CHAPTER II

CONTROL SYSTEM AND CIRCUIT DESCRIPTION

2.1 General Description

The printout and control system for neutron spectrometer consists of two timer - scalers, printout control, line printer, RFG and motor controller. Their auxiliary components are RF coil, motor, cam, microswitch and neutron detectors. With the help of the block diagram in Fig. 2.3 , the signal sequence diagram in Fig. 2.4 and schematic diagrams of the associated circuitry the operation of the system will be more clearly understood.

2.2 Main and Monitor Scalers

The Main and Monitor Scalers employed in the Neutron Spectrometer are ORTEC 431 Timer - Scalers. They have been set up and tested for proper operation, the Master - Slave - Normal controls can be switched as desired. Normally in a counting system, one-time (or scaler) would be selected as a Master and remaining scalers (or timers) would be selected as slaves. With this arrangement, the entire counting system can be controlled from the Master. The On-Off control on the Master would start and stop accumulation in all of the scalers and timers and the Reset push button on the Master would reset all of the system. In addition, a Gate signal to the Master could also exercise control over the entire system while individual Gate signals to the Slaves would control only that Slave Scaler.

The preset time interval signal from the rear panel Interval Connector of the Master to start and stop counting in the Slave Scaler will allow the On-Off switch on the Timer to start and stop counting in the scaler provided the scaler controls are set to permit counting. Referring to Fig.2.3 , the Main Scaler is used as the Slave while the Monitor Scaler acts as Master Scaler. As described in section 1.4 of chapter I, the Main Scaler records counts of neutrons scatterred from the specimen while the Monitor Scaler counts neutrons impinging on the specimen. Usually specific neutron counts are preset in the Monitor so that equal amount of neutrons incident on the specimen for each measurement is obtained. In this way when the neutron counts in the Monitor Scaler reach the preset value a signal from the Monitor Scaler will stop the neutron counting in the Main Scaler.

2.3 Printing Operation

The scaler is designed to operate as a part of an automatic data aquisition system. The characteristics of the scaler provides the data stored in its registers to the printout control in a serial by character format. The data is fed to the Print out control in six groups (characters), one following the other at a rate determined by the printout control. Each group or character is composed of four bits (BCD) of information in a 1248 code with a logical one being about +5V and a logical zero about 0V. The transfer of data starts with the most significant decade and proceeds sequentially to the least significant decade. Figure 2.4 shows the sequence of event for a scaler containing the number 705849. As a note of explanation, the Print command signal originates in the printout control. It can be initiated either manually, automatically by the scaler reaching a preset condition or triggered externally. The Start Data Transfer is supplied by the Printout Control to the Main Scaler in Fig. 2.4. When all data in the Main Scaler are transferred to the printer, a signal called Previous Module Finished (PMF) is generated at the negative going edge of the Start Data Transfer signal. The new signal will trigger RF - Motor Control unit and reset the whole system to restart data accumulation.

The following sequence of events illustrates how the scaler printing option in ORTEC 431 Timer - Scaler operates.

a. A Print Command is generated manually, by Preset or Triggering.

b. Scalers and Timers stop accumulating and remain static for one or two seconds.

c. All indicators go off except the most significant digit which is printed by the printout control.

d. Each of the remaining five digits are printed in succession and as each digit is printed the indicator for that digit is illuminated

e. The six digits in the printed format represent the data of each counting.

f. This sequence automatically repeats until Scaler-Timer is turn off.

2.4 <u>Printout Control</u> (see Fig. 2.6 to Fig.2.8)

Principally, the Printout Control works as the nerve centre of the system. It receives the information in BCD (Binary Coded Decimal) from the Main Scaler, decodes the information into decimal code and register the number in the Line Printer through its Mechanical Register. When all the registration is done, the Printout Control signals the Line Printer to print the registered data.

The signal PRINT COMMAND is used to actuate the transmission of the BCD - coded information from the Main Scaler to the Mechanical Register. This PRINT COMMAND signal can be initiated either manually by the Switch SW_1 or automatically by the signal called INTERVAL from the Monitor Scaler which controls the neutron flux incident on the sample to be investigated. At the beginning of the measurement a preset count is set in the Monitor Scaler and when the preset count level is reached the INTERVAL output of the Monitor Scaler will send a signal called INTERVAL to the Main Scaler to stop counting. The INTERVAL signal also routes to the Printout Control to initiate the PRINT COMMAND signal. Upon stop counting the Main Scaler will display randomly any of the six digits of the counter. Since the registration in the Line Printer should begin with the most significant digit it is necessary that the Main Scaler should display the most significant digit to be registered. This is done by the START DATA TRANSFER signal which occurs a few milliseconds after the PRINT COMMAND signal. In contrary to the PRINT COMMAND signal the START DATA TRANSFER signal is characterized by its positive going edge. The START DATA TRANSFER signal will initiate the transferring of the data from the Main Scaler to the Mechanical Register commencing with the most significant digit which will be simultaneously displayed in the Main Scaler.

