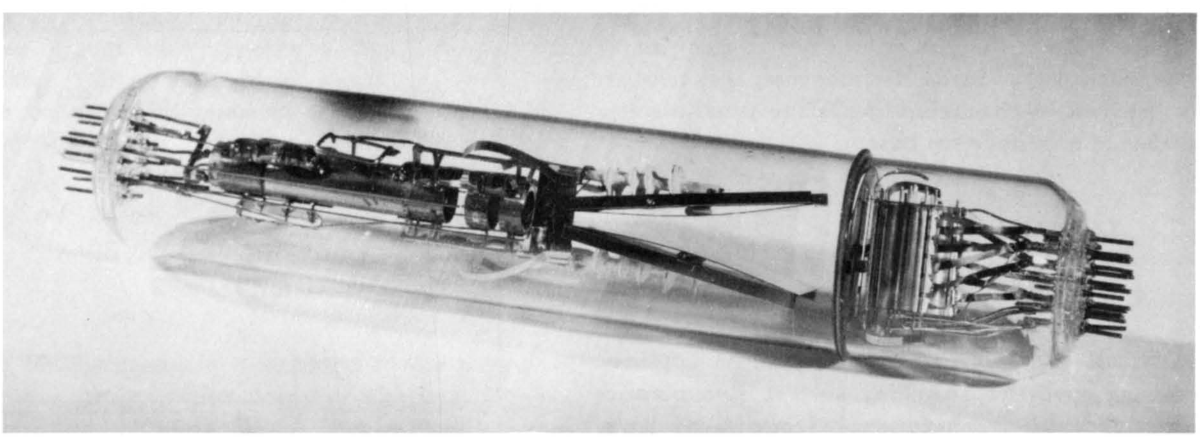

**Fig. 1 - Coding tube.**

*Developed on contract W7405-Eng. 26 Sub. 308 with the Atomic Energy Commission.

## Experimental Coding Tube

The tube made for this project (Fig. 1 and Fig. 2) comprises a conventional electron gun utilizing electrostatic focusing and deflection, a shield brought out on a ring seal and a target structure having two electron multipliers and ten signal output electrodes. The input switching signal is applied to one set of deflection plates. A fixed amplitude output signal appears on one of the collectors, selected in accordance with the amplitude of the input signal. The output signal amplitude can be modulated if desired by a signal applied to the control grid. The shield at the ring seal serves to isolate the collector electrodes and their associated circuits from the relatively large signals that are applied to the deflection plates.

The tube is usually operated with 1000 volts across the electron gun for which the control grid cutoff is about 20 volts, and 1000 volts across the multipliers. It is advisable to operate the collectors at ground potential and the cathode at minus 2000 volts.

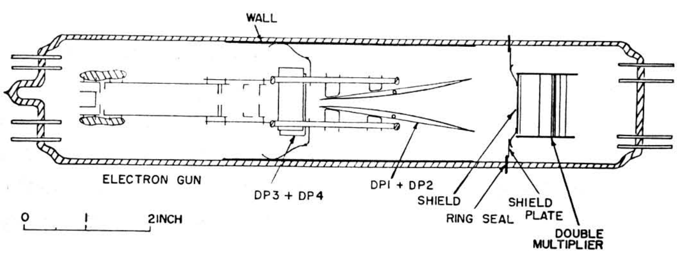


Fig. 2 . Cross section of coding tube.

## Number of Channels

The number of output channels available is arbitrarily chosen to be ten, since this was deemed to be a sufficiently high number both to be useful and to allow some latitude in design ingenuity, yet not so many as to require too many output leads. Furthermore, this number leaves a reasonable channel ratio for the usual resolution available in a cathode-ray tube.

## Deflection Sensitivity

Nearly all switching tubes are used in applications requiring aperiodic switching so that electrostatic deflection is necessary. Conventional electron guns have deflection sensitivities of approximately one spot size per volt. In the experimental tubes here described, two sets of deflection plates are used. The first set, quite short, is simply intended for centering on the target and could be omitted if target and gun are aligned carefully and provision is made to eliminate extraneous magnetic fields. It can also be used for sampling [8] in systems requiring it. The second set is long and specially shaped to increase the deflection sensitivity in the direction of input switching signal deflection. A deflection sensitivity of four spot sizes per volt is attained this way.

In other terms, conventional electron guns have deflection factors of about 150 volts per target diameter-kilovolt ultor voltage. With the special deflection plates, the experimental tubes have a deflection factor of 50 volts per target diameter-kilovolt. The total deflection angle is nearly 30 degrees.

## Output Current

The outstanding feature of the experimental tube is the use of an electron multiplier to increase the output current to a value that will eliminate the need of an amplifier stage between the coding tube and the subsequent circuits. Several ways of introducing a multiplier in the output have been tried. Most use a separate multiplier for each channel, causing the tube either to become clumsy, have spaces between channels, reduce the channel ratio, or limit the number of channels per tube. A single multiplier for all channels suffers from beam spreading within the multiplier and either introduces crosstalk between channels or reduces the channel ratio.

