A MULTICHANNEL PULSE AMPLITUDE ANALYSER

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Received May 13, 1957

(Communicated by Prof. H. J. Bhabha, F.R.S., F.A.SC.)

The method of measuring the energy distribution of nuclear particles, consists in converting the particle energies to electrical pulses, in detectors like ionization chambers, proportional counters, scintillation counters, etc., and scanning the resulting pulse height distribution. A pulse amplitude analyser, single or multichannel is necessary for this purpose. A multichannel analyser is preferable as the scanning is done in a single step.

For satisfactory operation, a multichannel analyser should possess the following basic characteristics: (*a*) The greater the number of channels, the quicker and more precise will be the information obtained from the analyser, (*b*) The stability of the instrument should be such that it is stable to at least one channel width, over fairly long periods of time, (*c*) High speed of analysis is necessary for certain type of experiments such as the study of radiations from short-lived nuclei, (*d*) The circuits and other design features should be of the simplest type in order that servicing presents no difficulties.

Among the multichannel analysers, described in literature, the one which is most often used is of the Wilkinson[1] type. In this method of pulse height analysis, the input pulse produces a gate, whose width is proportional to the amplitude of the pulse. The gate opens an oscillator for the time of its duration, and produces a train of pulses, their number being thus proportional to the amplitude of the input pulse. The oscillator pulses are then counted in a decoding unit and a count is recorded in the appropriate channel.

A great advantage of using Wilkinson's method is that the stability of the instrument is mostly dependent on that of the pulse height to time converter unit and this unit can be made highly stable.

In the present work, many modifications have been introduced in the decoding units to make the instrument as simple as possible, without lowering its speed of analysis.

The number of channels of the analyser has been fixed to be 25 and the entire spectrum is scanned in 4 steps, making a total of 100 channels. Since the selection of the 4 ranges is done by means of the number of oscillator pulses, and not by means of a discriminator bias adjustment, the uncertainty arising at the junction of two consecutive ranges is absent. Although, it would be preferable to have 100 channels in a single step, this would make the instrument too bulky, due to the increased number of recording stages.

This analyser can accept a maximum of 1000 pulses per second. It has not been made faster, as this requires more scaling capacity for individual recording units.

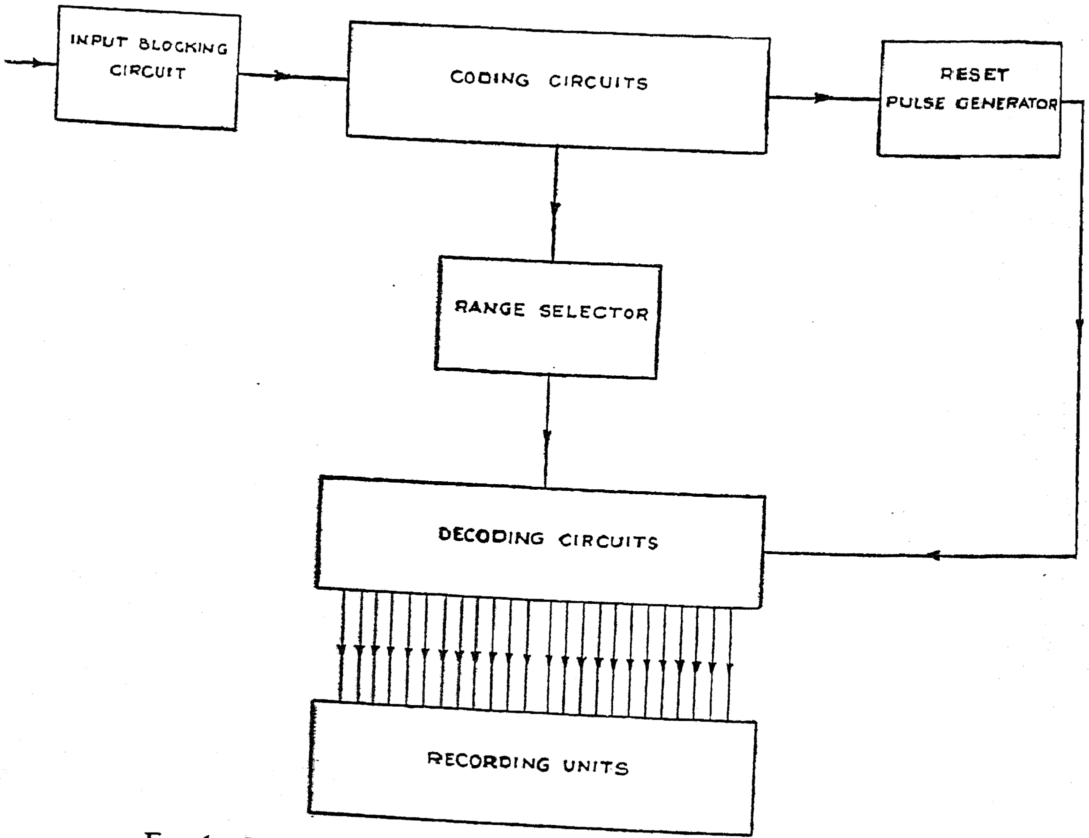


FIG. 1. Block Diagram. Multichannel Pulse Height Analyser.

