DESCRIPTION OF THE ANGULAR CORRELATION EQUIPMENT

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Table of Contents

I Introduction

II General Description

III Detectors

a) Mechanical construction

b) Voltage supply of the Ph.M.

c) Slow output

d) Fast output

IV Time analysis

a) Fast coincidence circuit

b) Slow triple coincidence

c) Time to pulse height converter (TPHC)

d) Calibration of the TPHC

V Energy analysis

a) Differential discriminators

b) Scaling system

VI Conclusions

I - Introduction

In the following pages a description is given of the construction details and calibration procedure of the "differential angular correlation equipment" built at the Instituto de Física "Dr.José A.Balseiro" during the summer 1965. Taking into account that some parts of the equipment will be modified and improved at a later stage, this description must be regarded as a preliminary one. When describing the pertinent parts reference is made to the projected changes.

The purpose of the equipment is the determination of the time and angle correlation between two successive γ -rays from decaying nuclei. The interpretation of the results can be used for determining spins of excited nuclear states, multipolarities of the emitted radiations, half-lives of nuclear excited states, and the interaction of nuclear moments with electromagnetic fields. This last part allows not only the determination of nuclear properties but also of some details of the structure in solids and liquids.

II - General Description

The equipment consists of two γ -ray detectors mounted on a "correlation table" (Fig.1). One of the detectors (Det.1) is fixed in angle with respect to the table but it is possible to align it with respect to the central source and the radial distance to the source is adjustable between 0 and 40 cm. The other detector (Det.2) is free to move around a central axis fixed to the table. The detector is supported by this axis and by two wheels gliding on a circular rail, 80 cm in diameter. Besides, it has the same possibilities for alignement and change of radial distance as Det.1. The central axis supports the source-holder which can be displaced in any direction in order to center the source with respect to the detectors.

Each detector is connected through several cables with three racks where all the corresponding electronics is mounted. One rack contains three power supplies: a regulated high voltage (up to 3.7 KV) supply, a low voltage (up to + and -40 V) supply, also regulated and a fixed + 85 V supply. This rack contains also the time analyzing circuitry ("time panel"). The second rack contains the energy selecting equipment, i.e. the differential discriminators ("D.D.") and three scalers. The third rack contains a 100 channels analyzer which will be replaced in the future by a transistorized 400 channels analyzer. All the equipment is fed by a voltage stabilizer which supplies (220 $\pm$ 2.2)V and up to 6 KW power.

The general block scheme of the equipment is shown in Fig.2. It should be pointed out that temporary changes may be made on the block scheme in order to perform special measurements (e.g. determination of half-lives longer than 200 ns).

Since most of the equipment is or will be transistorized and the measurements extend usually over long time periods, the room will be temperature stabilized in order to achieve the required stability in the operation of the equipment.

In the "correlation table", provision has been made for:

a) A future automatic operation of the equipment i.e. change of the angle between detectors, controlled by an electronic timer.

b) Placement of an electromagnet in order to make studies with external magnetic fields.

III - Detectors

a) Mechanical construction

Each detector consists of a NaI(Tl) crystal, 3.75 cm. dia. x 5.00 cm. high (Det.2) and 3.75 cm.dia. x 2.50 cm. high (Det.1) respectively. They are fixed on top of the 56AVP photomultipliers (Ph.M.) by means of a thin silicone grease layer. The crystal-photomultiplier system is housed in a light-tight, soft iron system which permits minor adjustments in order to insure an efficient light transmission from the crystal to the Ph.M. and includes three separate layers of μ -metal foils providing the required magnetic shielding of the Ph.M. The design makes provision for the use of light guides between the crystals and the Ph.M. whenever strong magnetic fields are used.

The Ph.M. housing is supported by a plate at the rear part of which the detector electronic box is placed. The Ph.M. socket serves as a connection between both parts. The box contains the circuits to provide the voltage supply of the Ph.M. and to receive and shape the output pulses. When looking from the rear end of the detectors, the Ph.M. supply circuit is mounted in the right circuit card whereas the slow and fast output pulse circuits are placed in the left card. All three circuits will be described separately.

b) Voltage supply of the Ph.M.

A voltage divider fed by the high voltage supply provides the required potentials for the dynodes of the Ph.M. (Fig.3). Some of these voltages can be varied in order to obtain the optimum response of the Ph.M.. The normal operation point lies between 2.0 KV and 2.5 KV and the current that flows through each divider is 3 mA at 2.5 KV. All the circuit but for some condensers is mounted on a plug-in card.

c) Slow output

A positive signal taken from dynode Nº 9 in the Ph.M. is fed to an emitter follower of high ($\approx$ 1 MΩ) input impedance and low ($\approx$ 100Ω) output impedance as shown in Fig.4. The rise time of this pulses is .5 µs and they have a 100 µs long tail. This pulse shape is required by the double delay line (DDL) amplifiers into which this pulses are normally fed. Whenever common RC amplifiers are used, instead of DDL, the pulses are further shaped by a differentiating preamplifier with a negative output, 6 µs in duration. In both cases (RC or DDL) after amplification pulses are analyzed in amplitud by differential discriminators (DD).

d) Fast output

At the anode of the Ph.M. a fast negative pulse is used for time analysis in the following way (Fig.4): Two fast NPN transistors, conducting heavily (40 mA) are cut by the negative anode pulse and produce at the collector a limited positive pulse of 1 Volt amplitud over a 150 Ω resistor. Each detector has two such limiter circuits producing two independent pulses. All four fast pulses are fed to the "time panel" through 4 ns/m delay cables (RG63B/U, 125 Ω) as shown in Fig. 5. For a gamma ray energy of 500 KeV and operating the Ph.M. at 2,2 KV the rise time of these pulses is between 3 and 4 ns.

