CHAPTER III

THE APPARATUS AND CONSTRUCTED CIRCUITS

From the basic circuits of Chapter II, the stabilized transistor circuits for standard neutron monitor are constructed. They will be used for the monitor intended for research concerning the study of "cosmic rays". This makes it not so difficult to change any component broken, either because they are worn out (after being used for a long time) or because of accident, as all components used for the circuits constructed can be easily obtained in Thailand.

3.1 General view of the apparatus

The apparatus was constructed with the following features

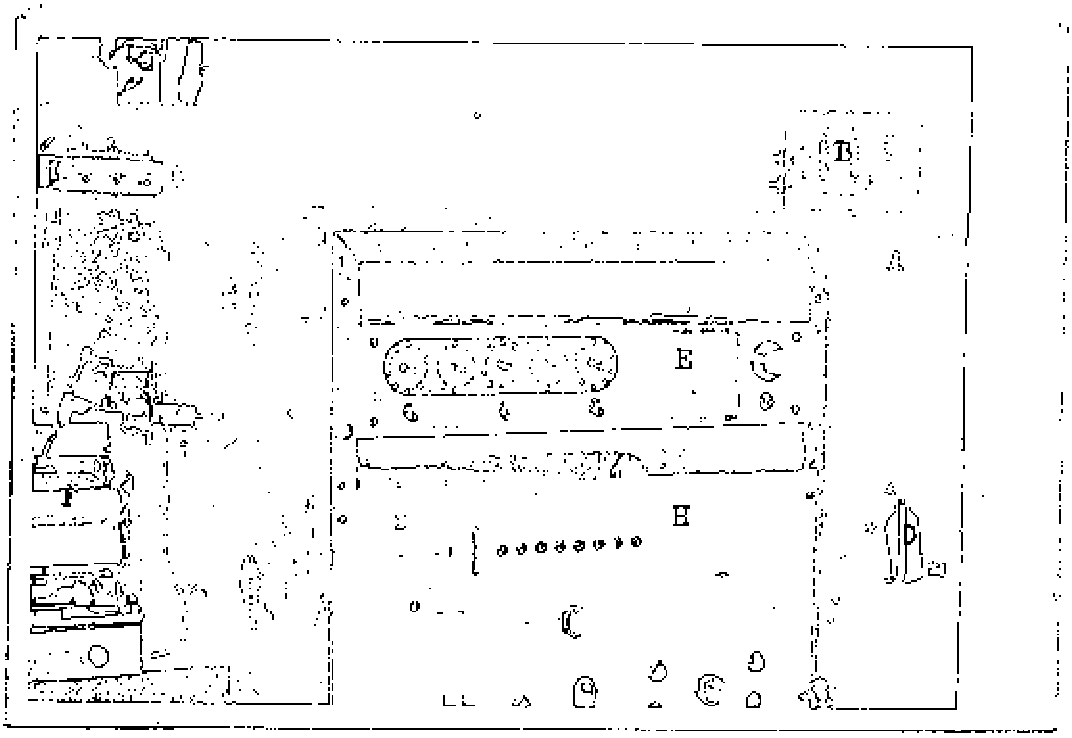
1 The neutron pile is Simpson's type (1).

2 The gas used in the container is boron-trifluoride ($B^{10}F_3$-counter)

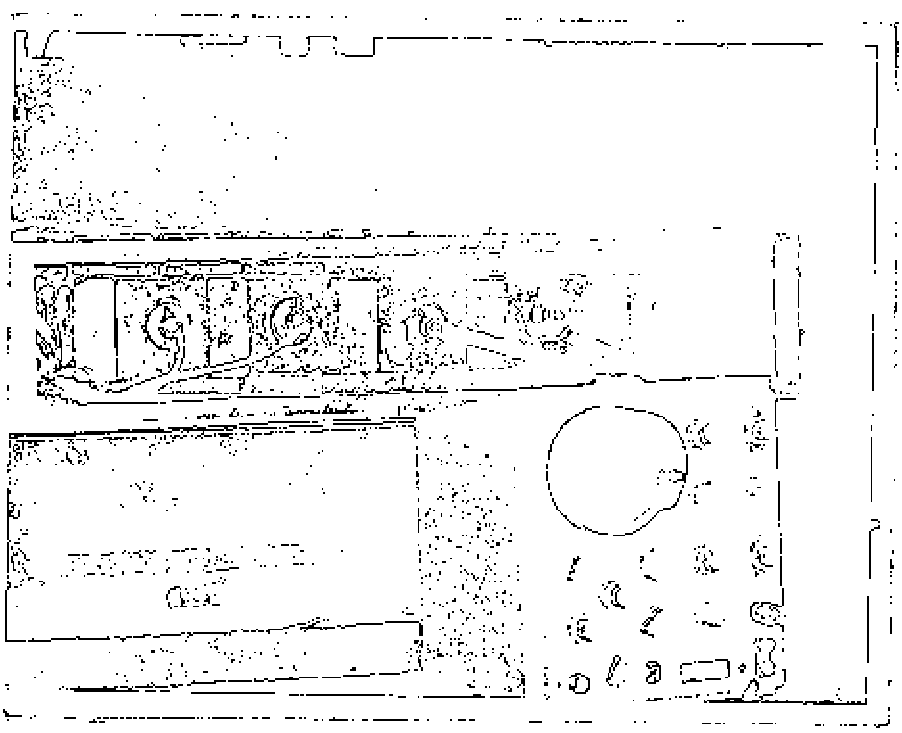
3 The electronic circuits were constructed on plastic plates.