CIRCUIT DESCRIPTION

The instrument is divided into different functional parts as shown in the block diagram Fig. 1. When a pulse is accepted by the instrument, the input blocking circuit, blocks all other pulses for a time until the accepted pulse is coded and recorded. Even though the time taken for a pulse to be coded and recorded depends on the amplitude of the pulse, for the sake of simplicity, the input is blocked for 1 millisecond. In the coding circuits the pulse amplitude is converted into a gate. The gate opens a blocking oscillator and produces a train of pulses for the time of its duration. The circuit constants are so adjusted that a pulse amplitude of 100 volts produces 100 pulses from the blocking oscillator. In the range selector pulses of amplitude 1–25, 26–50, 51–75 and 76–100 are selected by a band-switch. The method of selection is explained later. Thus the range selector gives in its output a train of pulses whose number is anywhere between 0 and 25, depending on the pulse height. The decoding circuit essentially consists of 2 ring scalers in matrix form and of simple coincidence circuits forming the intersection points of the matrix. The reset pulse generator produces a pulse which is delayed by about 40 microseconds from the trailing edge of the gate pulse produced in the coding circuit. This pulse resets the ring scalers of the matrix. If a train of seven pulses had been sent to the decoding scalers, when the scalers are reset, we get an output from the coincidence circuit at position 7 in the matrix. This pulse is counted in the recording scaler of channel 7.

The input blocking circuit (Fig. 2) is similar to the one described by Wilkinson. Negative input pulses are fed to one grid of the double cathode

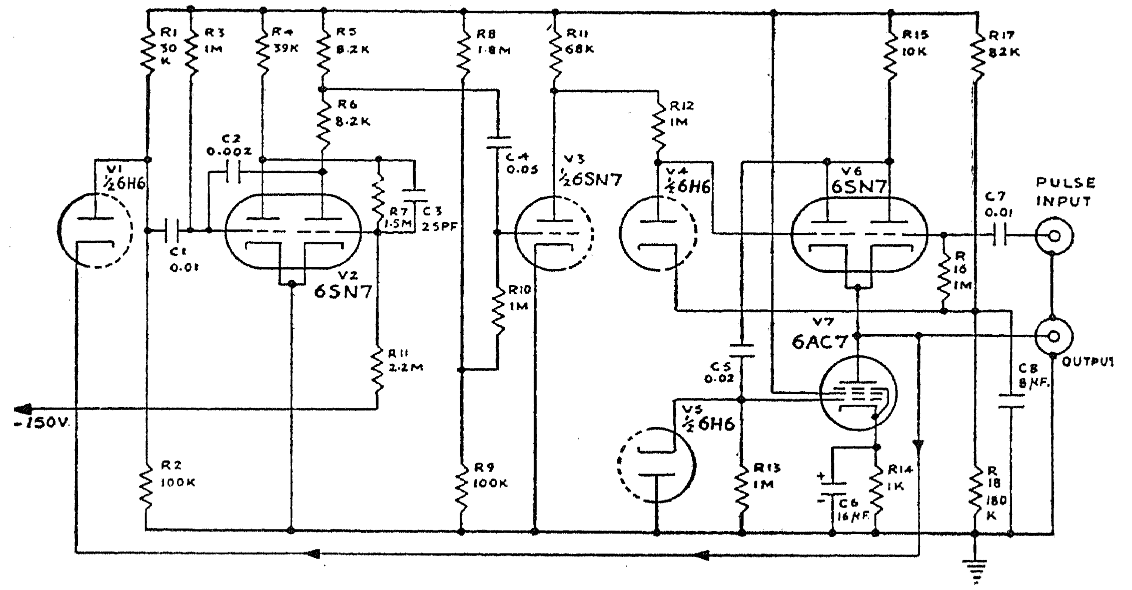


FIG. 2. Input Blocking Circuit.

follower V 6. The other grid is maintained at +40 volts by current passing in the tube V 3. The input pulse triggers the univibrator V 2 through the diode V 1. The gate pulse of the univibrator is about 1 millisecond wide. The negative gate cuts off the current in tube V 3 and raises the grid potential to 300 volts. This prevents the double cathode follower from passing any pulse during the 1 millisecond interval. The negative pulse from the cathode follower is inverted and fed to the pulse height to time convertor unit of the coding circuits.

Pulse height to time convertor circuit also is the same as that of Wilkinson with the only change that the values of charging condensor C and resistance R of the phantastron circuit are so adjusted that an input pulse of 100 volts amplitude produces a gate pulse at the output of about 800 microseconds duration.

