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GAIN VARIATION OF A PHOTOTUBE IN THE FREQUENCY DOMAIN AT VERY SHORT TERM

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ABSTRACT

A new very fast pulse generator with injected charge control is used to drive a LED-phototube configuration, reproducing the working condition of many experiments in High Energy Physics which make use of fast plastic scintillators. We have studied the behaviour of the Philips XP 2008 phototube operated under such experimental conditions. We find a gain shift vs frequency whose amount is a function of intensity of the light incident on the P.M. For an output ranging between 83 and 450 pC the gain shift at about 33 KHz varies in the range 15%÷ 33%.

1. - INTRODUCTION

According to the standard test procedure provided in the AMERICAN NATIONAL STANDARD(1), a phototube should not change its gain for frequency variations in a range of 10^3 to 10^4 Hz, if excited by light pulses coming from a NaI crystal exposed to a ^{137}Cs source.

Such a procedure implies that the light pulse duration must be ~ 500 ns, i.e. one order of magnitude greater than that we have for light coming from a fast plastic scintillator (NE 102, NE 110 etc.). Measurements performed by other authors(2) with a pulse width on the LED of 100 ns shown a gain dependence on frequency of about 5% at 8 KHz.

Fast scintillator-PM configuration is the one normally used in high energy experiments for timing and pulse height analysis. The study of the frequency response performed under these experimental conditions is possible, practically, only by the use of LEDs (or Laser Diodes as required). However, to reproduce the time characteristic of the fast scintillators it is necessary to drive the led with very fast ($t_r < 1,5$ ns; $t_f < 3$ ns) short (width $\sim$ 10 ns) and sufficiently high pulses (up to some tens Volts). Unfortunately it is difficult to find fast and calibrated pulse generators whose output does not vary appreciably as a function of the repetition rate. To solve this problem and also to automatize the measurements we developed and carried out(3) a charge-calibrated pulse generator with a precision better than 1% over the frequency range of 128÷ 33000 Hz, and with the facilities of programmability and read-out by on-line computer via CAMAC.

2. - EXPERIMENTAL METHOD

Measurements have been performed on a phototube Philips XP 2008 (Fig. 1) supplied through a 1.5 MΩ B-type voltage divider of high stability (TEMCO $\leq$ 50 pp M/^{0}C) and precision (1%) with a high voltage of -1494 $\pm$1 V

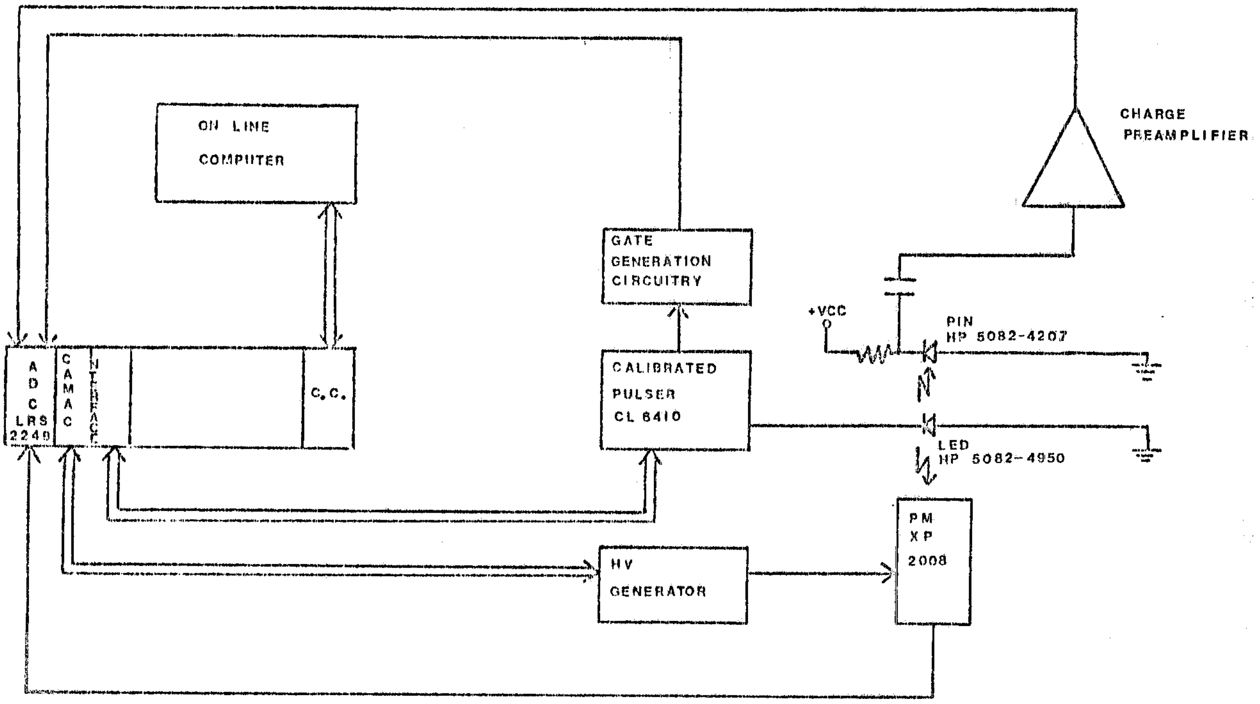

FIG. 1 - Experimental set-up.