4 The power supplies used are regulated.

5 The AC. line was stabilized by "CRAFT" AC. stabilizer model 1KD 22 no. 15632.



Photograph of the Apparatus



Photograph of the Pile

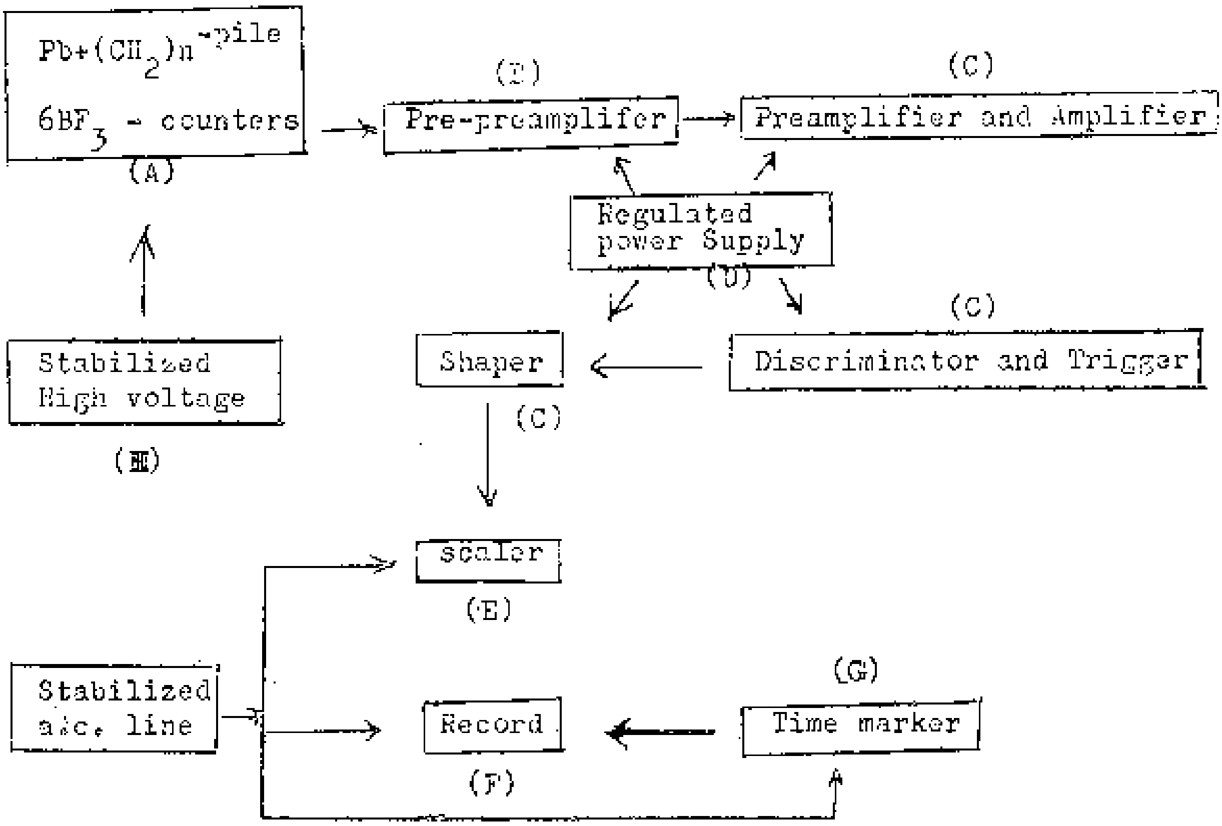


Fig. 3.1 Block Diagram of the apparatus.

