論 文
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計數率 增加에 따른 光增培管의 利得安定을 위한 궤환저항 효과에 관한 硏究

A Study of Feedback Resister Series Effects for Stabilizing the Gain of the Photomultiplier with Counting Rate Increase

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Abstract

The gain change of the photomultiplier which occurs as the count rate increased was examined. And simple feedback resistor series was introduced between 7th and 9th dynode for compensating the gain change.

The effect of the feedback resistor series was considerably good to reduce the gain change.

With the feedback resistor, the gain change was only 1.9%, when count rate was increased from 514 CPS (counts per second) to 1250 CPS.

Without the feedback resister, the gain change was 6.9%, when the count rate was increased from 530 CPS to 1250 CPS.

1. Introduction

One of the difficulties when we wish to make accurate measurements of the pulse amplitude distribution in scintillation counter is that the gain of a photomultiplier is usually not very stable. The amplitudes of the voltage pulses produced by a photomultiplier when viewing scintillations are known to depend not only on the luminous intensities and durations of the scintiliations but also on the pulse counting rate.

The variation of pulse amplitude with counting rate has been attributed to the changes of interdynode voltages which are know to occur when the current drawn by the photomultiplier from its dynode chain changes with counting rate.

In practice, this alterations cause variations of the multiplication coefficient and consequently a long term drift of the total gain.

In order to avoid these disadvantages, several photomultiplier gain stabilization circuit have been suggested. Such circuits are usually based on the following techniques which are voltage reference tube[1], silicon voltage reference diodes[2,3], emitter follower circuits[4] and reference line[5,6,7] for improving the voltage regulation of all stages, or at least the last few stages, of the dynode chain.

But there are so complicated that construction is not easy. Taking this point in to account, simple method was tried using voltage dependent resistor method.[8]

In this study, simple compensation method is introduced by adding a feedback resistor series to the multiplier dynode chain itself. Therefore it is simple and considerably cheaper than other methods.

2. Experimental Method

In order to examine the gain change with counting rates variation, NaI(Tl) scintiliation spectromenter was used as Fig. 1. NaI (Tl) crystal was 5"dia×4" deep and mounted on 56 AVP 14 stage photomultiplier. And Na^{22} ($3\mu ci$) γ-ray source used. And in this experiments, the coun-

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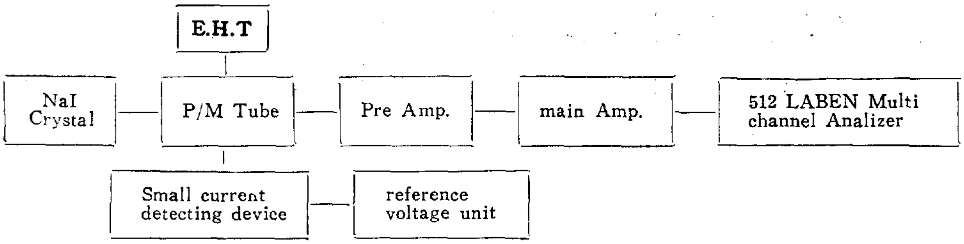