IV - Time analysis

The"time panel" includes the circuitry necessary for performing a fast coincidence, a slow triple coincidence and the time-to-pulse-height conversion (TPHC). It consists of six cards onto four of which the circuits are mounted whereas two cards are left free for future extensions. Power (+ 12V, -12V, + 85V and ground) is supplied through a six-line shielded cable that is connected at the rear apron. Each part will be described separately.

a) Fast coincidence circuit

As shown in Fig.5 two cables, one coming from each detector, are matched with a reflection cable whose length determines the duration of the pulses coming from the detectors. Whenever a temporal coincidence of two pulses occurs (i.e. both pulses overlap at the cable junction) the sum of them triggers a tunnel diode plus univibrator system (see Fig.6) giving a positive 10 Volt 1.5 μ sec output pulse. The current bias of the tunnel diode can be adjusted by means of a 10 turn potentiometer placed at the right side of the pannel.

The time resolution of the fast coincidence can be adjusted by changing the length of the reflection cable. Calling 2τ the time resolution if T is the delay (one way) of the reflection cable, then for ideal rectangular pulses (i.e. negligible-rise time):

$$2\tau = 4\,T$$

For real pulses with finite rise time, 2τ is shorter than $4\,T$. Therefore, the minimum time resolution is determined by the rise time of the pulses and for this equipment lies between 4 and 8 ns. The maximum time resolution is limited by the attenuation of the signals in the reflection cable and can be as long as several microseconds. The normal cable settings allow for $2\tau = 8$ ns (very fast coincidence) and for $2\tau = 120$ ns and 230 ns for half-life measurements. When looking from the front, the fast coincidence circuit is mounted in the first card from the right of the time panel.

b) Slow triple coincidence

The output from the fast coincidences is streched by means of a univibrator to an adjustable (with an internal potentiometer) length, as shown in Fig.7. This is done in order to match the time delay of both differential discriminators, whose output pulses together with the streched pulse feed a common collector triple coincidence circuit.

The output of the triple coincidence is shaped by a univibrator and after going through an emitter follower, is available for scaling coincidences or to open the gate of the multichannel analyzer, The output pulse is negative 10 Volts, 3 μ sec long.

c) Time to pulse height converter

The converter (TPHC) operates (Fig.8) much in a similar way to the fast coincidence. Pulses from both detectors overlap and add on a forward biased diode. A second diode, which is reverse biased cuts the lower part of the sum pulse. This last bias is adjustable through a 10 turn potentiometer placed at the left side of the pannel. Thus, the pulse going through the second diode has a constant height and a length which is linearly related to the relative delay between both input pulses. Therefore, after a two step integration, the output pulse has an amplitude which is also linearly related to the time delay between both input pulses. It has to be noted that, depending on the cable setting, the highest output pulse may correspond to the shortest or to the longest delay. The present situation (Fig.5), corresponds to the first alternative.

The pulses, after going through an emitter follower are send to the multichannel analyzer (MCA). Since each pulse height corresponds to a certain time delay between radiations 1 and 2, the channels in the MCA corresponds to a time scale which has to be calibrated.

The time resolution of the converter, defined as the full width at half maximum (fwhm) of a prompt peak is about 3 ns for a γ -ray energy of 500 KeV detected with NaI(Tl) crystals and with 2,2 KV on the Ph.M.

The time range of the converter is determined by the length of the reflection cable and is equal to 2T' where T' is the delay of this cable, Presently the circuit operates at two different time ranges, namely 115 ns and 225 ns as required by the half-lives involved in the measurements. The TPHC circuit is mounted on the first card from the left of the "time panel".(Looking from the front).

b) Calibration of the TPHC

Since the pulse rise time and the Ph.M. transit time are dependent on the energy of the radiation it is not convenient to calibrate the TPHC and MCA with a pulse generator. Instead one should use a prompt source (i.e. negligible half-life in the intermediate level) with γ -rays having energies larger than the ones in the source to be measured and set the DD to accept the Compton portions of the prompt source spectrum that have the same energies as the source to be measured.

By introducing various cable delays in branch 3 of Fig. 5 one obtains several shifted prompt peaks which give the time calibration. It is assumed that the cable delays are known. For RG63L/U cable the delay is (4.0 ± 0.08) ns/m. If better accuracy is desired, a VHF oscillator can be used to measure the cable delays in a separate measurement.

V - Energy analysis

a) Differential discriminators

The slow output of the detectors is used for energy selection. The pulses are fed to differential discriminators (DD) which select those pulses whose amplitude lies within the limits of the window E and E- dE. Both levels can be selected in the front panels of the DD units. The pulses selected produce an output pulse, which appears about 1,5 μs delayed respect to the input pulse. This internal delay of the DD depends somewhat on the position of the window and the amplitude of the accepted pulses. Each DD provides two output pulses. One (1 V negative) is fed to a scaler and the other (10 V positive) is used for the triple coincidence. Since the amplitude of the slow output pulses is proportional to the gamma-ray energy, the DD units permit the selection of γ -rays of the adequate energy.