3.2 Neutron pile

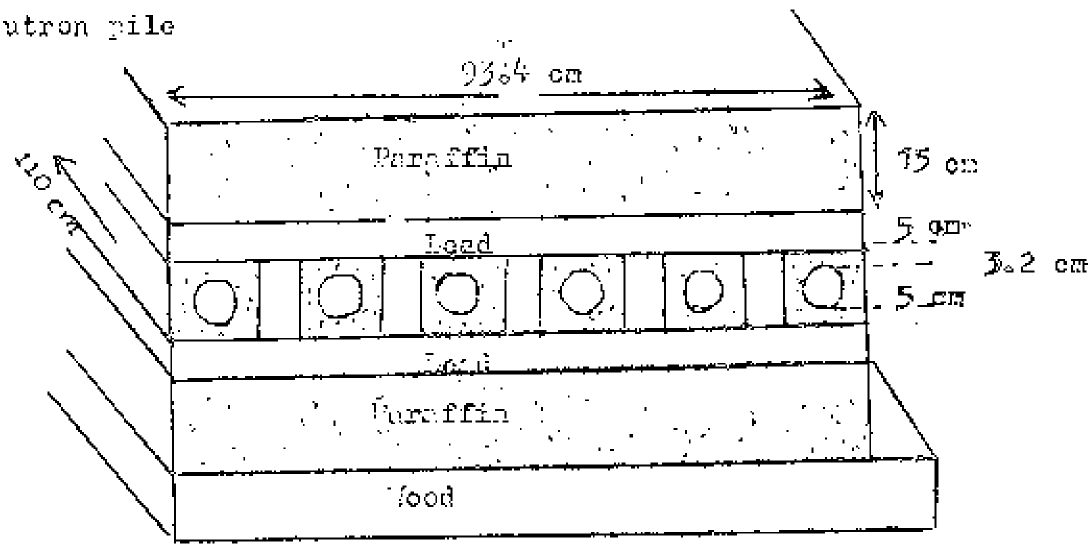


Fig. 3.2 A simplified drawing giving a front view of the frame construction of the standard neutron monitor of the Physics Department at Chulalongkorn University

The BF_3 - counters lie in a horizontal row. Each counter is surrounded by layer of paraffin (hydrogeneous material) 3.2 cm. thick which is called the "inner moderator". The function of the moderator is to slow down, or to moderate the neutrons to the suitable thermal energy to facilitate their capture by the boron trifluoride in the BF_3-counters. The inner moderator is a block of paraffin of 11.4 X 11.4 cm^2. cross section area and at the center is a hole 5 cm. in diameter for fixing the counter. The block is 110 cm. long. A counter inside an inner moderator is called a "counter assembly".

Surrounding the "counter assemblies" is a mass of lead 5 cm. thick which is called the "Producer" , and acts as the main source of neutrons in the monitor. The producer was built of ninety 20 X 10 X 5 cm^3 and twenty five 20 X 11.4 X 5 cm^3 lead bricks.

Surrounding the producer and the counter assemblies is a paraffin enclosure 15 cm. thick, called the "Reflector", which also moderates the neutrons and reflects back the neutrons which might escape from the pile. Another function of the reflector is to absorb unwanted low energy neutrons from the atmosphere and from material in the vicinity of the monitor. The reflector was built of two blocks of paraffin of dimensions 112 X 102 X 15 cm^3 . and four blocks of paraffin of dimensions 116 X 39 X 15 cm^3 .

3.3 Electronic circuits

The general characteristics of the circuits are as follows(3).

1. They are highly stabilized by the feed-back loops and bias compensation.

2. The noise is kept low by using low noise transistors and by keeping the collector current low.

3. They are independent of temperature over a fairly wide range.

4. They have high input impedance and low output impedance to match the BF_3 - counters and the cable line to the scaler repectively.

5. The overall circuits are well protected from any outside disturbances such as triggers or sparks.

The circuits consist of pre-preamplifier, preamplifier, amplifier, discriminator, and wave shaper.

3.3.1 Pre-preamplifier

The pre-preamplifier is a four-stage direct-coupled circuit. Two "AF 117" and two "2 SA 12" transistors were used. The circuit was designed to possess a high input impedance and a low output impedance to match the BF_3 - counters and the cable line to the preamplifier respectively. Its gain is maintained almost constant at about 50. Fig 3.3 shows the circuit of the pre-preamplifier.

Direct-coupled amplifier can be used at frequency that ranges right down to zero and it is possible to reduce the stability factor of at least one stage to less than unity by combining direct-coupling with a resistive feed back circuit around several stages. Phase shift problem by coupling can be neglected by this method.