In the experimental tube made for this project, two multipliers are used, one for the odd-numbered channels and another for the even-numbered channels. The first dynode encountered by the primary beam (SA in Fig. 3) has five square apertures punched in it such that the "lands" between the apertures are equal in

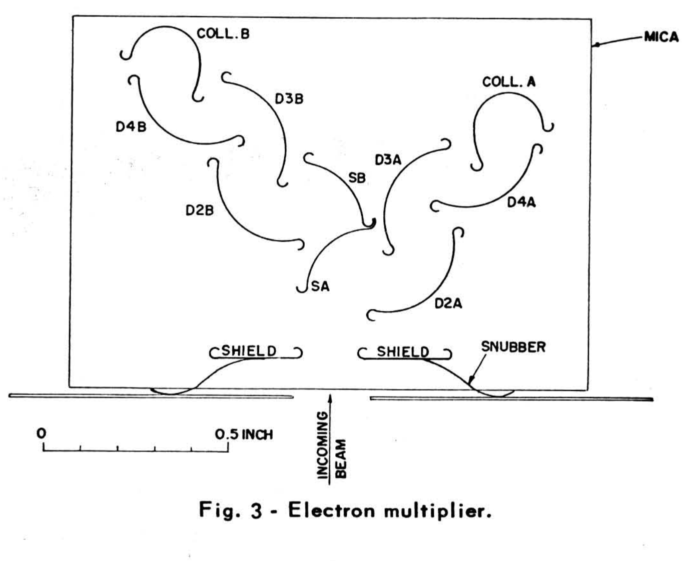


Fig. 3 - Electron multiplier.

width to the widths of the apertures. A primary electron striking a "land" produces secondary electrons that proceed through multiplier A to one of its odd-numbered collectors. However, a primary electron that arrives at an aperture in dynode SA, continues through to dynode SB at the same potential. Secondary electrons produced there proceed through multiplier B to one of its even-numbered collectors. The channel edges are thus determined by the aperture edges in dynode SA, which, because it separates the electrons into the groups that go through one or the other multiplier to their respective collectors, has been called the "separode". Since the primary beam must either strike a land of the separode or go through an aperture to strike the dynode SB, there are no spaces between channels, and the overlap during which there is simultaneous output from two adjacent channels is only as wide as one spot size.

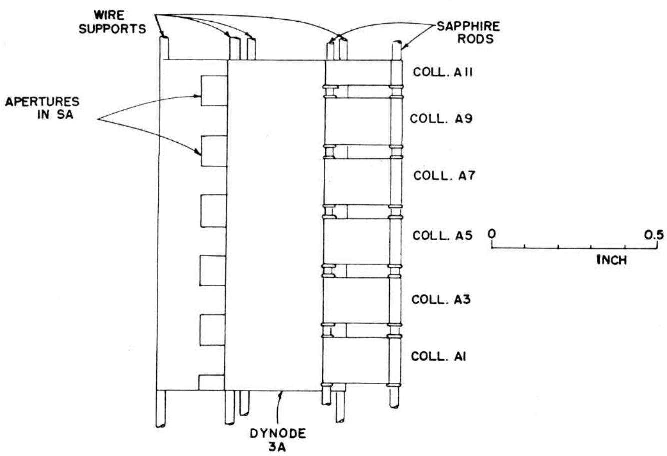


Fig. 4 - Elevation of electron multiplier.

With 250 volts per dynode, four gainful silver-magnesium dynodes, 1000 volts across the whole multiplier, a 6-microampere primary beam produces a 2-milliampere output current. This output current can be measured from an oscillogram such as in Fig. 5. This gives the output signal that appears across a 10,000-ohm load resistor. For calibration the separate vertical line is the unscanned oscillogram of a 15-volt peak-to-peak sine wave.

## Channel Ratio

The channel ratio is determined by the number of channels and the resolution possible with best focus at the apertures in the separode. A conventional electron gun producing a circular spot was chosen because it is believed that with it a smaller spot can be obtained than with a line beam gun which has the additional possible difficulty of alignment of the line beam parallel to the aperture edges. It is hoped that the loss in primary beam current can be made up by the gain of the multiplier. The small beam current, 6 microamperes, was chosen to obtain a small spot, 4.5 mil at 4.3 inch from the center of the focusing lens, with 1000 volts from cathode to target. With an 0.9-inch target, 10 apertures, this provides 200 spot sizes per target diameter and a channel ratio of 20. It should be mentioned that the definition used for spot size is that distance the center of the beam moves in scanning across a sharp-edged metal ribbon while the signal current to the ribbon varies between 10 percent and 90 percent of maximum value. This is exactly the action of the beam as it moves across an aperture edge of the separode. This is demonstrated in the output oscillogram in Fig. 5.