Fig. 1. Block diagram of experiment

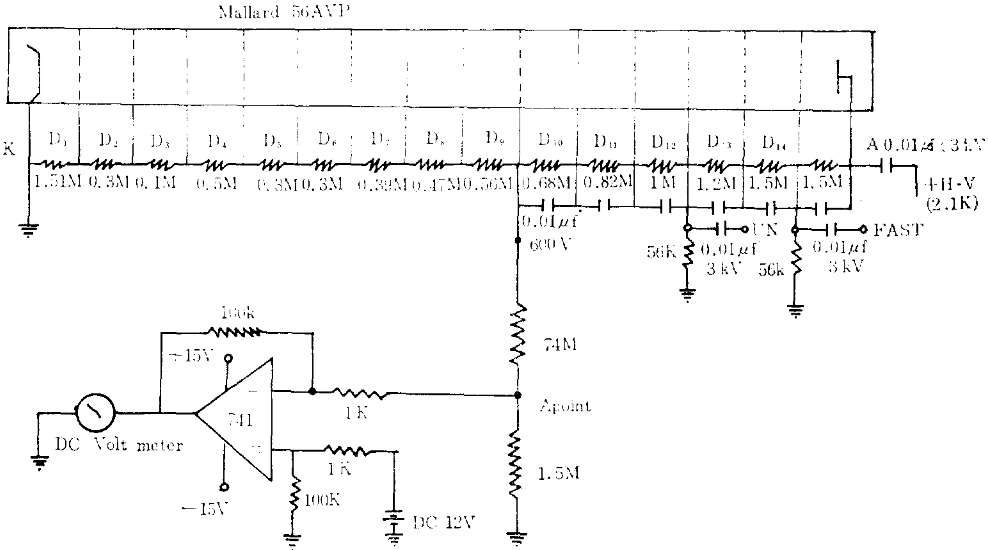

Fig. 2. Photomultiplier dynode chain and detecting circuit.

ting rates was a function of the distance of the source from detector.

Therefore, counting rates were varied with changing the distance, as 7cm, 17cm, 25cm.

The overall voltage applied to photo tube was 2.1kV.

The 9th dynode was used for detecting voltage change as the counting rates varied.

To investigate the voltage change at the 9th dynode, the resistor series was made with differential amplifier which amplifies voltage difference between referance voltage and voltage detected from resistor series of point A.

Thus resistor series was consisted of very large value of resistor to reduce the voltage droping effect when the resistor series was added in parallel.

The circuit diagram of the resistor series is shown in Fig. 2.

And differential op amp. was built as shown in Fig. 2.

For this amplifier, Texas Instruments Standards 14 pin 741 I.C. was used.

The pulse from the 12 th dynode of the photomultiplier due to the detection of γ-rays in the NaI (T1) orystal were amplified by preamplifier and main amplifier.

The pulse height distribution was displayed by 512 Laben multi channel Analyser.

Typical pulse hight spectrum is shown in Fig. 3.

This spectrum is due to γ-rays of Na^{22} with energies of 0.51 MeV, 1.28 MeV.

The energy associated with each prominent peak in the spectrum was plotted against its position as indicated by the circle point as shown in Fig. 3.

The graph of the γ-ray energy against channel number is linear, and the reciprocal of the slope of this line is taken as a measure of the gain of

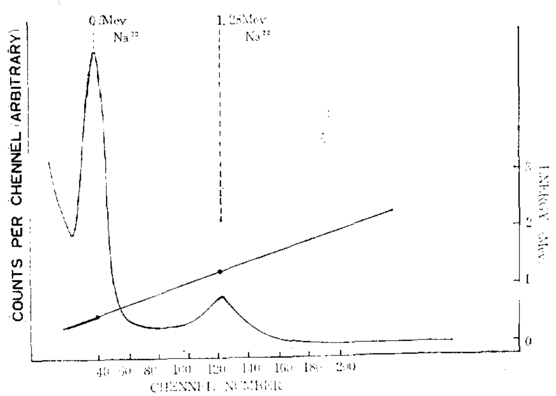

Fig. 3. A typical pulse height spectrum and calibration line, when the NaI (Tl) crystal detector is used with Na^{22} γ-ray source.

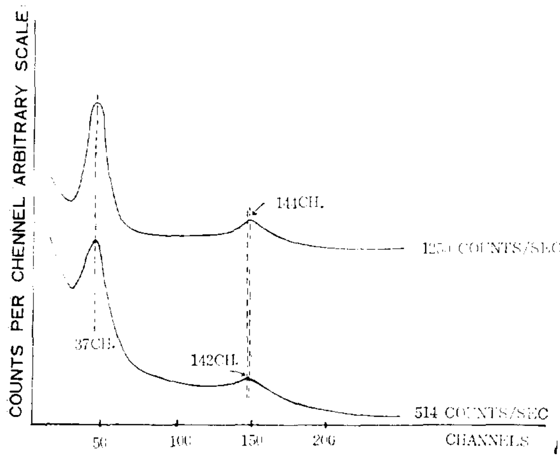

Fig. 4. Series of pulse height spectra without feedback series resistor.

the spectrometer in channel per MeV.

The counting rates was varied by altering the distance of Na^{22} γ-ray source from detector.

The pulse height spectra were recorded at 530, 800, 1250 cps. without feedback series.

The pulse height spectra are shown in Fig. 4. with respect to 530,800, 1250 cps.