b) Scaling system

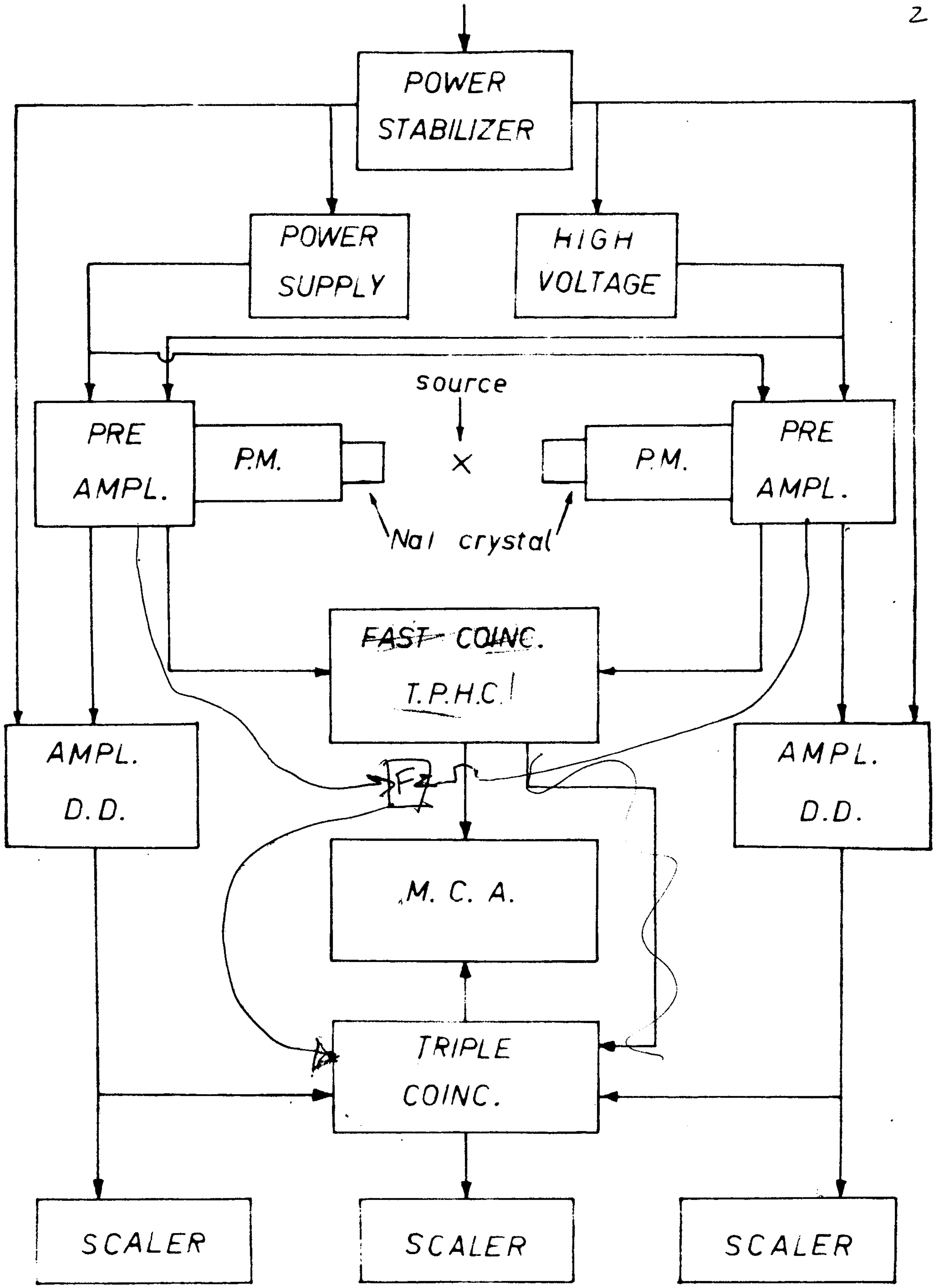
The output from both DD and the output of the triple coincidence are recorded on three scalers. The scalers reading single counting rates from the DD have a capacity of 10^{11} counts, whereas the coincidence scaler has a capacity of 10^7 counts. All three can stand a maximum counting rate of 50 KC.