The gated oscillator is shown in Fig. 3. The rectangular negative gate from the Wilkinson circuit is fed to the grid of tube V 2 which is normally conducting. Thus this tube is cut off and the blocking oscillator V 1

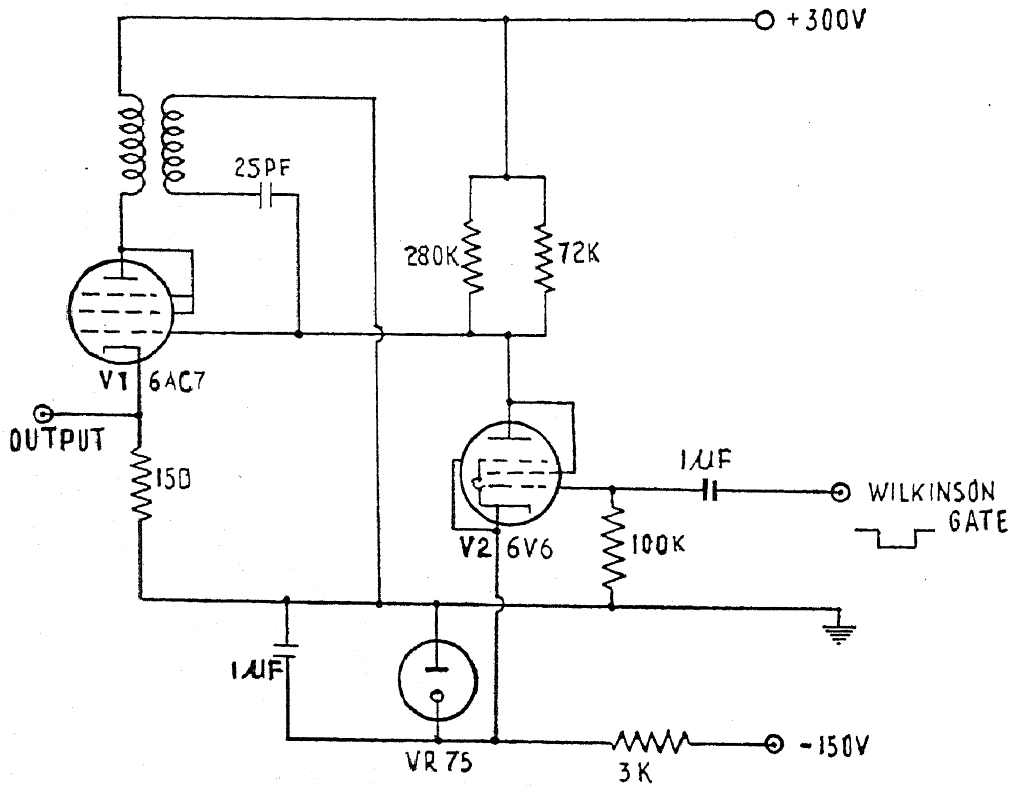


FIG. 3. Gated Oscillator.

produces oscillations for the duration of the gate pulse. The oscillator frequency is quite stable and is kept at about 150 kcs. Pulses are obtained at the cathode.

The time gate from the pulse height to time converter unit is differentiated and the pulse corresponding to its trailing edge is made to trigger a univibrator, which gives a gate pulse of 40 microseconds' duration. The positive pulse, corresponding to its trailing edge is used as the reset pulse.

A block diagram of the range selector is shown in Fig. 4. The pulses from the oscillator are fed to a scale of 25 consisting of two scales of 5 in cascade, so that output pulses are obtained for every 25. These pulses are again fed to a ring of 4. The negative gate from the 1st tube of this ring lasts from 25 to the reset time or to 100. This gate is applied to a 6 A C 7 pentode coincidence A which selects oscillator pulses only from 0–25. For any pulse