The voltage at 9th dynode was increased as the counting rate increased. The voltage variation at 9th dynode due to the counting rate change is shown in Table 1.

Table 1. The voltage variation at 9th dynode due to the counting rate change.

counting rate	variation of 9th voltage
530 cps	865+1.5V
800 cps	865+2.8V
1250 cps	865+4.6V

3. Feedback Resistor Design

According to the results of the gain change feedback resistor series was constructed.

In order to design feedback resistor, 6th, 7th, 8th and 9th dynode voltage checked while photo multiplier was performed. It was 580V, 660V, 753V and 865V, respectively.

When the feedback resistor is added to the photo multiplier dynode chain between 9th and 7th, the output gain of the 9th dynode would be distributed as Fig. 5(a), against to 7th voltage change.

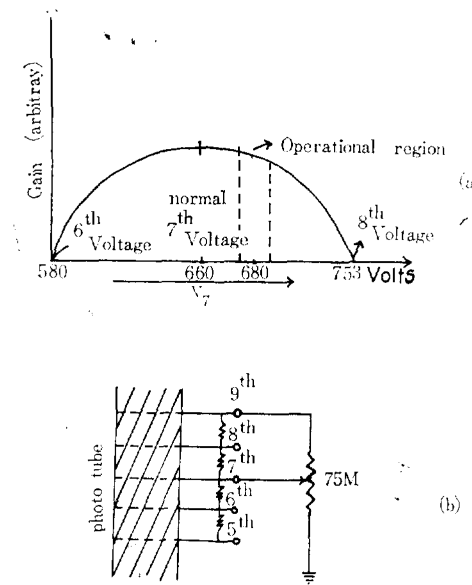

Fig. 5. Gain distribution against 7th dynode voltage change (a), and feedback circuits (b).

Referring the data of the voltage change and the pulse height spectra gain shifts shown in Fig. 4. it is reasonable to use the declining curve of the gain in Fig. 5(a).

Then, as the 9th voltage increased, feedback voltage to 7th dynode would be increased, therefore the output gain of the 9th dynode would be declining. The total gain of the 9th dynode would be maintained nearly constant.

Finally, the 7th dynode voltage was determined at 680 volts as 7th dynode operational fixing voltage by considering ufficient voltage change at 9th dynode.

4. Results

Through a number of experiments, the shift of the peak was found as shown in Fig. 4.

It can be seen from Fig. 4. and Table 2, that the shifts in the position of the peaks caused by the change of counting rates moves towards higher channel number.

When adding the feedback resistor series to 9th, 7th dynode (Fig. 6), the shifting effect is reduced considerably smaller than without feedback resistor series.

A quantitative comparison of the variation in gain with counting rate was made by determining the gain in channels per MeV, from the γ-ray energy Vs channel number as shown in Fig. 7 (A) and (B).

The percentage change in gain is defined as 100 (Gn-G530)/G530 when without the feedback, and 100 (Gn-G514)/G514 when with the feedback.

Where Gn is the gain in channels per MeV at the counting rate of n cps.

From above equation, G530 is 150.65 and G800 is 154.54 and G1250 is 162.33.

And with the feedback resistor series, G514 is 136.36 and G1250 is 138.96.

From the definition, the gain change is calculated as below(Table 3).

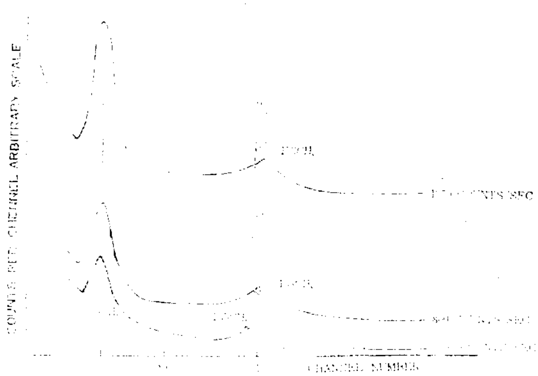

Fig. 6. Series of pulse height spectra with feedbackresistor series.