(ripple less than 0.1 Vrms). The measurement set-up was arranged with a 10 bits charge-integrating ADC (LRS 2249) with a gate of 60 ns (to reproduce completely the real working conditions of a PM) and with a gallium phosphide green LED, HP 5082 - 4950 type(4), directly coupled to the PM's photocathode.

Generally(2) green LEDs present a thermal stability better than red LEDs, also with respect to spectral sensitivity of the phototube, and its long term stability is such as to arrive at 0.5% in one day with constant temperature. The external LED temperature in our measurement was 24 $\pm$ 0.5 ^{0}C. Each measurement is the average of 10.000 events. Measurements have been taken starting with the reference frequency of 128 Hz, up to $\sim$33 KKz, with nine steps (power of two). Moreover, such measurements have also been repeated varying the charge injected into the LED. This procedure detects eventual dependences of gain on amount of incident light, and especially it reproduces the real extreme working conditions of a PM: small, medium, high light intensity. A

PIN diode HP 5082 - 4207 type(5) coupled to a charge preamplifier(6) driving a reading ADC (LRS 2249), has been successively used to verify carefully the absence of gain variations of the LED vs frequency. Our experimental results show no gain variation of the LED vs frequency within ±2%. This relatively low accuracy however, is due to noise effects of the PIN-preamplifier circuitry according to measurements performed by means of a calibrated pulser.

In advance, some test has been done, using an HP 8082A pulse generator, to check the response of the LED at frequencies up to 1 MHz. With a pulse driving the LED of 5 V/50Ω of amplitude and width of 50 ns, no appreciable light output variations of the LED vs frequency has been observed.

3. - RESULTS

The digital value (0.25 pC/bit) read from the charge-integrating ADC vs frequency (nine values), at constant charge injected to the LED, are reported in the horizontal line of Table I. The same measurements have been repeated, moreover, for seven values of charge injected to the LED, and they are also shown in Table I.

TABLE I : Digital value (0.25 pC/bit) from PM's output read by the charge-integrating ADC vs frequency (nine values). The measurements are listed for the seven values of charge injected to the LED.

ACD LDD	128 Hz	256 Hz	512 Hz	1024 Hz	2048 Hz	4096 KHz	8.2 KHz	16.4 KHz	33 KHz
250	332	329	332	338	245	353	361	367	381
300	553	549	555	567	579	592	608	623	649
350	787	783	795	812	830	851	874	900	939
400	1031	1033	1052	1075	1100	1129	1162	1199	1256
450	1279	1282	1309	1338	1373	1410	1543	1500	1578
500	1534	1539	1574	1610	1653	1699	1753	1813	1915
550	1799	1807	1851	1895	1945	2043	2106	2180	2316

ADC = 0.25 pC/bit
LDD = Arbitrary Unit

The gain variation of PM vs frequency, for constant charge injected to the LED is plotted in Fig. 2. As normalization factor has been taken the digital value read from the ADC LRS 2249 at the lowest repetition rate (128 Hz)*. According to Table I the value of gain variation has been calculated for all the seven different values of the injected charge.

4. - CONCLUSIONS AND DISCUSSION

Our results show a general increase of the PM gain when the excitation pulse rate is increased. Moreover this gain depends on the intensity of the driving pulse and it increases with the increasing of this intensity. A check carried out by means of an HP 5082 - 4207 diode excluded appreciable variations of the light emitted by the LED vs frequency variations. Quantitatively, using the frequency of 128 Hz as a normalizing factor, and that of 33 KHz as the maximum frequency, the gain increase of the PM starts from ~ 15% (for weak driving pulses i.e. about 83 pC on the reading ADC) to arrive at ~ 29% (for strong driving pulses, i.e. about 450 pC on the reading ADC).

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*This variation can be described by a second order polynomial function in the log ν variable (see appendix).