The registration is achieved through the Mechanical Register of the Line Printer. The solenoid of the Mechanical Register operates with a current pulse of amplitude 1 A and 30 ms pulse width. The most significant digit will be registered first and then the consecutive digit will be registered and so on until the last significant one is registered. At the end of registration of a digit, the BCD information of the next digit will be transmitted to the Printout Control to be decoded into decimal one. This is done during the release time of the solenoid of the Mechanical Register after completing the registration of the foregoing digit. As shown in the Signal Sequence (Fig. 2.4) the release time of the Mechanical Register is 25 ms. The Registration Action is actuated by the signal called PRINT DRIVE with a period of 55 ms. The complement of the PRINT DRIVE named PRINT ADVANCE is used to initiate the transmission of the BCD data of the next consecutive digit to the Printout Control where it will be decoded for registration. After the completion of the registration of all six digits in the Main Scaler, the Printout Control will send a signal called PRINT to the Line Printer to actuate the printing mechanism in the Line Printer to print the registered information. The PRINT signal is actuated by the positive going edge of the THIS MODULE FINISH signal and has a pulse width of 30 ms which is long enough for the Line Printer to print all the registered data. The positve going edge (to logical 1) of the THIS MODULE FINISH signal is used to latch the Printout Control to stop sending the signals START DATA TRANSFER, PRINT DRIVE and PRINT ADVANCE allowing the next data accumulation to be carried out again.

2.5 Radio Frequency (RF) (see Fig. 2.9)

With the Mode Switch (SW_3) in Auto position only, the signal Print Command (PC) can reach the Preset Counter input. The Previous Module Finish (PMF) signal which has its origin in the Printout Control Unit is modified from This Module Finish (TMF) signal by allowing the latter to pass through a buffer for proper matching with the input of Gate A_2 . like the P.C. signal the function of the PMF signal starts at its negative going edge and stops at its positive going edge. Coupling through an RC differentiator the output of Gate A_2 is used to actuate A_3 giving a Reset Signal to Main and Monitor Scaler for all positions of Mode Switch.

The PC signal after passing the Mode Switch (at Auto position) will actuate the Preset Counter and Display Unit (to be described in the following section), the output of which is directly coupled to the input of Gate A_1 . The same PC signal is also coupled to the Gate A_1 through an RC integrator. As soon as the PC counts is equal to the number already preset in the Preset Counter and Display Unit there will be a narrow negative going pulse at the output of Gate A_1 .

At position 1 of Selector Switch SW_4 the output signal of A_1 will act as the clock pulse of FF_1 the output of which will drive transistor Q_{19} ON and OFF to actuate the Control relay of RF power. Thus the RF power will be switched ON and OFF according to the level of output Q of FF_1 . With Q output of FF_1 at logical 1 (+5V), transistor Q_{19} will conduct and close the relay contact and the RF power to the sample under investigation will be turned ON. Similarly, when Q is at logical 0 (0 Volt) transistor Q_{19} will be cut-off and RF power will be turned OFF through the relay at the collector of transistor Q_{19} . At the ON-state of RF power the $\overline{Q}$ output of FF_1 will be at logical 0 (0 Volt) allowing the current passing through the LED and the LED will be lighted. Note that owing to the signal delay at CLEAR input of FF_1 the output Q of FF_1 will be at logical 0 and the RF power will be turned OFF. The FF_1 will change its state upon receiving a clock pulse from Gate A_1 only.

At position 2 of selector Switch SW_4 the negative output signal from Gate A_1 acts as clock pulse at the clock input of FF_1 and FF_2 in order to control the RF power and sample driving motor simultaneously. The motor is used to change the angular position of the sample relative to the incident neutron beam. The Flip-Flop FF_1 works in the same manner as described earlier (SW_4 at position 1). The combination of closed-loop RC integration at the CLEAR input ensures that the Flip-Flop FF_2 will always be in proper state (with Q at logical 0 and $\overline{Q}$ at logical 1 levels) regardless of the position of the microswitch at the moment the Power Switch is turned ON. The normal operation of the microswitch after turning the Power ON is at ground level with $\overline{Q}$ at logical 1 and Q at logical 0. At this position of the microswitch no base current is supplied to transistor Q_{21} to operate the relay and the driving motor stands still.