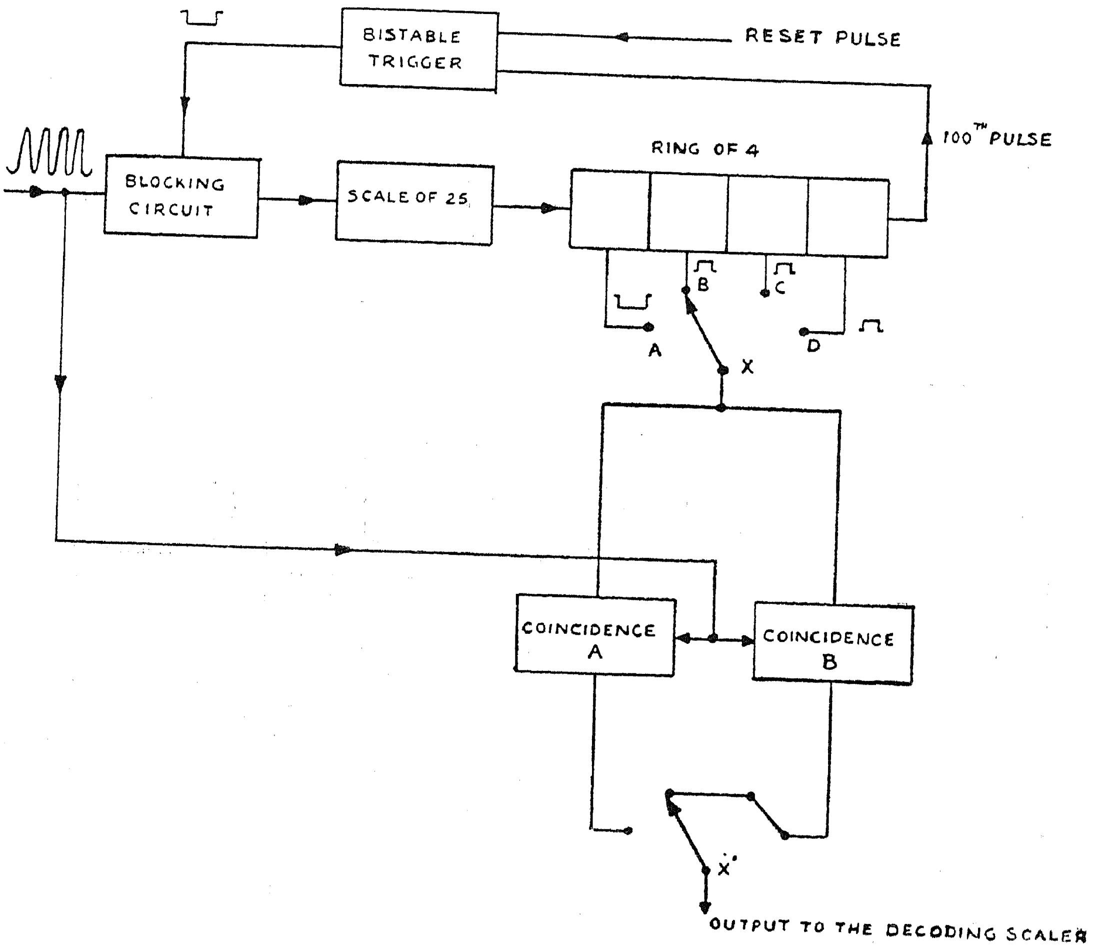


FIG. 4. Diagram of Range Selector

train of above 25, only 25 pulses are passed to the decoding unit if the band-switch is in postion 1. But nothing is recorded in the decoding unit as channel 25 is absent. If the number of pulses in the initial train is below 25, they will be passed on to the decoding unit. In the 2nd, 3rd and 4th tubes of the scale of 4, we get positive gates which last for the range 26–50, 51–75 and 76–100 respectively. These gate pulses are fed to another 6 A C 7 coincidence B and its output gives pulse trains of 25 or less depending on the position of the band-switch and whether the pulse train ends within that range or not. If the number of pulses in the pulse train is more than 100, spurious counts will be recorded in the lower channels; for instance, a pulse train of 108 will be recorded in the 8th channel. In order to avoid this, the input pulses to the range selector are given through another diode blocking circuit, which cuts out the oscillator pulses above 100.

The decoding unit (Fig. 5) consists of 2 rings of 5 scalers in cascade. The ring scaler circuit is due to Gatti[2] (Fig. 6). In the normal conditions, the second half of the 1st tube and the 1st half of the other 4 tubes in each

