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AUTOMATIC GAIN CONTROL OF A PHOTOMULTIPLIER AND RELATIVE ELECTRONIC LINEAR CHAIN

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An automatic control system of a photomultiplier gain and of its electronic linear chain, which can be used also in presence of a high radiation level, is described.

1. Introduction

In order to do a pulse height analysis from a photomultiplier it is generally required to control the gain stability of the photomultiplier itself and of the following electronic chain.

For this purpose we have studied and built an automatic gain control system (AGC) which is simple and can be used when a high radiation level is present, as for instance near a particle accelerator[1]). This system also does not interfere with the circuitry of the experimental apparatus of which the photomultiplier is part.

Many different AGC systems have been suggested up to now. It will be convenient for us to examine some of them on the basis of used light source and of the way the gain control was performed.

Valekx[2]) suggests of using an artificial light source, in order to increase the photomultiplier background current in such a way that from a comparison of dc anode current with a reference current it is possible to control the gain of the photomultiplier.

This system is, however, useless if a high and not reliable radiation level is present. Using a low frequency light pulse[3]), which gives a modulation of the photomultiplier noise and an electric filter selecting the pulses gives remarkable advantages with respect to the previous system. Nevertheless this system does not solve completely the problem of the radiation background and it requires large block capacitors on the dynodes.

Furthermore, with the previous systems, it is impossible to control the stability of the electronic linear chain.

Fast light sources, as photodiodes or hydrogen lamps, by which it would be possible to avoid the previous disadvantages don't present, until now, a sufficient reliability. However, they also require a very stable pulse system.

Natural light sources, like the scintillations produced by an α or γ radiation with a long half-life in a plastic scintillator, are constant in the time, but they have not been used[4,5]) to solve the problem of the separation between the photomultiplier background and the pulses from the source.

All the systems we mentioned check the photomultiplier gain by varying the high voltage supply.

This gives, in principle, the disadvantage of the

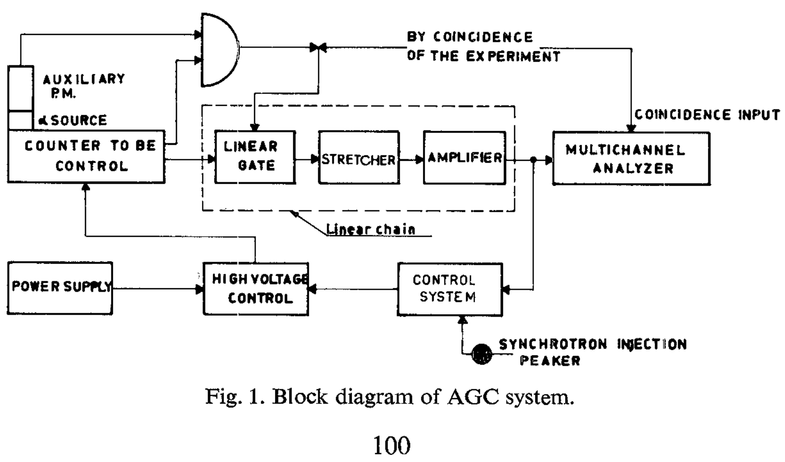

Fig. 1. Block diagram of AGC system.