Direct-coupled pre-preamplifier is most suitable for the work.

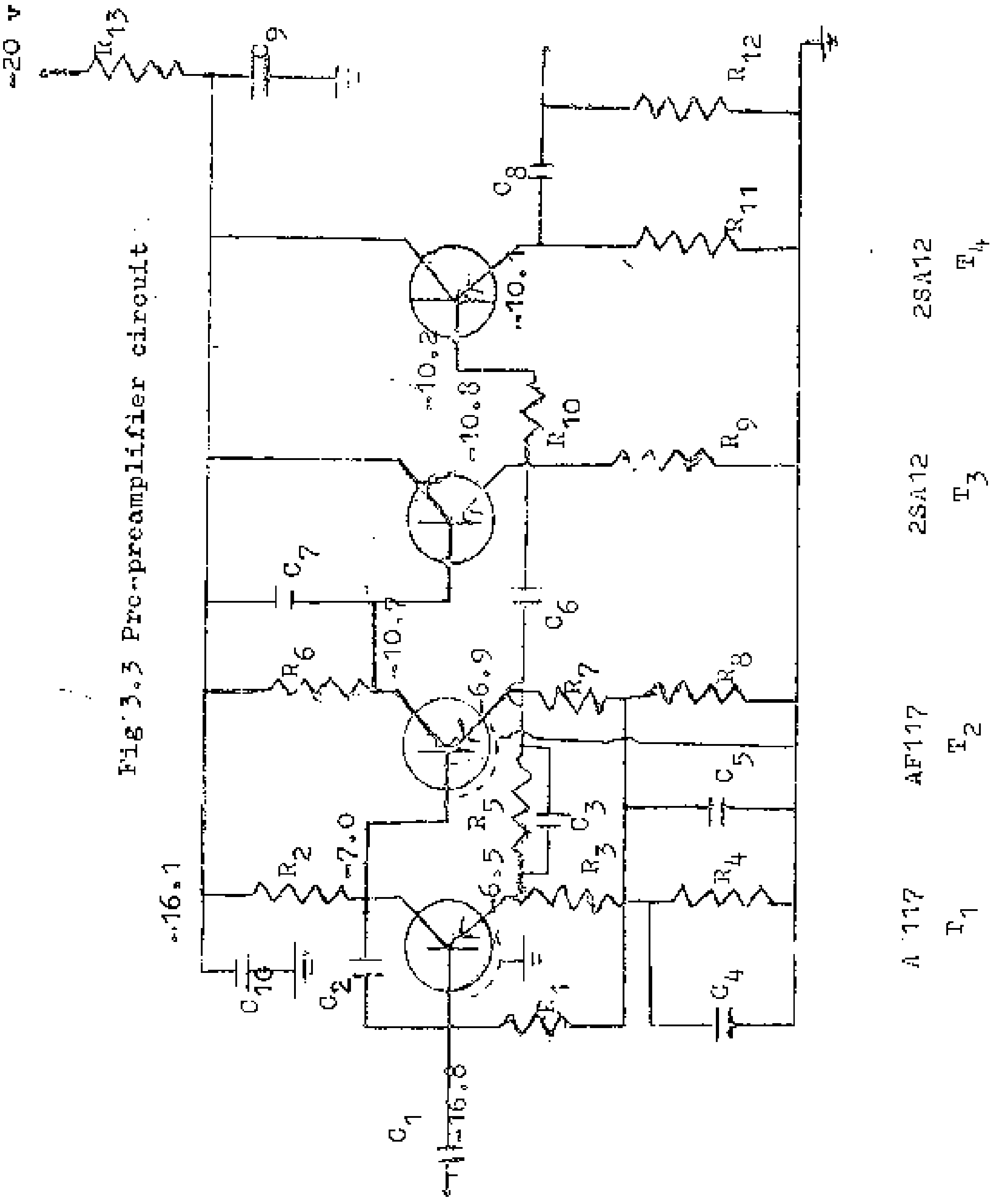


Fig 3.3 Pre-preamplifier circuit

Refer to Fig 3.3

R_1	=	10 kilo-ohms
R_2	=	10 kilo-ohms
R_3	=	100 ohms
R_4	=	6.8 kilo-ohms
R_5	=	10 kilo-ohms
R_6	=	10 kilo-ohms
R_7	=	100 ohms
R_8	=	15 kilo-ohms
R_9	=	6.8 kilo-ohms
R_{10}	=	10 kilo-ohms
R_{11}	=	6.8 kilo-ohms
R_{12}	=	1 kilo-ohms
R_{13}	=	680 ohms
C_1	=	.002 μf
C_2	=	.0012 μf
C_3	=	5 pf
C_4	=	10 μf
C_5	=	10 μf
C_6	=	.027 μf
C_7	=	47 pf
C_8	=	.1 μf.
C_9	=	10^4 μf
C_{10}	=	10^4 μf

C_1 was used to block high voltage. The first two transistors used (AF 117) have low collector capacitance and low noise level. They are both common-emitter, so it is suitable for temperature compensation (2.10).