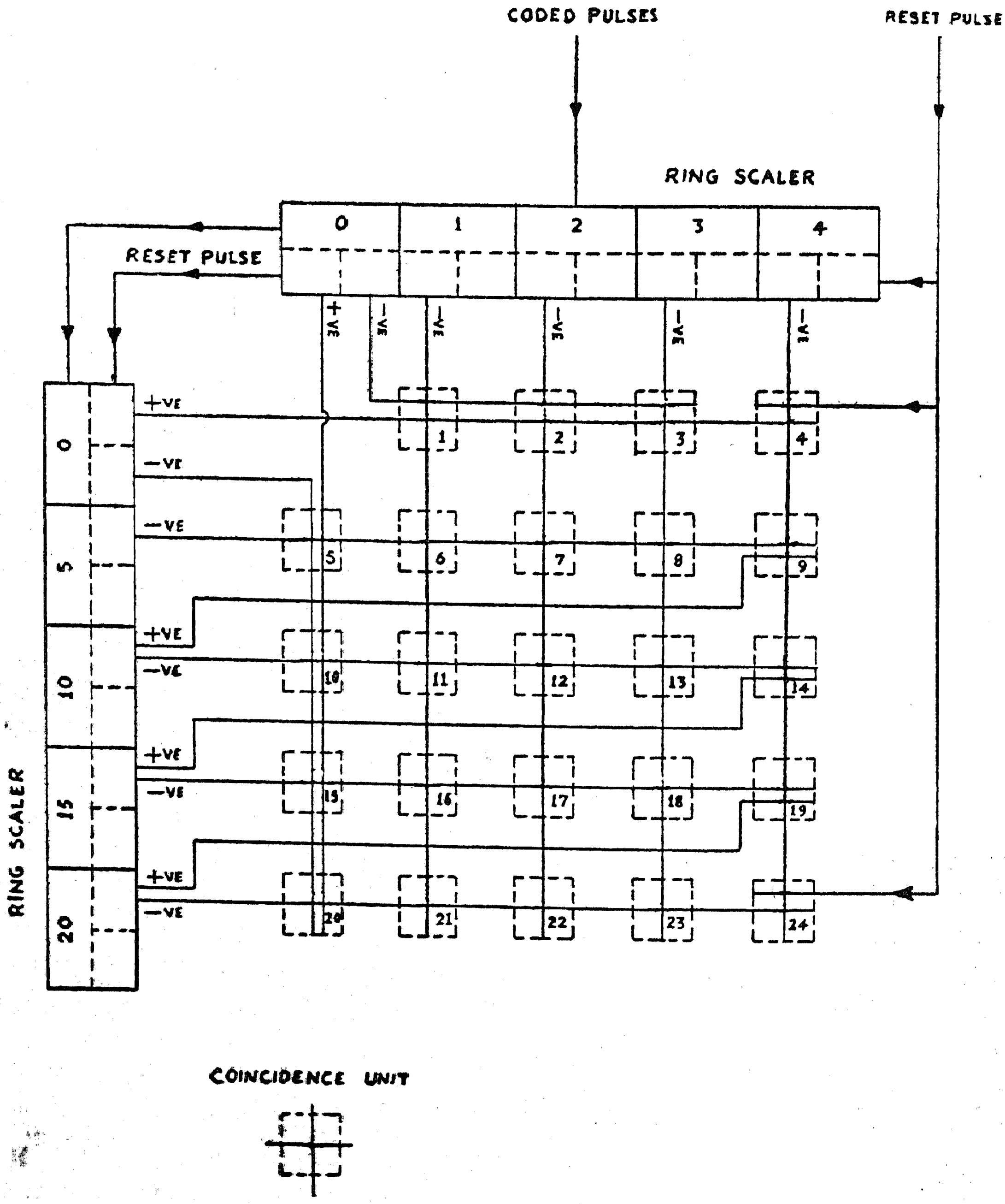


FIG. 5. Decoding unit.

ring are conducting. If a train of 17 pulses have passed through the scalers, then the 2nd tube of the first ring and 3rd tube of the 2nd ring will be left with their second halves conducting. If now the scalers are reset, we get negative pulses from the plates of the first halves as they flip over to their normal state. These negative pulses are taken through cathode followers to the coincidence circuits.

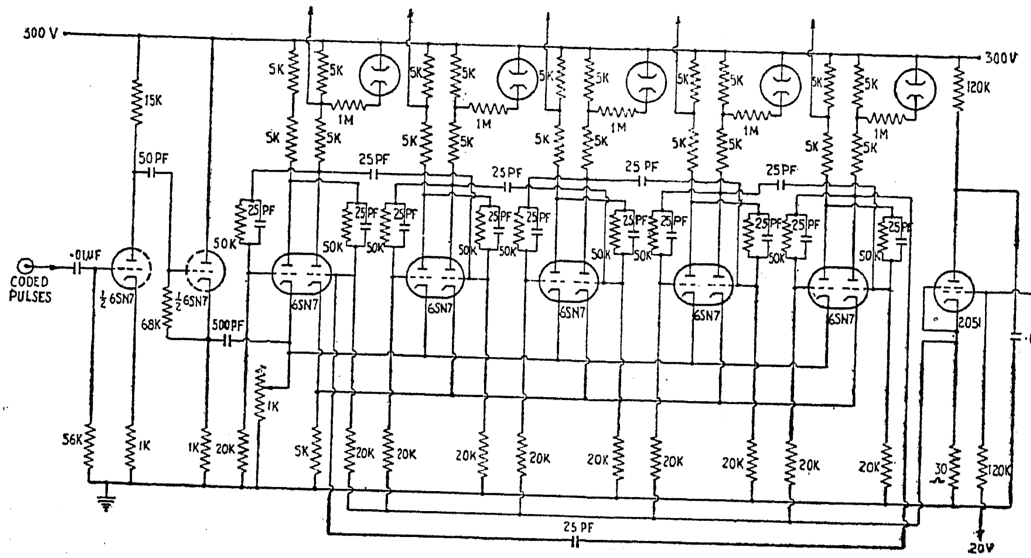


FIG. 6. Ring of Five scaler.

The resetting of all the ring scalers is done by a single pulse. The grid resistances of the second half of the 1st tube and the first half of all the other tubes, in each ring scaler are connected to ground through a common resistance of 30 ohms, which forms the cathode load of the thyratron 2051 (Fig. 6). The reset pulse fires the thyratron and the large positive pulse at its cathode, resets the ring scalers.

A simple double triode coincidence circuit (Fig. 7) gives a large negative pulse at the cathode. The ratio of the output pulse when there is coincidence to that when only one pulse is fed to the coincidence tube, is about 3. A negative voltage discriminator is biassed to accept only the coincidence pulse, and gives at its output a negative gate, which is fed to the dekatron in the recording unit.

Such simple coincidence does not suffice for all the points on the matrix, for while the pulse train is advancing, the scalers give output pulses and we may get a coincidence outputs at the points 4, 9, 14, 19 and 24. For instance, when the 10th pulse arrives the 4th tube of the 1st ring and the 2nd tube of the 2nd ring return to their normal state thus giving coincidence output which may be recorded in the 9th channel. In order to avoid this we feed

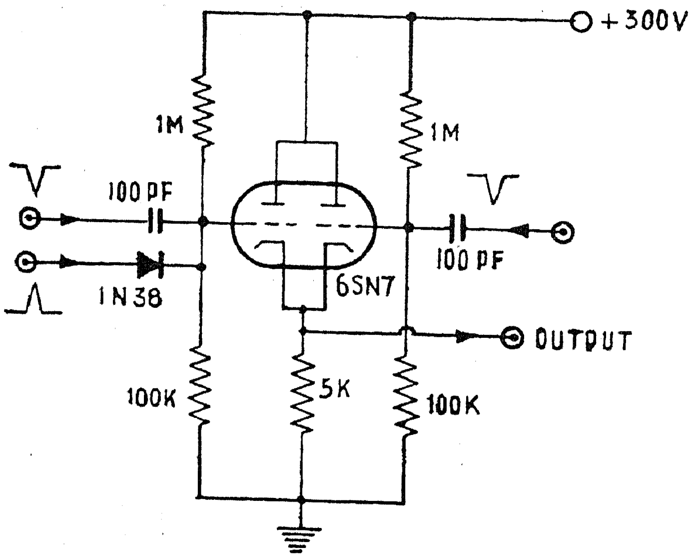


FIG. 7. Coincidence Unit.