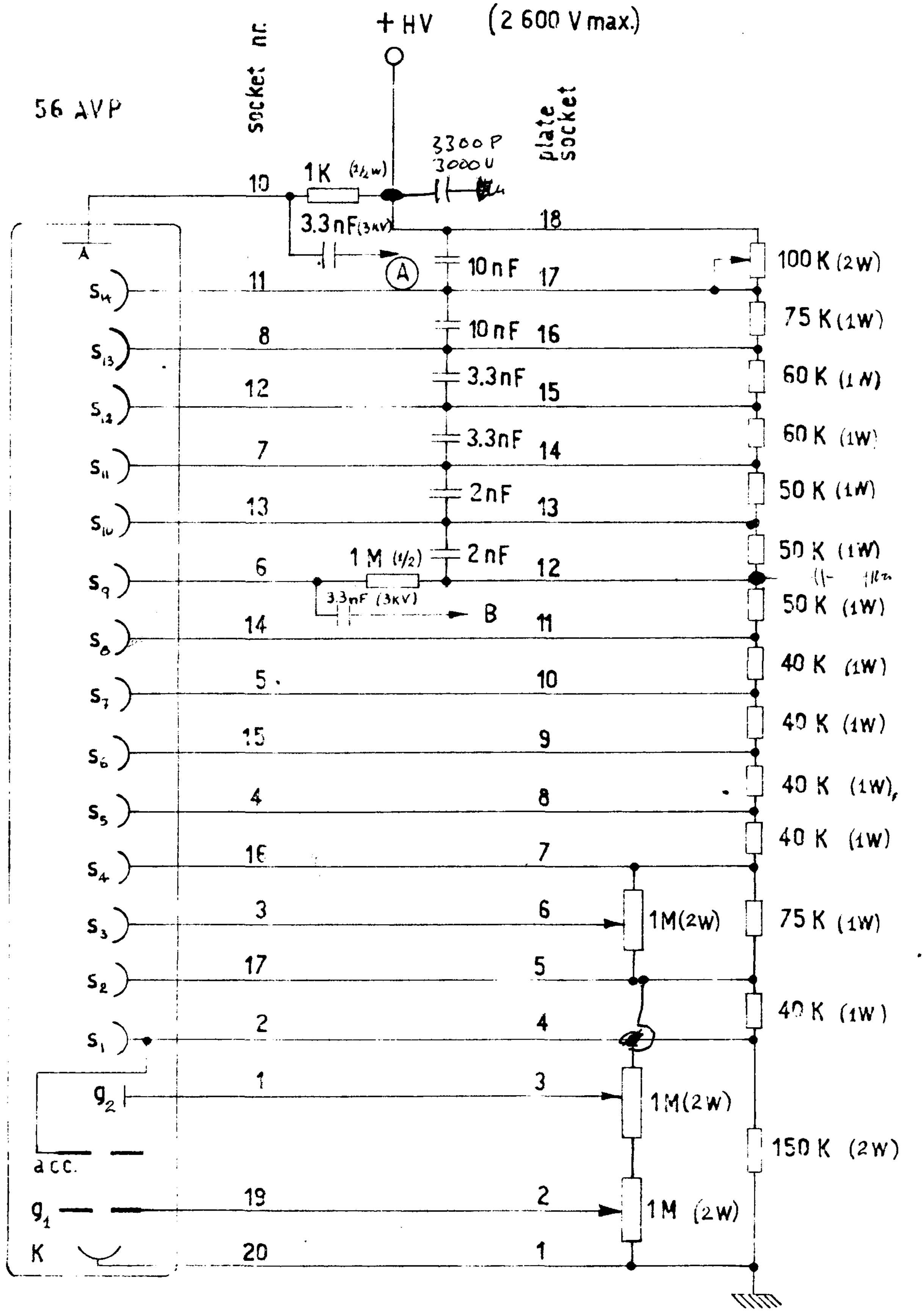
VI - Conclusions

The equipment described provides a suitable and stable system for differential angular correlation measurements. As it was mentioned earlier some parts will be modified in the future e.g. a TPHC will be added with a longer time range for measurements involving time observations longer than 200 ns. Faster scalers are under construction and mechanical improvem improvements will allow the use of light guides for measurements in strong magnetic fields.

ACKNOWLEDGMENTS

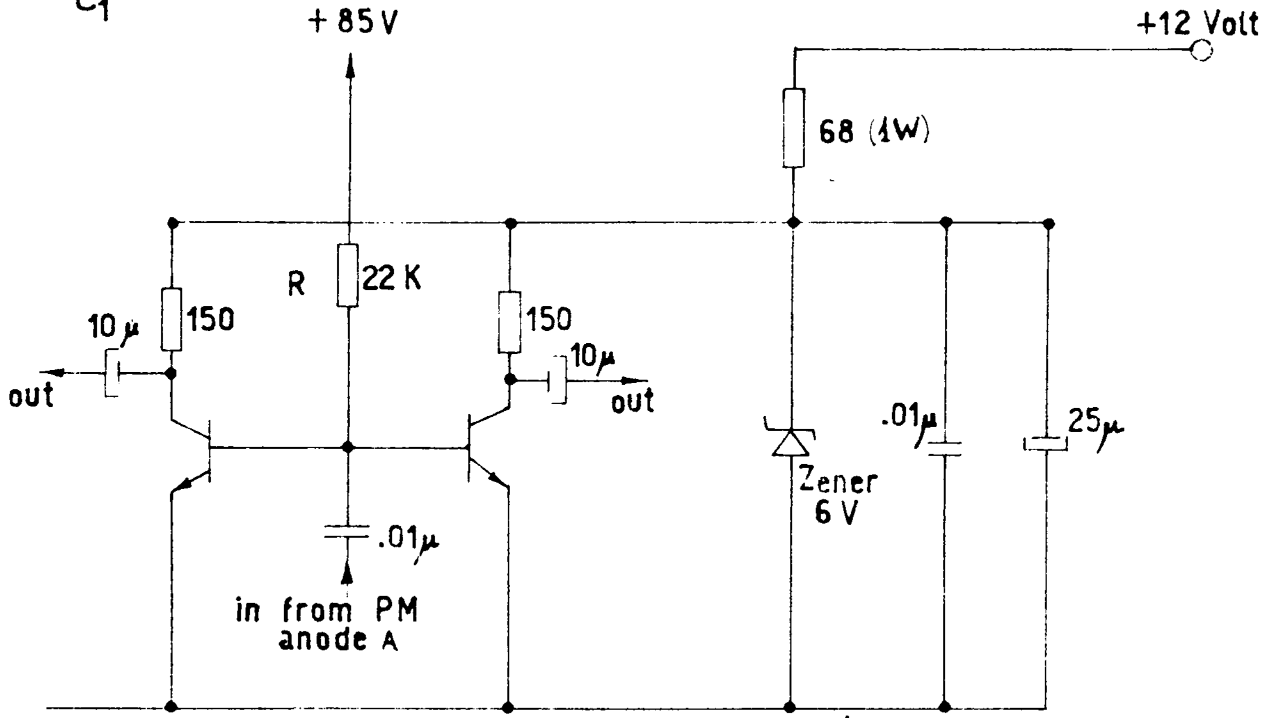
We acknowledge the help of the Swedish Institute for International Assistance (NIB), of the Argentine Atomic Energy Commission and of the Argentine Scientific and Technical Research Council, who provided the means for the construction of this equipment.