High frequency is negatively feedback through C_2 . R_3 and R_4 was used for negative d.c. feedback while only R_3 was used for a.c. Negative voltage feedback loops from the emitter of T_3 to the emitter of T_1 , - increases the stability or decreases the stability factor and also increases the input impedance of T_1 to match the BF_3-counter. R_7 and R_8 were used for the same purpose that R_3 and R_4 were used for T_1 . R_8 was also used for d.c. feedback to the base of T_1 while R_8 was used in series with R_1 for increasing the stability or decreasing the stability factor of T_1 (see Table 2.1).

C_7 was used for low frequency compensation, passing high frequency signals from the collector of T_2 to ground. R_{10} increases the linearity of the pre-preamplifier.

The last stage is the emitter follower in order to match the cable line to the preamplifier. C_9 and R_{13} were used as filter and C_9 is also most important for protecting electric disturbance from outside.

The collector-current of the circuit constructed is given below:

$$I_{C\,max} \text{ for AF 117} = -10 \text{ ma},$$

$$I_{C\,1} \approx -\frac{16.1-7.0}{10\times10^3} \text{ a},$$

$$\approx -0.91 \text{ ma},$$

$$I_{C\,2} \approx -\frac{16.1-10.7}{10\times10^3} \text{ a},$$

$$\approx -0.54 \text{ ma},$$

$$(I_{B_2} , I_{B_3} \approx 0)$$

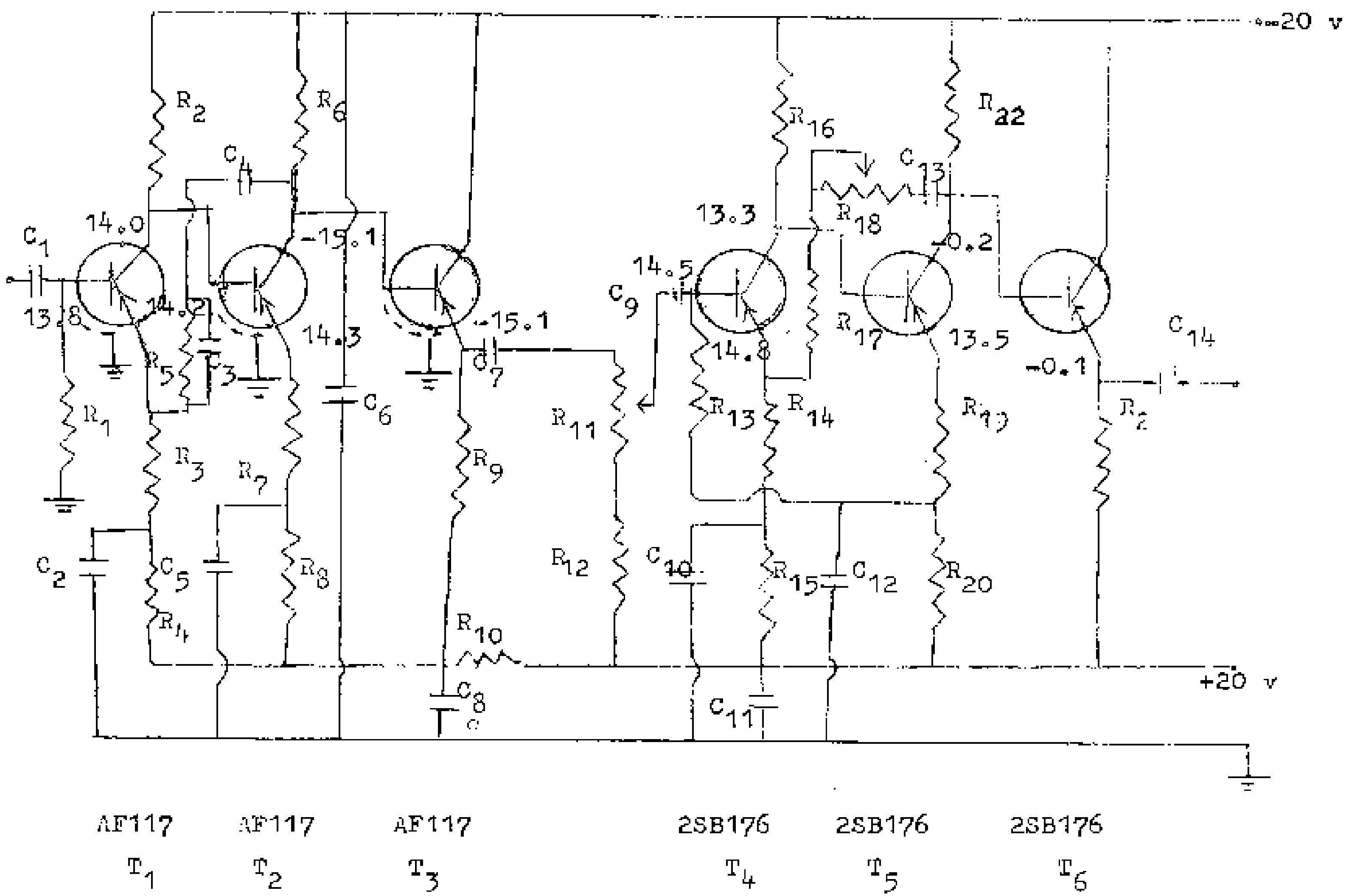
3.3.2 Preamplifier

The preamplifier circuit used is the same as that of the pre-preamplifier except that the input capacitance C_1 .056 Mf and R_{12} 100 ohm resistor were used instead of the .002 Mf capacitance and 1 K resistor used in the pre-preamplifier. Signal drop decreasing as increasing input capacitance and stability factor decreasing as decreasing R_{12} . The gain of the preamplifier was maintained almost constant at about 45.

3.3.3 Amplifier

The amplifier is a five-stage direct-coupled and one R-C coupled circuit. Three "AF 117" and three "2 SB 176" transistors were used. Its gain was maintained almost constant at about 450.

Fig 3.4 Amplifier circuit



Refer to Fig 3.4

R_1	=	3.3	kilo-ohms
R_2	=	15	" "