in a positive pulse from the 3rd tube in the 2nd ring which cancels one of the negative pulses to the coincidence. At the points 1, 2, 3, 4, 5, 10, 15 and 20, the coincidences are established by the negative pulses from the same ring. As a result, *e.g.*, No. 2 will give coincidence, even when pulse trains of 7, 12, 17 or 22 have been fed and the scalers reset. To avoid this, we feed positive pulses from the 1st tube of the ring as indicated in Fig. 5. In the case of 4, it will require 2 positive pulses to cancel spurious counting since the arguments for 9, 14, 19 and 24 as well as 1, 2, 3, 5, 10 held here. One of the cancellation pulses is avoided by giving a negative pulse from the reset. These cancellations are done by just applying pulses through diodes to one of the grids of the coincidence tube and hence do not involve more tubes. A triple coincidence with the negative reset pulse as the third, eliminates spurious coincidences in the 24th channel. The 25th channel is absent, as it cannot be uniquely defined. Each channel has a recording unit consisting of a scale of 100 followed by a resettable call counter.

The scale of hundred consists of 2 dekatrons of the type GC 10 B in cascade. The output pulses from this scale of hundred is fed to another dekatron of the type GS 10 C. In this tube, each of its ten cathodes is brought out to separate terminals, such that positive gates appear successively at these terminals when the tube is counting. Each of these cathodes is directly connected to one of the terminals of a neon, the other terminals of all the neons being returned to a common negative bias. Thus for every 100th pulse, the neons light up successively giving a display of the counts in that channel and a visual indication of the spectrum in that range can thus be obtained.

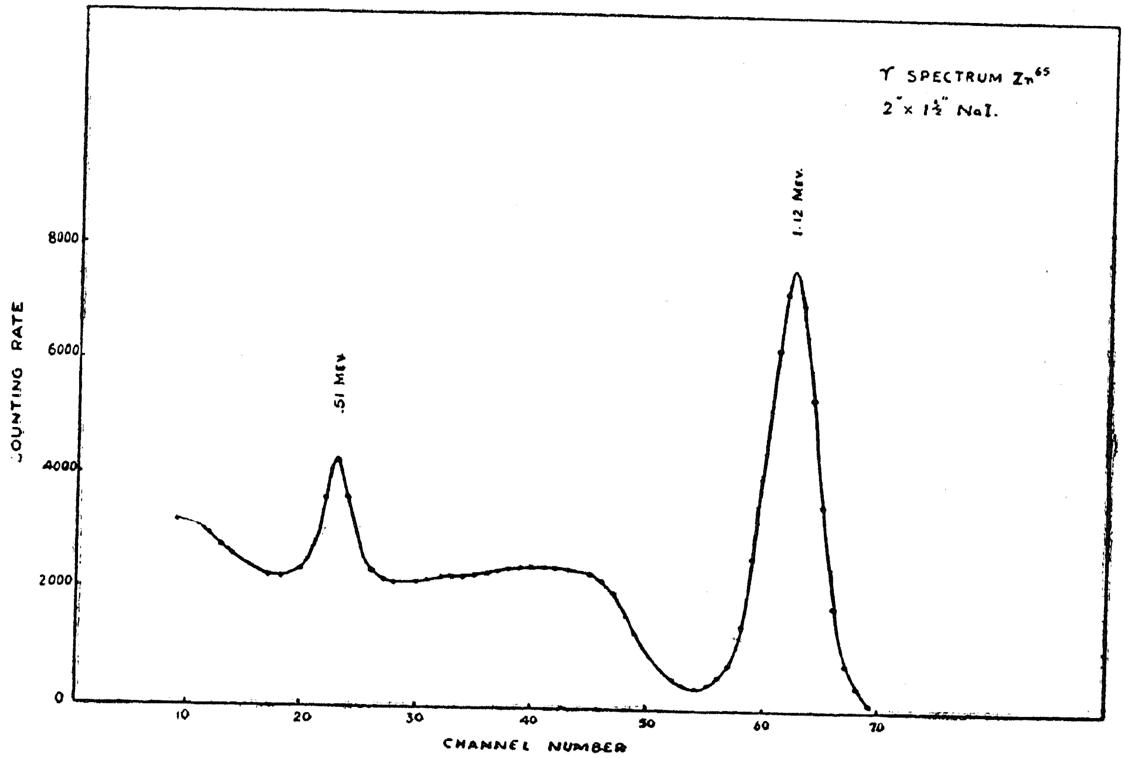

γ SPECTRUM Zn^{65}
2" × 1½" NaI.
1.12 MeV.
.51 MeV
COUNTING RATE
8000
6000
4000
2000
0
10
20
30
40
50
60
70
CHANNEL NUMBER