POWER STABILIZER
POWER SUPPLY
HIGH VOLTAGE
source
PRE AMPL.
P.M.
P.M.
PRE AMPL.
NaI crystal
~~FAST COINC.~~
T.P.H.C.
AMPL. D.D.
AMPL. D.D.
M. C. A.
TRIPLE COINC.
SCALER
SCALER
SCALER



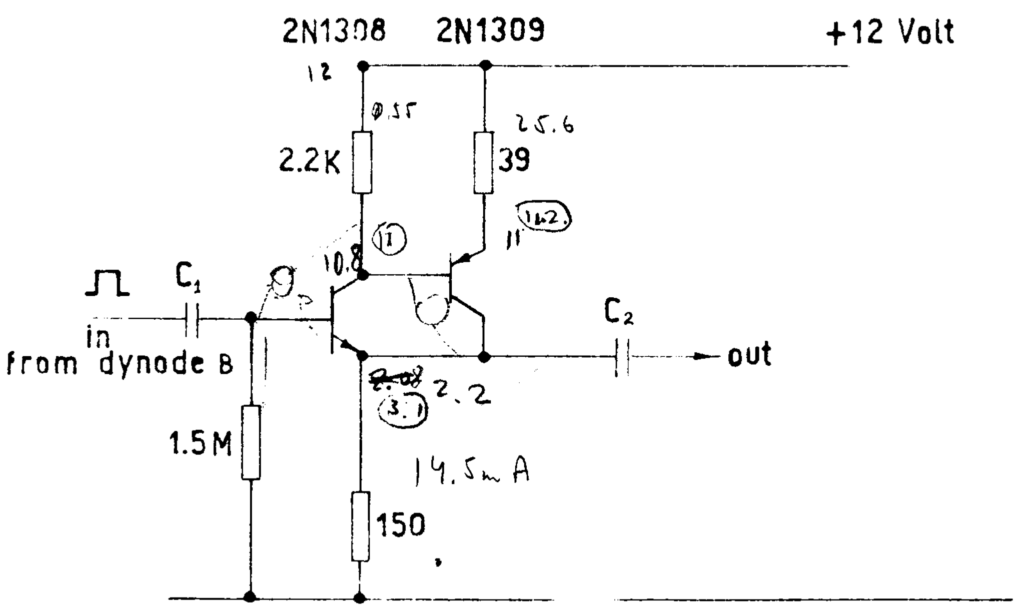
(A) output to limiters (B) output to Diff. Disc.

C1 LIMITER (FAST OUT)

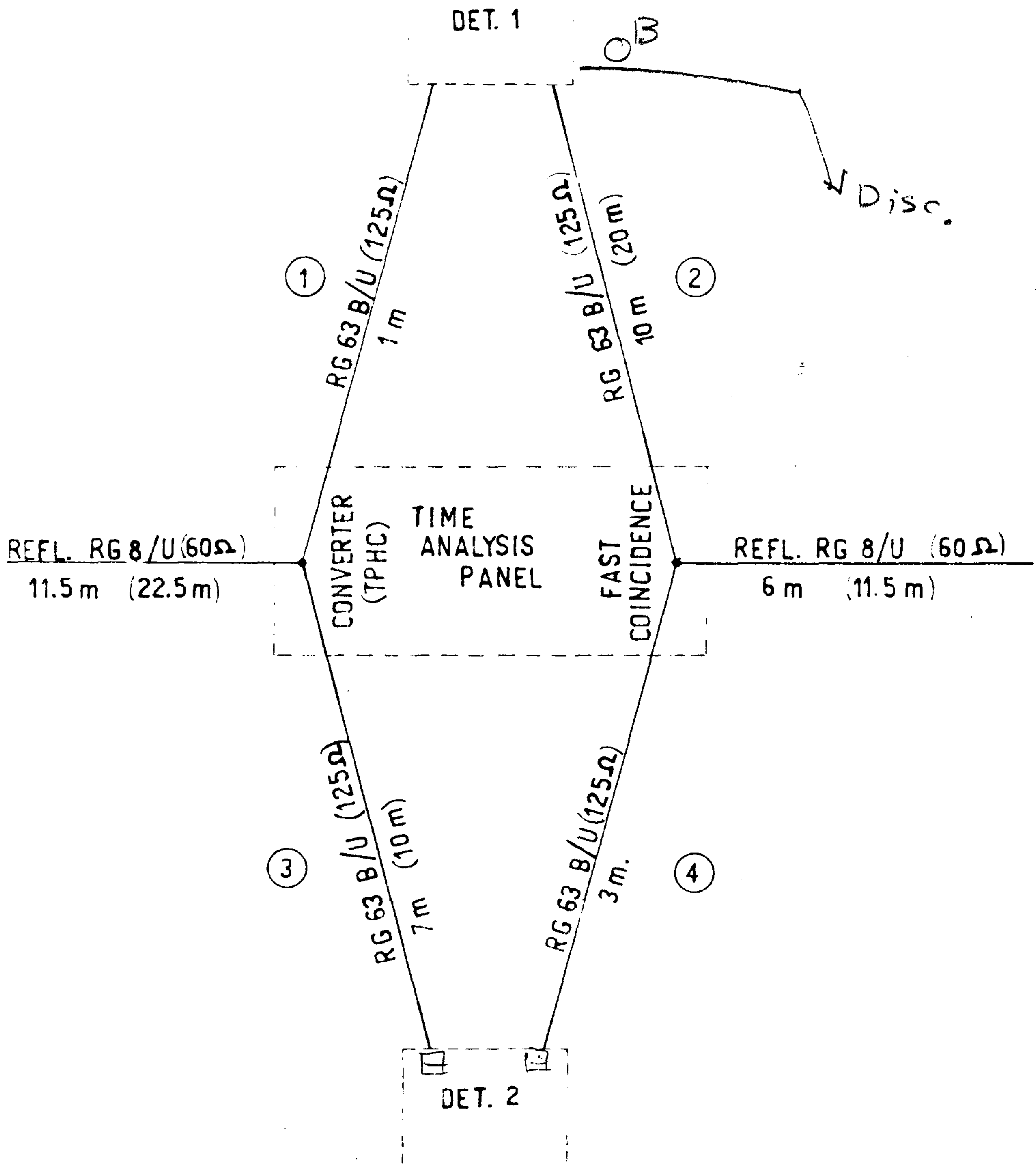


Note: Out is adapted to 125 Ω cable. The resistor R (~50 – 3 K) has to be adjusted to allow 40 mA through each transistor. (Transistorsare 2N2257)

C2 EMITTER FOLLOWER (slow out)