R_3	=	150	ohms
R_4	=	220	"
R_5	=	18	kilo-ohms
R_6	=	5.6	" "
R_7	=	1	" "
R_8	=	1.8	" "
R_9	=	10	" "
R_{10}	=	330	ohms
R_{11}	=	3	kilo-ohms
R_{12}	=	1	" "
R_{13}	=	33	" "
R_{14}	=	220	ohms
R_{15}	=	2.2	kilo-ohms
R_{16}	=	15	" "
R_{17}	=	4.7	" "
R_{18}	=	5	" "
R_{19}	=	330	" "
R_{20}	=	2.2	" "
R_{21}	=	10	" "
C_1	=	.9	μF
C_2	=	4	"
C_3	==	47	pf
C_4	=	27	"
R_{22}	=	8.2	kilo-ohms

C_5	=	4	μf
C_6	=	25	"
C_7	=	.025	"
C_8	=	10	"
C_9	=	.025	"
$C_{10}=C_{11}=C_{12}$	=	10	"
C_{13}	=	.025	"
C_{14}	=	.1	"

The important point of the design of the amplifier is to create an amplifier that can be used at frequencies ranging right down to zero and simultaneously is stable enough for the purpose of our work. The gain must also be high enough.

Direct-coupling is most suitable if the problem of drift can be neglected. Its disadvantage is that the voltage of the output increases as more stages are added, for common emitter stage, because the base voltage of each stage has to be the same as the collector voltage of the previous one.

The low values of input current drift may be obtained by operating the input transistors at low values of collector current (7). The input voltage drift is only slightly dependent on collector current, the increase in $\Delta V_{BE}/\Delta T$, as collector current is reduced, may usually be neglected. In order to reduce the leakage component of I_{CBO} , the collector-base voltage should be held as low as possible .

Optimizing the low-frequency noise performance also calls for low values of collector current and collector-base voltage. In general, the precautions taken to reduce drift also tend to give low noise. The stability of an amplifier is determined primarily by the input stage. This stage is therfore operated at bias conditions which produce minimum drift.

The amplifier designed is composed of two sets. Each set has two direct-coupled common-emitter stages and one emitter-follower stage. The transistors used are of the same type. This arrangement (Fig 3.4) canget rid of the disadvantages mentioned above and also compensates for the drift (2.10).