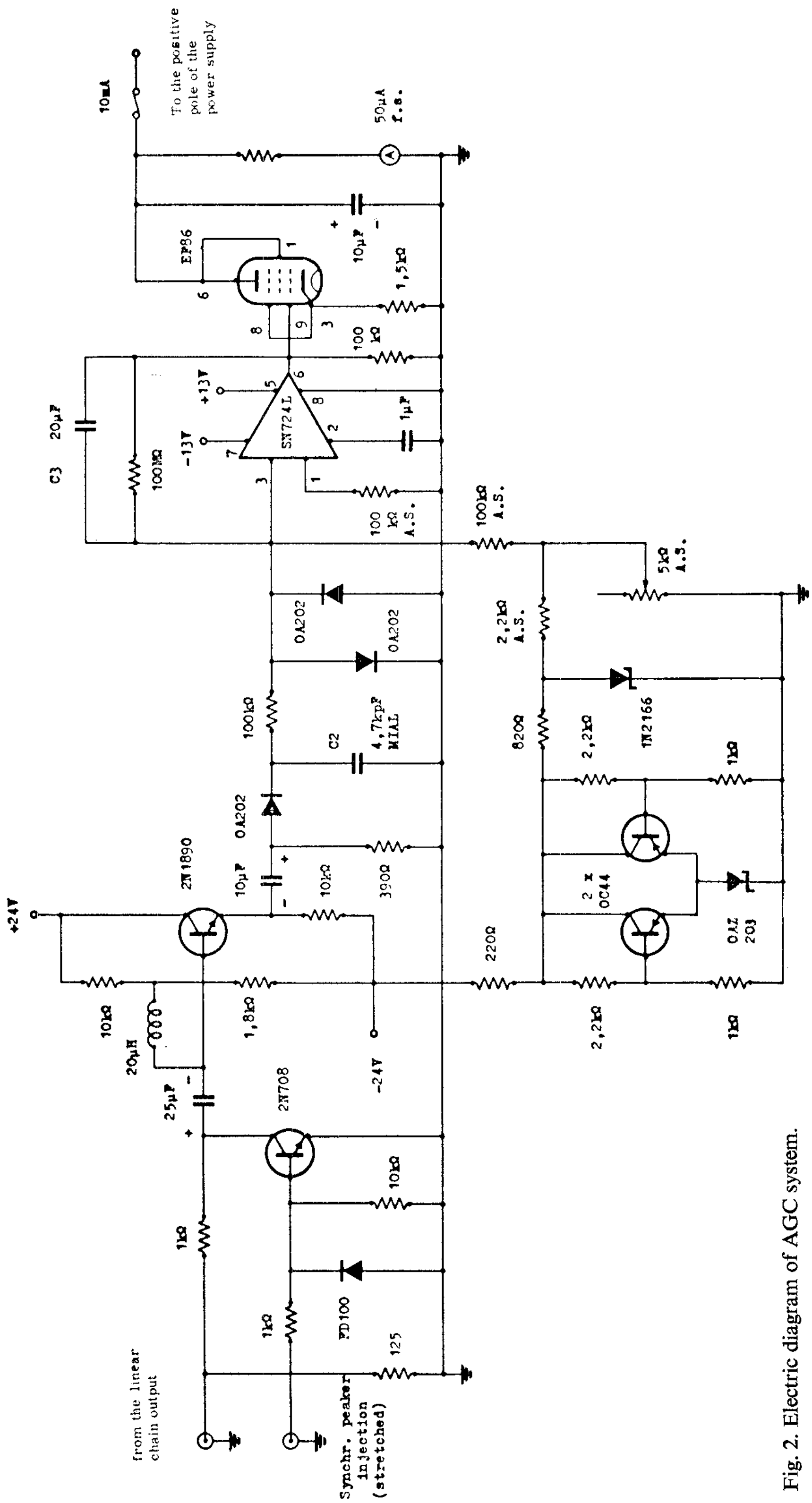

Fig. 2. Electric diagram of AGC system.

electrons transit time variation in the photomultiplier. However, in order to correct the gain variations, a variation of the voltage supply $\lesssim 100$ V is usually enough. The variation of the transit time of the electrons is then restricted to a normally allowed range ($\lesssim 2$ ns).

This drawback can be avoided[3]) completely if one regulates only the voltage supply of the last dynodes.

We quote here that more complex systems[6–8]) have been realized in which, by the way, the amplitude of the photomultiplier output signals is controlled by using a Raysistor.

2. Apparatus description

Fig. 1 shows the block diagram of the AGC system inserted in the experiment. The gain of the photomultiplier and of his electronic linear chain is controlled by varying the voltage supply of the photomultiplier itself.

For this purpose an electronic tube is mounted in series with the photomultiplier power supply.

The high voltage applied to the photomultiplier is then equal to the voltage of the power supply minus the voltage drop in the tube. This voltage drop is regulated in this way: the difference, between a reference voltage and a voltage proportional to the average value of the pulses of the photomultiplier exposed to a suitable light source is amplified and sent to the grid of the tube.