FIG. 8

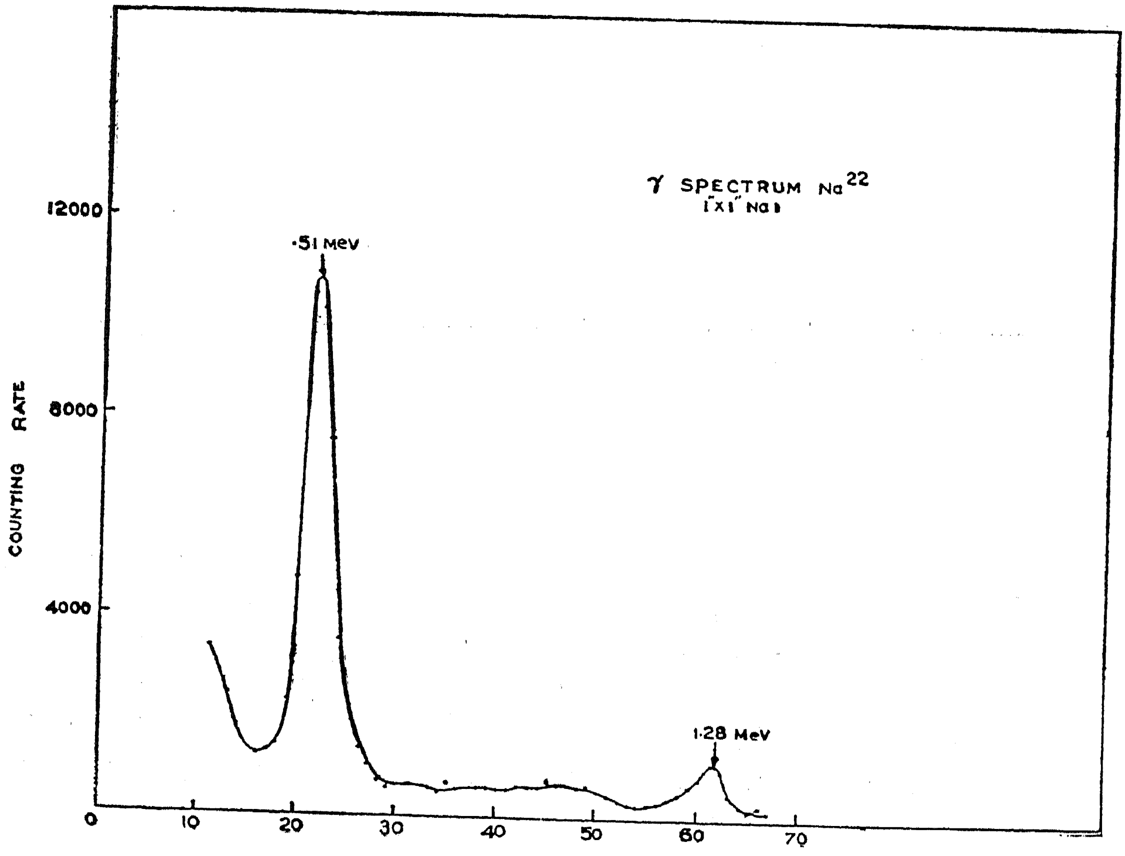

γ SPECTRUM Na^{22}
1"×1" NaI
·51 MeV
1·28 MeV
COUNTING RATE
12000
8000
4000
0
10
20
30
40
50
60
70
CHANNEL NUMBER

FIG. 9

The pulse analyser was tested by obtaining the spectra of the standard γ-ray sources, Zn^{55} and Na^{22}. These are shown in Figs. 8 and 9. Fig. 10 gives the γ-spectra of Mg^{27} and Al^{28} obtained by irradiating Al^{27} with neutrons from the reactor, Apsara at Trombay. The peaks at 0·84 Mev. and 1·01 Mev are due to Mg^{27} (half-life $\approx$ 9·5 min.), and that at 1·78 Mev. is due to Al^{28} (half-life $\approx$ 2·3 min.).