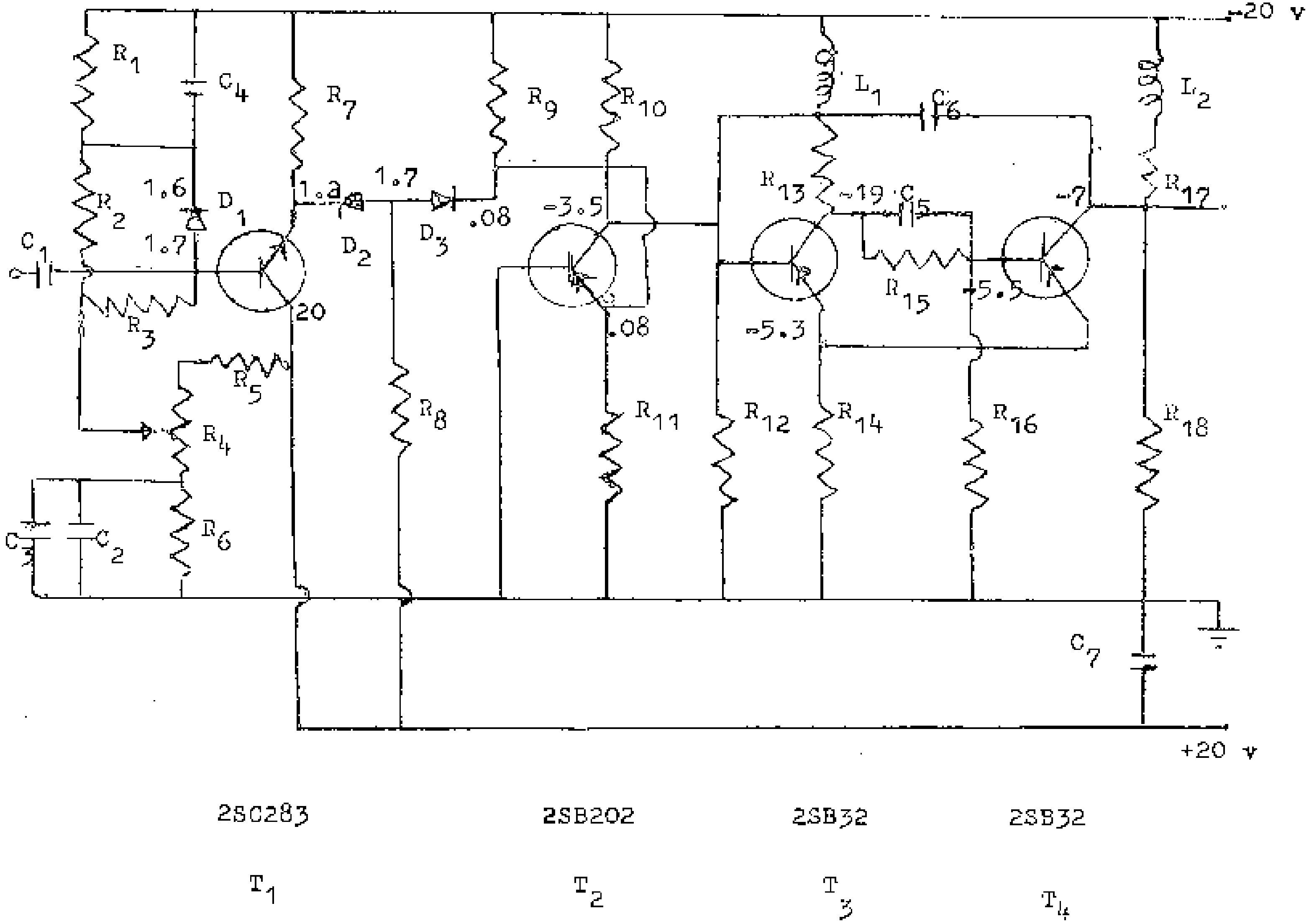
R_1 is used for reducing the stability factor. Resistor R_3 and R_4 were used for negative d.c. feedback for T_1 while R_4 was also used for filter for +20 v. The same method was applied to the other set.

The feedback factor for the second set can be controlled by R_{18} and the gain can be controlled by R_{11}. So the circuit stability and gain can be controlled to the desired point.

3.3.4 Discriminator

The discriminator is a one transistor circuit.