The light source consists of a plastic scintillator on which a solution of ^{241}Am nitrate has been evaporated to obtain a particle source of about 5×5 mm^2 and about 100 pulses/sec. (The energy of the α particles is ≈ 5 MeV and the half-life 458 y.)

Radiation damage in the crystal lattice produces effects greater than 1% on the scintillation power only after some months[9]).

The light produced by the α particles in the scintillator is sent both into the photomultiplier to be controlled and into a small auxiliary photomultiplier (Philips XP1110) which is in coincidence with the former one, to separate the pulses of ^{241}Am from the photomultiplier background. For this purpose we used a micrologic coincidence circuit with very low input threshold to be insensitive to its variations.

These pulses are sent through the electronic linear chain to the AGC system.

We note that, with respect to the photomultiplier background a fast light source of about 100 pulses/sec, widely sufficient for us, does not interfere with the experiment.

Fig. 2 shows the electrical diagram of the control system. Its input is interdicted during the time in which the pulses relative to the experiment are present in the linear chain (for instance during the spill-out of an accelerator). By means of an emitter-follower the pulses are fed onto an integrator which supplies at the output a positive direct voltage proportional to the average value of the pulses. To build up this integrator we used a monolithic operational amplifier, Texas 724L.

In order to make the system independent from changes in the pulse length of the linear stretcher in the linear chain, (we are interested only in the peak value) the operational amplifier is preceded by a peak integrator with a short time constant, which also increases the open loop gain.

Also a negative reference current is sent to the virtual ground of the amplifier. This current is regulated when the AGC is switched on for the first time in such a way that one can work with suitable set parameters (as the photomultiplier high voltage, the pulses attenuation and so on). The reference current, the capacitor of the peak integrator and the offset at the amplifier's output are chosen to do the control system independent from temperature changes in the range 0–50° C.

With reference to fig. 2, the integrator gain, that is the ratio between the continuous level v at the output and the mean level of the pulses v_α at the input is given by

$$v/v_\alpha = -C_2 R_3 f_\alpha,$$

where f_α is the average frequency of the ^{241}Am pulses. It is easy to show that the stabilization factor S, which is defined as the ratio between the percentage variations of the gain and the percentage changes of the average amplitude v_α, is in first approximation,

$$S = 1 + nAv_\alpha/v_T,$$

where n is the number of dynodes, v_T the photomultiplier voltage supply and A is the gain of integrating circuit times the tube gain.

In our case, for $S \approx 100$, with a 14 dynode photomultiplier (Philips 58AVP) and with a ratio v_α/v_T of about $3\,^0/_{00}$ we made $A = 3000$.

Of course the AGC system performance is better if A can be made greater. The statistical fluctuations in the α particles and photoelectrons emission are responsible of a fluctuation in the voltage applied to the grid equal to

$$\overline{V_g^2} = \tfrac{1}{2}\overline{V_\alpha^2} f_\alpha R_3 C_2^2/C_3,$$

where C_3 is shown in fig. 2.

In our case the statistical fluctuations on the photomultiplier voltage supply are smaller than $0.3\,^0/_{00}$.