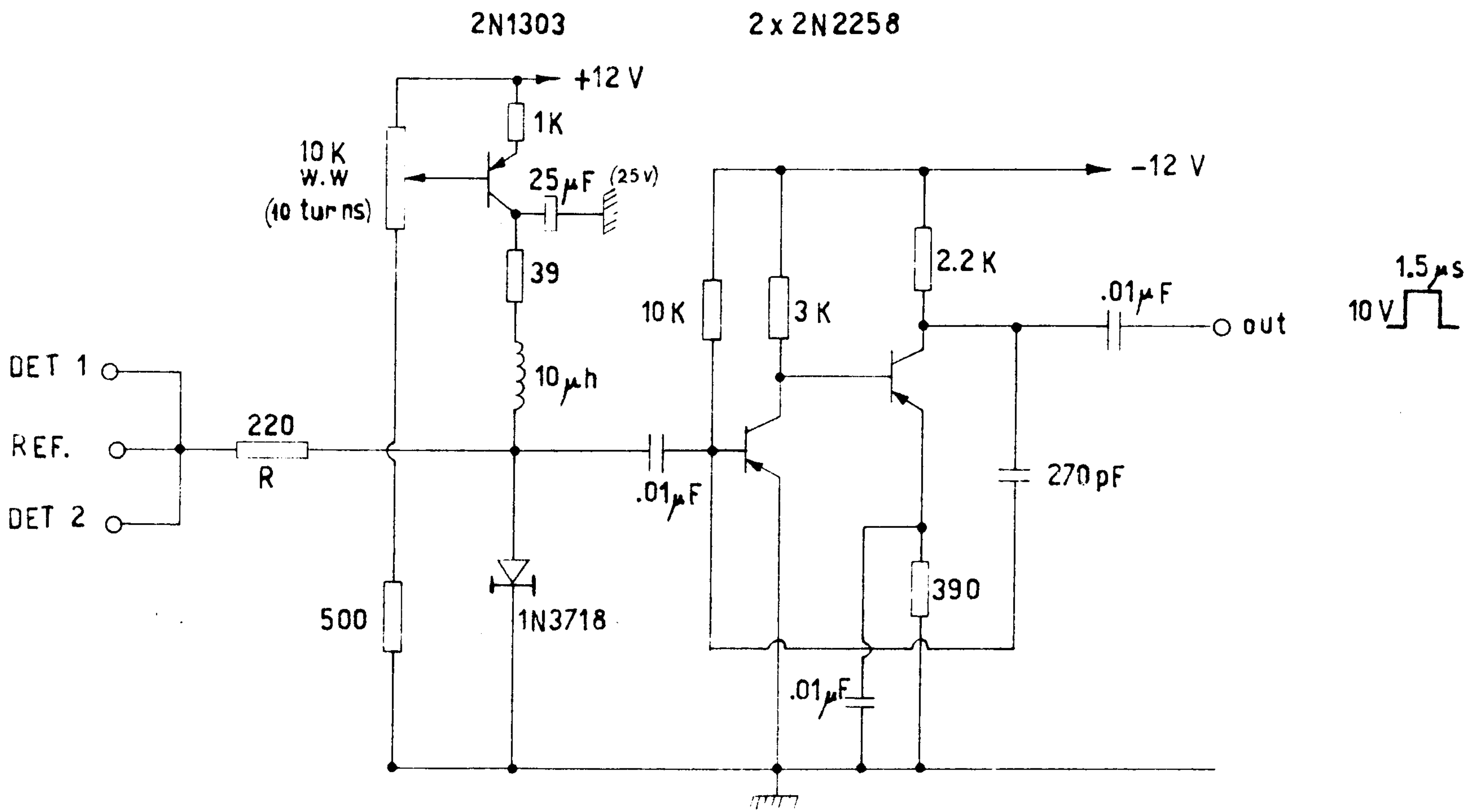
Note: C1 and C2 should be adjusted according to the input and output impedance. The follower is linear for positive pulses up to 10 volt