## Crosstalk

With the present arrangement of two multipliers, adjacent channel crosstalk is nil since the electrons are directed by the separode into only one multiplier and cannot possibly reach a collector simultaneously in both multipliers. Some small amount of spreading of the beam as it traverses a multiplier can be tolerated since the neighboring collector that can be reached is two channels away. However, the beam does spread appreciably in the multiplier so that electrons do reach the *second-adjacent* collectors as indicated by the output oscillogram in Fig. 5. This is the output signal from the collector of channel 4 as the beam is scanned across the target. It naturally has its greatest output while the beam is in channel 4. There is no signal at all while the beam is in either of channels 3 or 5, the adjacent channels, but there is some output while the beam is in either channels 2, 6, or even 8. For binary signals this is small enough to be clipped out by a threshold circuit but it would not be satisfactory for the switching of a modulated beam signal.

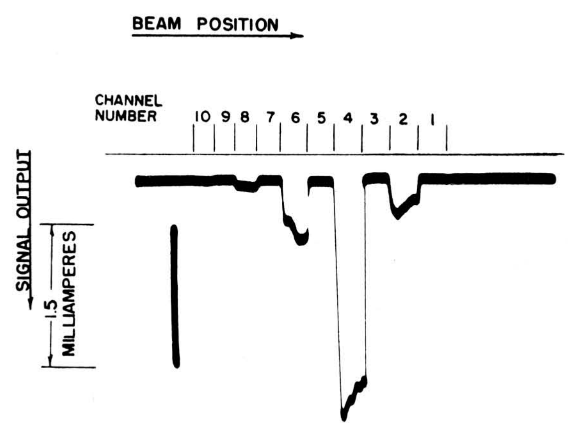


Fig. 5 - Oscillogram of output signal from dynode 4B.

## Further Problems

*Shading*

It is evident in the oscillogram of Fig. 5 that the output is not ideally constant over the width of the channel. This is undoubtedly a result of variations in secondary emission of the silver-magnesium dynodes causing a variation in the gain of the multiplier. There is need for more careful processing of the dynodes and possibly either a wobbling signal on the centering deflection plates or the use of a short line beam to obtain an averaging effect.

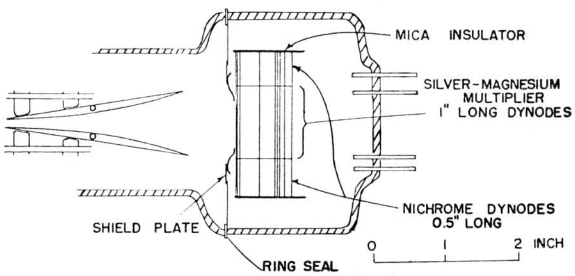


Fig. 6 - Coding tube with field guard dynodes.

*End effects*

A definite loss of signal in the end channels (1, 2, 9 and 10) was observed, a result of charging of the mica end plates in the multipliers. A tube having long dynodes so that the end extensions acted as field guards did not exhibit this difficulty (Fig. 6).

## Conclusions

It has been shown that a simple arrangement of common electron multipliers can be used to increase the output current of a switching tube without reducing the channel ratio or introducing spaces or overlaps in the switching range.

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## References


1. D. D. Grieg, J. J. Glauber and S. Moskowitz, "The Cyclophon: A Multipurpose Commutator Tube", *Proc. IRE,* Vol. 35, pp. 1251-1257, November 1947.
2. R. W. Sears, "Electron Beam Deflection Tube for Pulse Code Modulation", *Bell System Technical Journal,* Vol. 27, p. 44, January 1948.
3. A. M. Skellett, "Electrostatically Focused Radial-Beam Tube", *Proc. IRE,* Vol. 36, pp. 1354-1357, November 1948.
4. W. E. Glenn, Jr., "Pulse Height Distribution Analyzer" *Nucleonics,* Vol. 4, pp. 50-61, June 1949.
5. A. G. Kandoian and A. M. Levine, "Experimental Ultra-High-Frequency Multiplex Broadcasting System" *Proc. IRE,* Vol. 37, pp. 694-701, June 1949.
6. D. A. Watkins, "The Ten Channel Electrostatic Pulse Analyzer", *Rev., Sci., Inst.,* Vol. 20, pp. 495-499, July 1949.
7. G. W. Gray and A. S. Jensen, "Deflection of Cathode-Ray Tubes in Sequence", *RCA Review,* Vol. XI, pp. 527-533, December 1950.
8. R. P. Stone, C. W. Mueller and W. M. Webster, "A Time-Sampling and Amplitude-Quantizing Tube", *Proc. IRE,* Vol. 43, pp. 960-966 August 1955.