3. Performance

We simulated the gain variations by inserting a

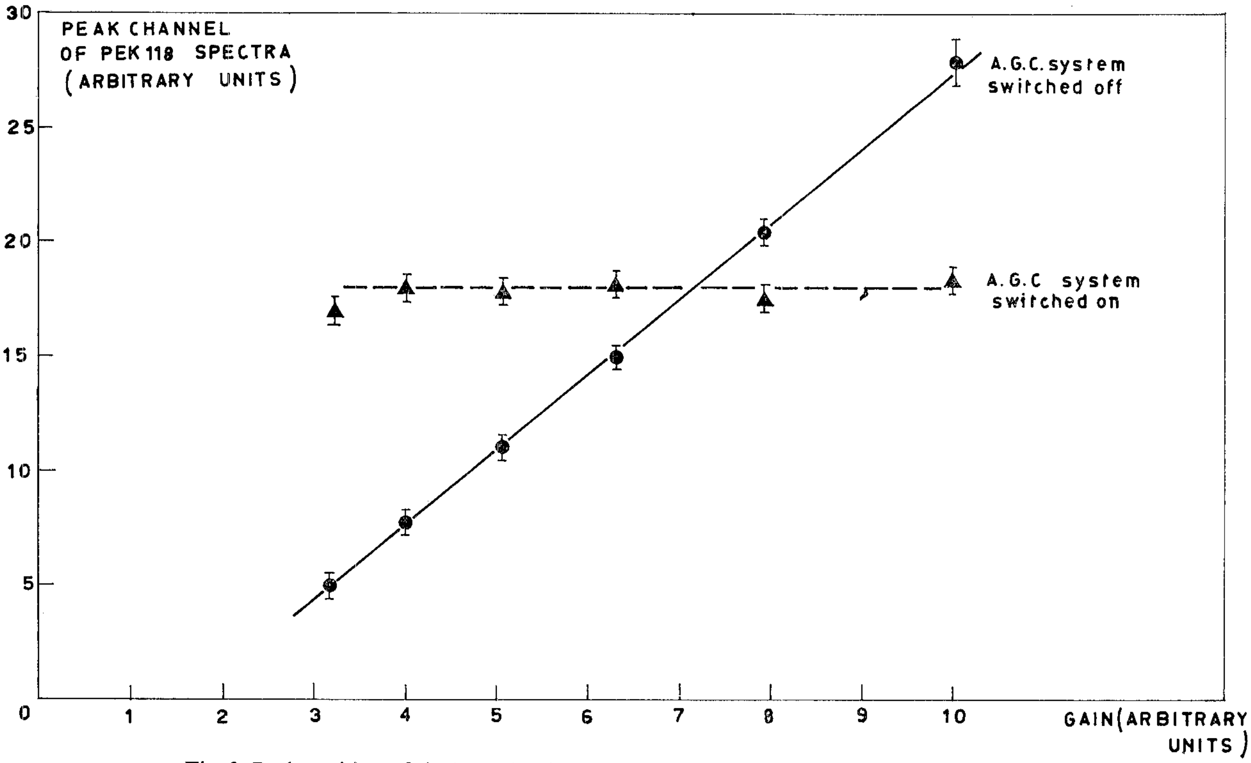

Fig. 3. Peak position of the PEK 118 lamp spectrum vs the gain of the electric linear chain.

resistive attenuator in series to the photomultiplier dynode and anode respectively. In fig. 3 we reported the gain of the linear chain versus the peak position of the spectra we obtained by sending the pulses of the photomultiplier exposed to the light pulses of a nanosecond baryum-titanate lamp (PEK 118) to a multichannel analyzer (with the AGC system switched on or off respectively). The stability of such lamp was continuously checked during the trials.

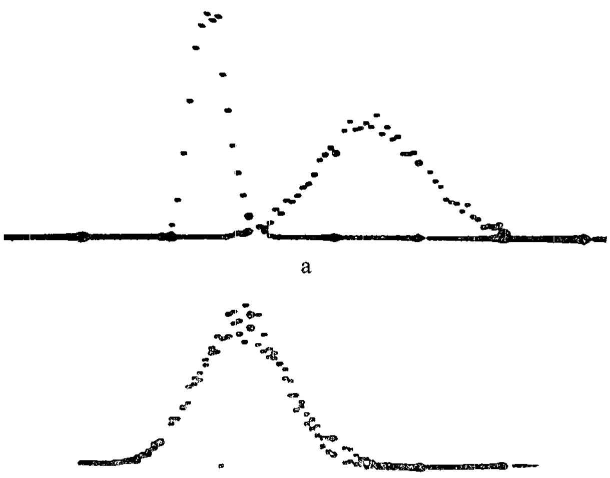

Fig. 4. Photos of the PEK 118 lamp spectra on a multichannel analyzer. a. Two spectra obtained by inserting attenuations 1 and 2.81 on the photomultiplier dynode with the AGC system switched off; b. Same as before but with the AGC system switched on.