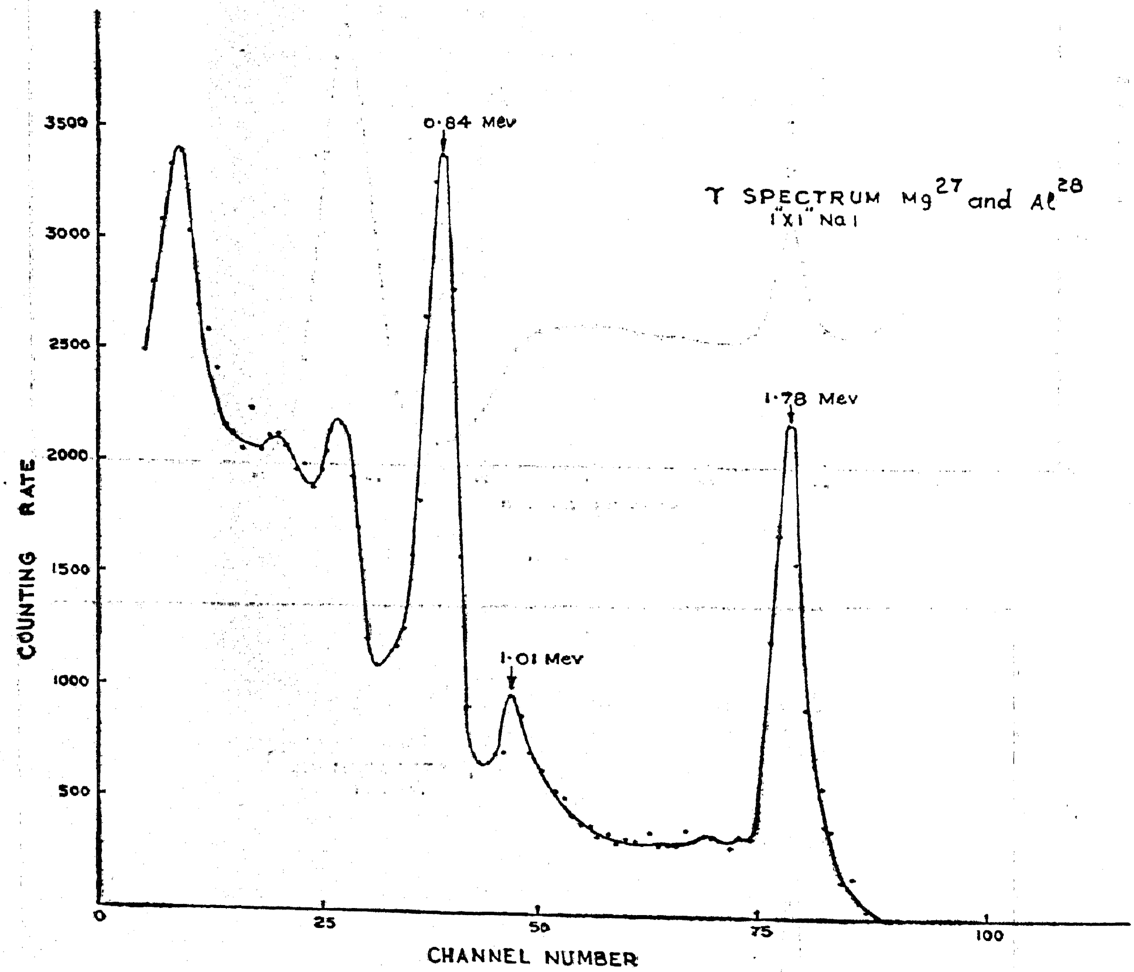
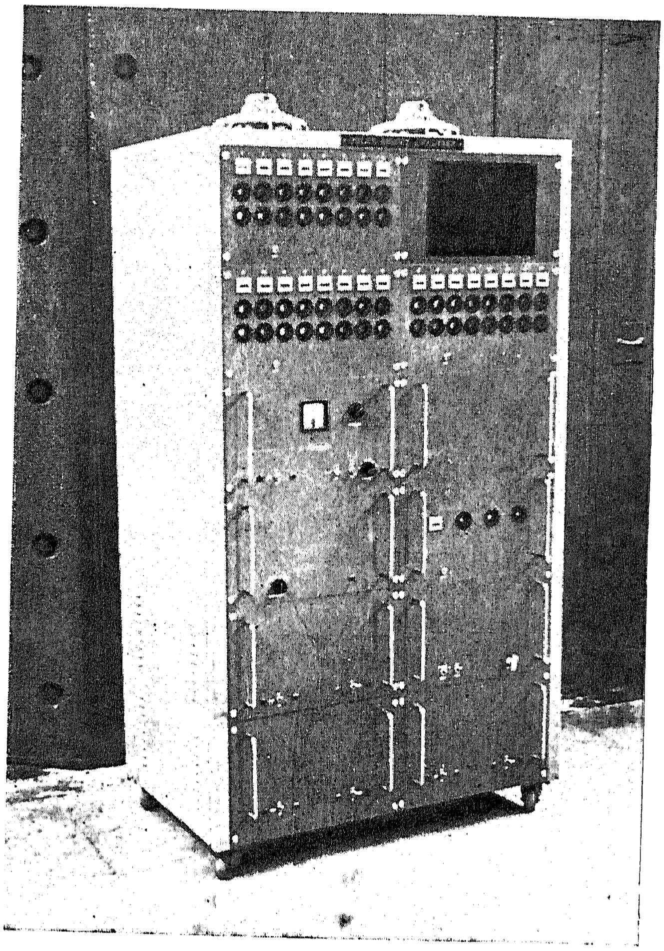


FIG. 10

It is also possible to use this instrument as a time analyser in experiments such as a time of flight spectrometer. A bistable trigger circuit can be made to give a gate pulse of the duration of the time interval between two pulses, one corresponding to the time at which the neutron in a time of flight spectrometer leaves the source (*e.g.*, a chopper) and the other, to the time when it is counted by the detector after a known flight path, the time of detection depending on the neutron energies. This pulse gates the oscillator instead of the gate from the pulse height to time converter unit in the analyser; the instrument then works as a time analyser with the channel widths equal to



the period of the oscillator (about 8 microseconds). This system will only permit the recording of a single neutron for each burst; hence it can be used only in those cases, where low intensities are expected, as in the case of a chopper.

ACKNOWLEDGEMENTS

We thank Dr. R. Ramanna for helpful discussions. We also wish to thank Mr. Raote for his assistance.

REFERENCES

1. Wilkinson, D. H. .. *Proc. Cambridge Phyl. Sec.* 46, 1950, 508.
2. Gatti .. *Rev. Scientific Instruments*, 1953.