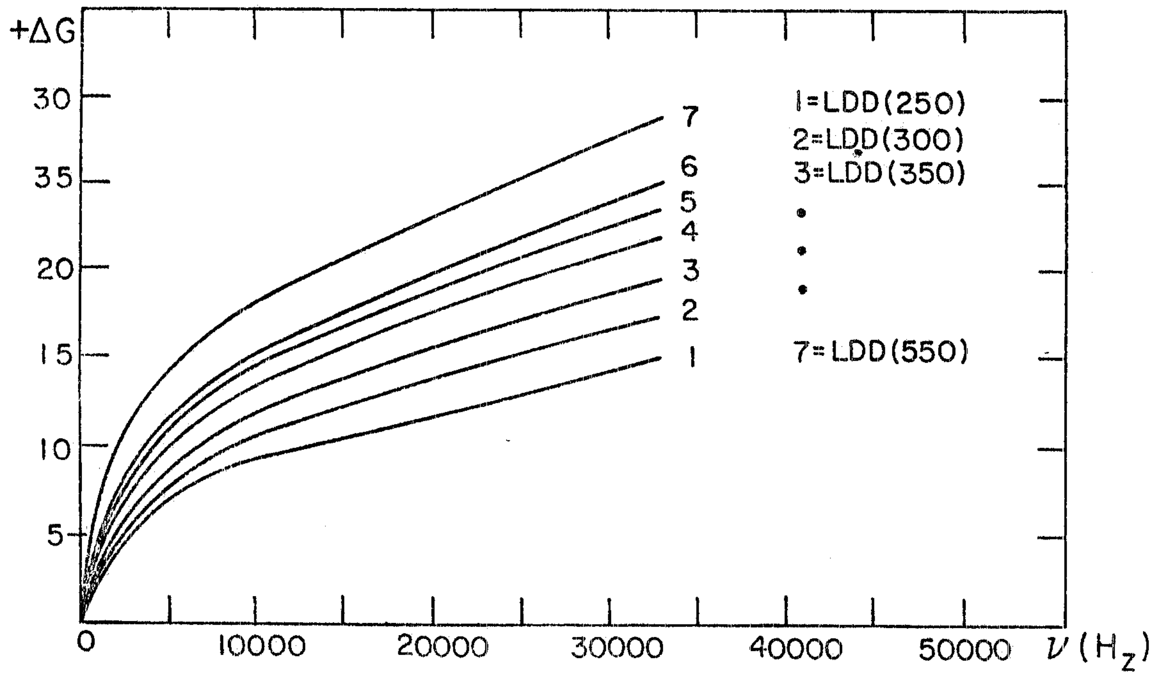

FIG. 2 - Gain variation of the PM vs frequency for seven values of light intensity. The LDD(250) is the smallest value, the LDD(550) is the higher value of incident light intensity.

The measurements reported have been taken in conditions quite different from those stated in the AMERICAN NATIONAL STANDARDS. They differ also from the measurements performed by W.L. Reite and G. Stenge(2) who found a gain variation of about +5.8% at 14 KHz and +5.2% at 8 KHz for a pulse width of 100 ns, temperature of 21 ^{0}C, and probably low light intensity (we estimate 80% of our smallest intensity).

Our results represent meaningful measurements because thay are made with a pulse width really comparable to the typical times produced by means of fast plastic scintillators. Our measurements and the results of ref. (1,3) suggest that the gain increase of PM vs frequency becomes significant by reducing the pulse width of incident light. We have repeated the same measurements on other PMs type XP 2008 and results agree within ~ 20%.

Finally this anomalous effect shows the need of a more critical examinations of the PM response in those cases when a considerable variation of counting and/or intensity will be present. Particularly in all those experimental conditions where the "energy" analysis of the PM response is performed during the burst at a time $t \neq t_0$, t_0 being the beginning time of the particle bunch.

ACKNOWLEDGEMENTS

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APPENDIX

The gain variation plotted in Fig. 2 is fitted with sufficient accuracy by the function

$$G=A\,(\log \nu^{*})^{2}+B\,(\log \nu^{*})$$

where the A,B, constants depend on the light intensity on the PM and are listed below:

LDD	A	B
250	2.49	0.16
300	2.96	0.01
350	3.08	0.52
400	3.00	1.66
450	3.10	2.04
500	3.27	2.15
550	3.45	3.36

and ν^{*} is: $\nu/128$.

REFERENCES

(1) American National Standard ANSI n° 42.9 (1972) and IEEE std 398 (1972); "IEEE Standard Test Procedures for photomultipliers for Scintillation Counting and Glossary for Scintillation Counting Field", (1972).
(2) W.L. Reiter and G. Stengl, Nucl. Instr. and Meth. 169, 469 (1980).
(3) R. Baldini et al., A very fast programmable pulse generator with injected charge control, Nucl. Instr. and Meth. (1980), to be published.
(4) Hewlett Packard, Optoelectronic Designer's Catalog (1980), p. 113.
(5) Hewlett Packard, Optoelectronic Designer's Catalog (1980), p. 20.
(6) The low-noise charge preamplifier has been developed starting from a design of T. Droege at Fermilab, Batavia, by two of us (F. Celani and G. Levy) together with Prof. M. Coli of CNEN, Laboratori Nazionali di Frascati, in the LNF and has been optimized to be used with the HP 5082-4207 PIN photodiode.