Fig 3.5 Discriminator circuit



Refer to Fig 3.5

R_1	=	10	kilo-ohms
R_2	=	1.5	"
R_3	=	68	"
R_4	=	2	"
R_5	=	220	ohms
R_6	=	150	"
R_7	=	3.3	kilo-ohms
R_8	=	3.9	"
R_9	=	330	"
R_{10}	=	2.7	"
R_{11}	=	22	"
R_{12}	=	2.7	"
R_{13}	=	220	ohms
R_{14}	=	180	"
R R_{15}	=	2.7	kilo-ohms
R_{16}	=	1.8	ohms
R_{17}	=	470	ohms
R_{18}	=	10	kilo-ohms
C_1	=	220	pf
C_2	=	1	μf
C_3	=	10	nf
C_4	=	.1	μf
C_5	=	37	pf
C_6	=	15	"
C_7	=	2000	μf

$L_1 = 10\ \mu h$

$L_2 = 15\ \mu h$

$D_1 = D_2 = D_3 =$ "OA79" germanium diode

The important point for the design of the discriminator is to maintain the bias of T_1 constant as temperature varies and at the same time the discriminator can deliver the largest possible signal to the next stage. Bias compensation (2.9) was used. The diode "D_1" was used to keep I_b of T_1 constant where as "D_2" was used to keep the output voltage of T_1 constant. The diode "D_3" was used to keep the output of T_2 constant.

Common collector NPN transistor was used as the discriminator in order to match T_2 and at the same time to reduce the drift (2.10). The discriminator was set by biasing the base voltage of the transistor through R_4. The resistor "R_8" was used to keep D_2 and D_3 biased in the forward low impedance region. The common-base stage followed by common-emitter stage arrangement can eliminate the drift also.

The choke coils L_1, L_2 and capacitor C_5 were used for adjusting the edge of the pulse of the square wave output. The capacitance was determined by increased by trial and error. Sensitivity of the output stage can be increased by positive feedback through C_6.

3.3.5. Amplifier shaper

The amplifier shaper is a two stage R-C coupled circuit. Both transistors are emitter-follower stages. The output is suitable to match the cable line to the scaler.

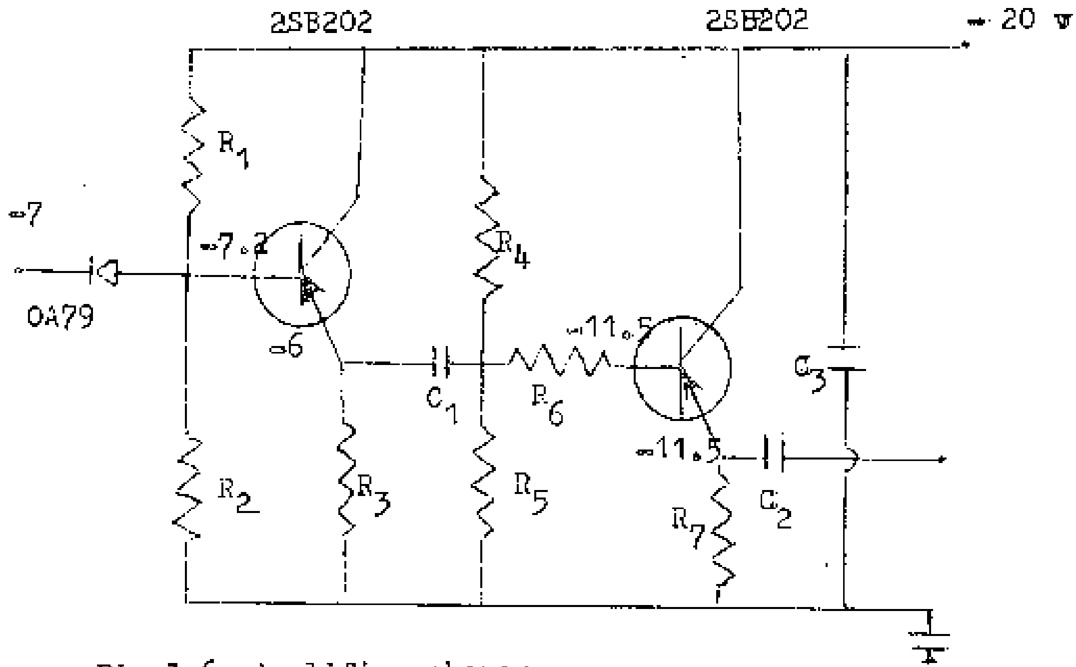


Fig 3.6 Amplifier shaper

Refer to Fig 3.6

R_1	=	15	kilo-ohms
R_2	=	4.7	"
R_3	=	3.9	"
R_4	=	8.2	"
R_5	=	12	"
R_6	=	2.2	"
R_7	=	3.9	"
C_1 = C_2	=	.1	Mf
C_3	=	2,000	"

The diode "D" was used as detector to block any accidental positive pulse. The differentiating circuit composed of C_1 and R_5 was used to change the square pulses from the trigger to the sharp pulses suitable for the scaler.