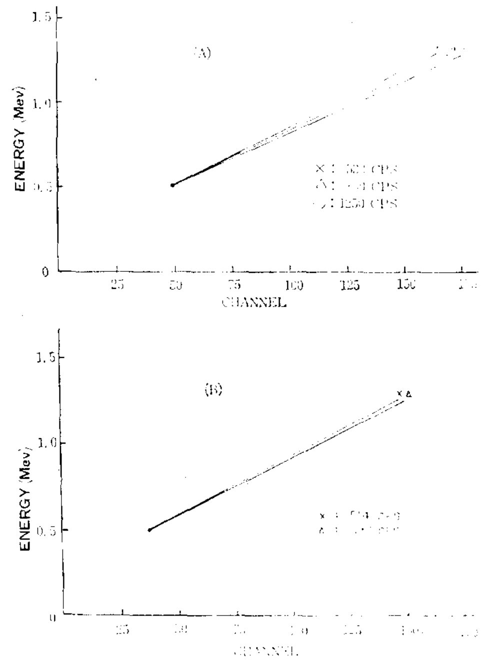

Fig. 7. Calibration line of the spectra(A) without feedback resistor (B) with feedback resistor

Table 2-A. Channel Variation due to counting rate change without feedback resistor

cps \ Energy	0.51MeV	1.28MeV
530	49 channel	165 ch
800	49 channel	168 ch
1250	49 channel	173 ch

Table 2-B. Channel Variation due to counting rate change with feedback resistor

cps \ Energy	0.51MeV	1.28MeV
514	37 ch	142 ch
1250	37 ch	144 ch

Table 3. Calculation of the Gain Change

Mode	Calculation	Gain Change
without feedback resistor	100(G800-G530)/G530	2.58%
	100(G1250-G530)/G530	6.90%
with feedback resistor	100(G1250-G514)/G514	1.90%

The gain change in percentage is depicted in Fig. 8.

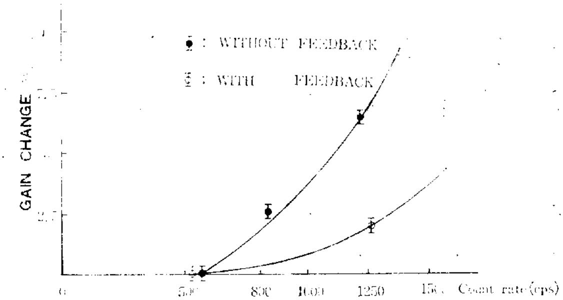

Fig. 8. Percentage gain change with counting rate.

From the results, it is easily found that the feedback resistor series effect is reasonably good in compensating a gain change.

5. Conclusion

In this experiments, gain change of the photomultiplier was examined and simple feedback resistor series was used for compensating voltage change at 8th dynode.

The effect of the feedback resistor series was considerably good to compensate the gain change. With the feedback resistor, when the counting rate changed from 514 CPS to 1250 CPS, the gain change in percentage was 1.9%. While without feedback resistor, the gain change was 6.9% when the counting rate changed from 530 CPS to 1250 CPS.

The higher counting rate, though, was not studied in this experiments, it can be sure that feedback resistor series will give a good results like in the case of small counting rate change.

One of the good advantages of this method for compensating gain change in photo tube is that it is more simple and easier than other method such as gain stabilizer.

And specially this can be achieved by cheap resistor series.

References

1. R. Stump and H.E. Talley; Rev. Sci. Instr. 25 (1954)
2. B.d'E. Flagge and O.R. Harris; Rev. Sci.Instr. 26 (1955)
3. R.W. Hendrick; Rev. Sci. Instr. 27 (1956)
4. A. Barna; Nucl. Instr. and Meth. 24 (1963).
5. H. de Waard; "Stabilizing scintillation spectrometers with counting rate difference feedback" Nucleonics, Vol. 13, No. 7 (1955).
6. K.W. Marlow; "A system for stabilizing the gain of a scintillation spectrometer." Nuclear Inst. & Meth. 15 (1962).
7. M. Ageno and Felici; "Photo multiplier gain stabilization circuit," Rev. Sci. Instr. Vol. 34, No. 9
8. R.B. Galloway and D.G. Vass; "A voltage dependent resistor dynode chain to reduce the variation of photo multiplier gain withcounting rate," Nucl. Instr. and Methods, 49 (1967).
9. Robert F. Coughlin and Fredrick F; "Operational amplifiers and linear integrated circuits," 1977. Prentice-hall.
10. Mullard Photo multiplier tube catalogue, Mullard Limited.