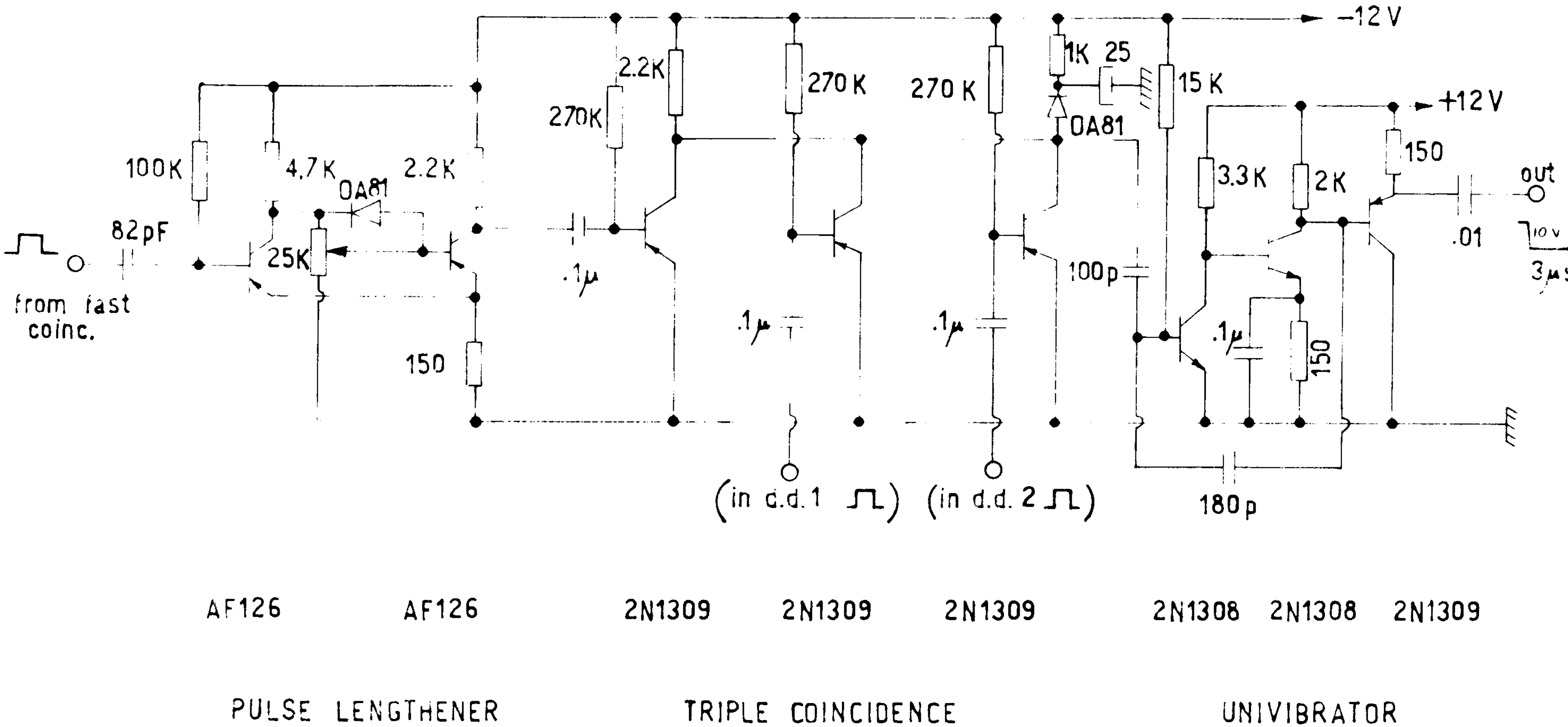
Note: the cable delay is

RG 63 B/U 4ns/m
RG 8/U 5ns/m

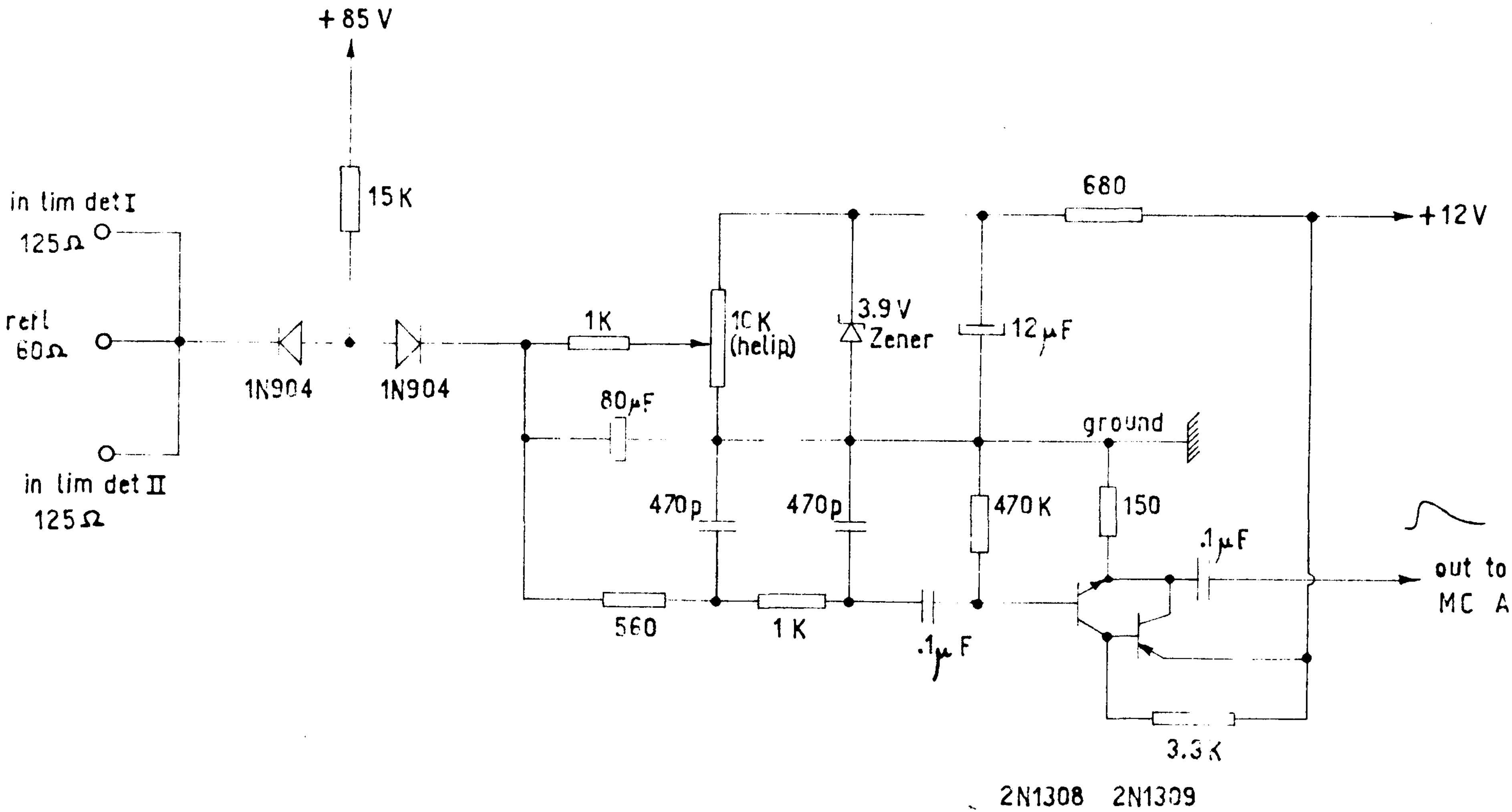
Cable lengths indicated correspond to 110 ns range. Cable lengths in brackets correspond to 220 ns range.