Fig. 4a,b reports, in a single photograph two spectra of the PEK118 lamp: with the AGC system switched off (a) and switched on (b) obtained by inserting attenuation 1 and 2.81 on the electronic linear chain.

We note that a possible reason of the gain change is the change of the photomultiplier power supply voltage: the AGC system also works the way of making the photomultiplier voltage independent from the power supply. Fig. 5 shows the photomultiplier voltage vs the voltage supply when the AGC system is on.

The control system is also independent from temperature changes in the range 0–50° C. This is obtained by using silicon diodes and some temperature stabilized resistors and capacitors. In addition we note that the system is widely independent from the voltage supply of the auxiliary photomultipliers.

We have tested the stability of the system for many months by checking the position of the spectra of ^{241}Am particles with a multichannel analyzer.

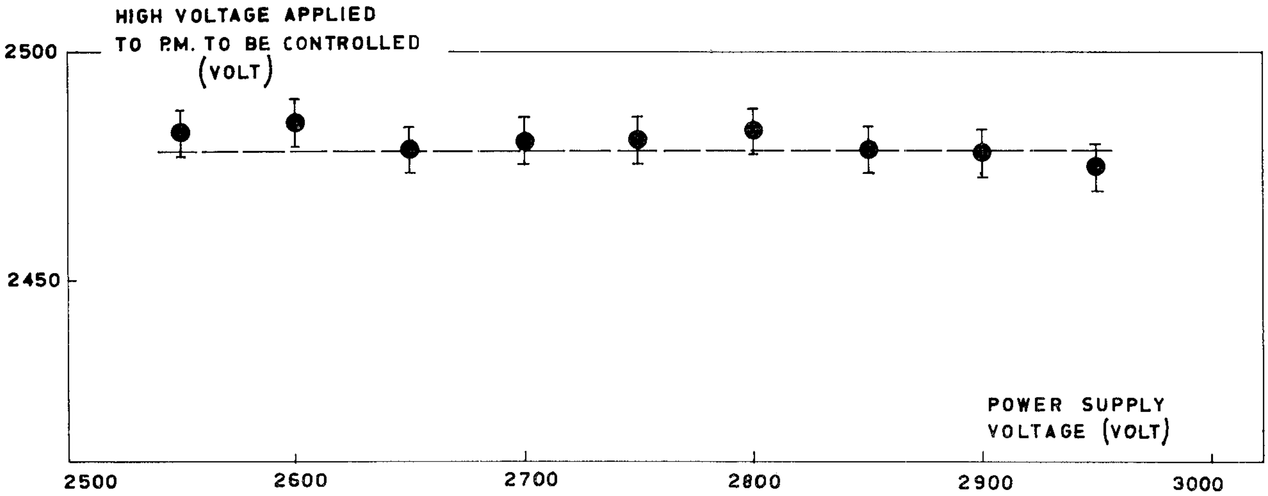

Fig. 5. High voltage applied to photomultiplier vs the voltage supply values.

Finally we remark that our AGC system has a characteristic time constant of about 150 sec. This limit is due to the time necessary to discriminate between the gain variations and the statistical fluctuations in the α particles and photoelectrons emission.

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References

[1]) We note that the control system here described is at present in use in two different experiments working at the 1.1 GeV electron-synchrotron of Frascati.
[2]) F. G. P. Valekx, Nucl. Instr. and Meth. **10** (1962) 234.
[3]) M. Ageno and C. Felici, Rev. Sci. Instr. **34** (1963) 997.
[4]) H. de Waard, Nucleonics **13** (1955) 36.
[5]) S. A. Scherbatskoy, Rev. Sci. Instr. **32** (1961) 599.
[6]) K. W. Marlow, Nucl. Instr. and Meth. **15** (1962) 188.
[7]) J. L. Black and E. Valentine, Nucl. Instr. and Meth. **31** (1964) 325.
[8]) U. Tamm, Nucl. Instr. and Meth. **40** (1966) 355.
[9]) J. B. Birks and F. A. Black, Proc. Phys. Soc. A**64** (1951) 511.