Note: The value of R should be adjusted according to the amplitude of the input pulses.
The value 220Ω is for 1 volt pulses.

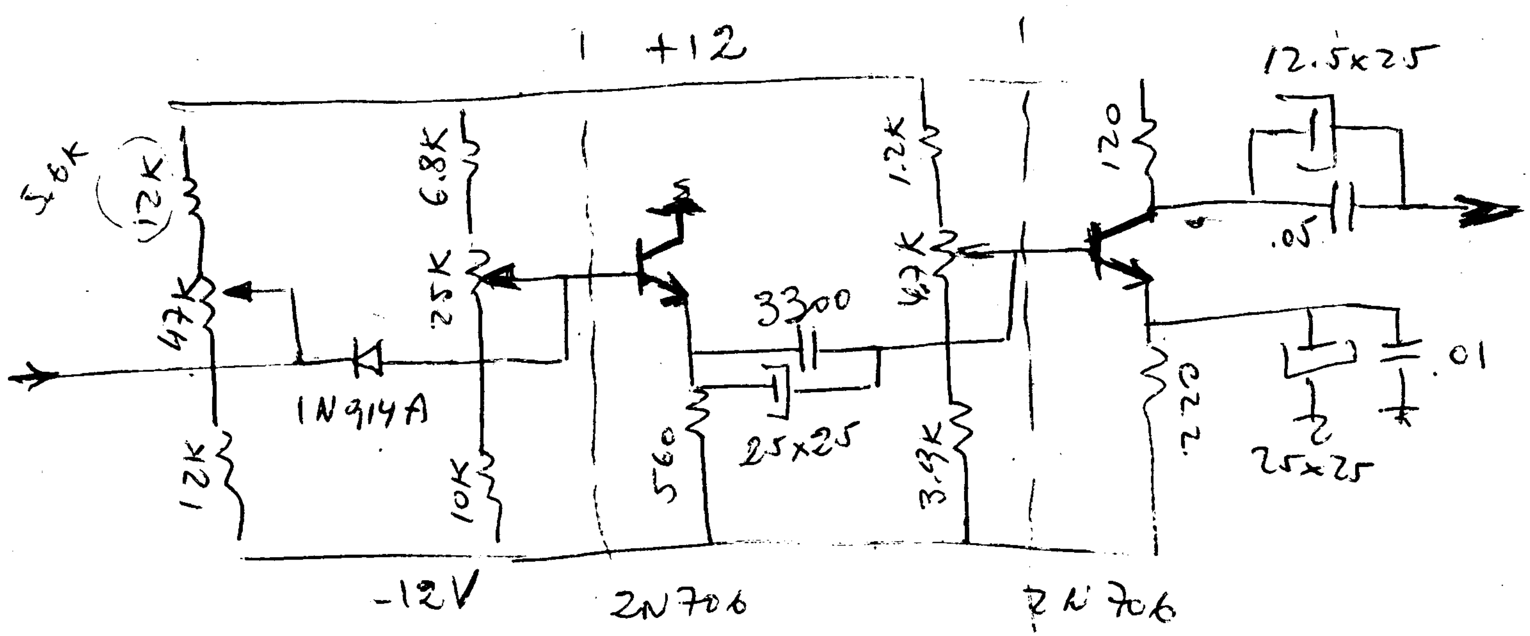


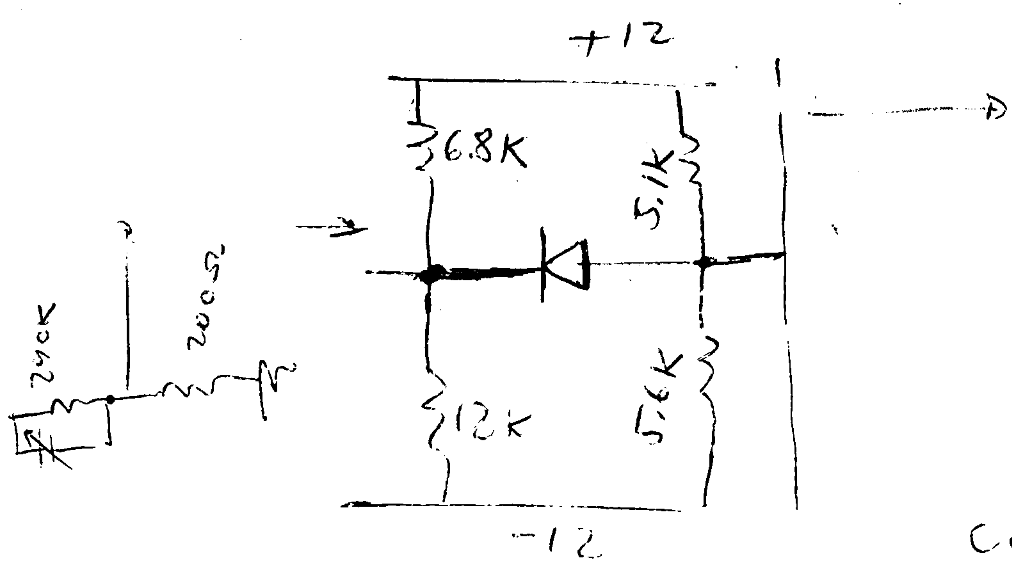
All resistor are 1/4 watt.



+85 V
15 K
in lim det I
125 Ω
refl
60 Ω
in lim det II
125 Ω
1N904
1N904
1K
10 K
(helip)
3.9 V
Zener
12 μF
680
+12 V
80 μF
ground
470p
470p
470 K
150
.1 μF
out to
MC A
560
1 K
.1 μF
3.3 K
2N1308
2N1309

CONVERSION TIEMPO AMPLITUD





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