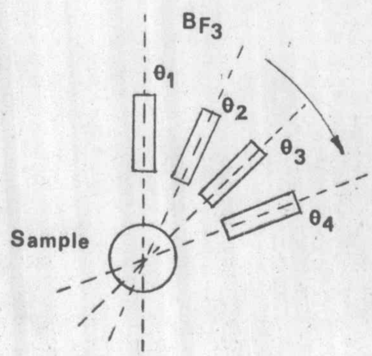
When Flip-Flop FF_2 receives negative clock pulse from Gate A_1 FF_2 will change state, i.e., Q will be at logical 1 and $\overline{Q}$ will be at logical 0. The Q output supplies base current to transistor Q_{21} which will conduct and actuate the relay at its collector supplying power to the sample driving motor to change the angular position of the sample until the cam coupled to the motor actuate the microswitch to change FF_2 to its other state with Q at logical 0 and $\overline{Q}$ at logical 1. At this state of FF_2 the motor is brought again to stand still since transistor Q_{21} supplies no current to the relay controlling the sample driving motor. With $\overline{Q}$ at logical 0 the LED D_{25} will be lighted showing that the sample driving motor is ON, and it will extinguish when $\overline{Q}$ changes to its other state. Since the $\overline{Q}$ output of FF_2 is connected with the input of Gate A_3, the output of Gate A_3 will be at logical 1 as long as the sample driving motor is ON, during which the Main and Monitor Scalers will be reset to zero by logical 1 by signal of Gate A_3. As soon as the sample is changed to the desired angular position the Main and Monitor Scalers will start counting until the preset cycle is completed when the driving motor is ON agin to change the sample to next angular position. If desired the operator can change the angular position of the sample manually by depressing push button switch SW_5. In this case the base current will be supplied directly by +5V supply and the motor will be turned ON as long as the depressing of SW_5 continues.

At position 3 of SW_4 the CLEAR input of FF_1 is connected to ground holding the Q output of FF_1 to logical 0 and RF power is turned OFF. The Flip-Flop FF_2 still receives the negative clock pulse through SW_4 at its input. The Flip-Flop FF_2 and Gate A_3 works in the same manner as in the case with switch SW_4 at position 2 described above.

Selector switch SW_4 and the Push Button Switch SW_5 provide the operator with various combination of operation as desired by the measurement. This may be shown in the following illustrative examples :-

Example 1 Mode Switch at AUTO position, Selector Switch at position 1, Preset Count is set at 3.

In this case the Main and Monitor Scalers will count two times (one time less than the number in the Preset Counter) for each state of RF power (ON and OFF). The counting of the Main and Monitor Scalers repeat itself until the MODE SWITCH is turned to NORMAL position. The angular position of the sample may be changed by depressing the MANUAL push button switch.



Printout Data on Main Scaler

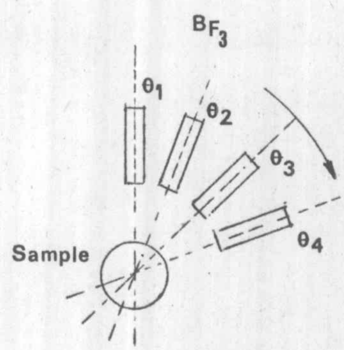
135650
132795 RF ON at θ_1

245891
239752 RF OFF at θ_1

183952
184051 RF ON at θ_2
(angle changed manually)

Example 2 Mode Switch at AUTO position, Selector Switch at position 2, Preset Count is set at 3 .

In this case the Main and Monitor Scalers will count two times (one time less than the number in the Preset Counter) before the sample is changed to the next angular position. At the same time the RF power control change its state from the previous one (ON to OFF or OFF to ON). The counting and angle changing cycle repeat itself until the MODE SWITCH is turned to NORMAL position.



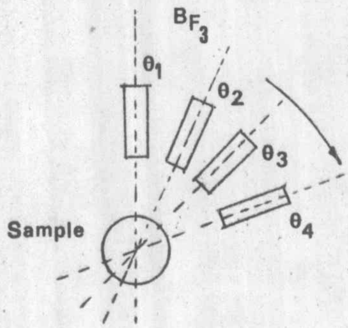
Printout Data on Main Scaler

323346 332379	RF ON at θ_1
435321 453269	RF OFF at θ_2
526380 541036	RF ON at θ_2

(angle changed automatically)

Example 3 Mode Switch at AUTO position, Selector Switch at position 2, Preset Count is set at 3 .

In this case the RF power is turned OFF at all angular position of the sample. The Main and Monitor Scalers count up to two times as in example 1 and 2 before the preset cycle repeats itself at the next angular position of the sample which is changed by the driving motor.



Printout Data on Main Scaler

234682	RF OFF at θ_1
244567	
300468	RF OFF at θ_2
311690	
436732	RF OFF at θ_3
430011	

It is to be noted that the last line (third line in the examples) in the printout format is left blank as an indication of the beginning of the next group of data. The blank line corresponds to the last count in the preset counter. This can be achieved by resetting the data in the Main Scaler before registration command begins.

2.6 Preset Counter and Display Unit (see Fig. 2.10)

The PC (Print Command Signal) enters the input of a BCD (Binary Coded Decimal) counter which will count from 1 up to 9 before it is reset to zero. Its four output terminals A, B, C and D are directly connected to the inputs of the decoder driver which converts the BCD coded signals to decimal digit. The decoder driver has output power high enough to drive a gas-filled display (NIXIE) tube which has internally built-in digits from 0 up to 9. The preset count is set by a thumb-wheel switch, the four inputs of which are connected to the four outputs (A, B, C and D) of the BCD counter. These four inputs of the preset thumb-wheel switch are named 1 2' 4 and 8. The thumb-wheel switch acts as an AND gate and is internally wired for BCD operation. Its output is directly connected with the base of a transistor MPS 3706 which serves as a buffer for Gate A_1 in Fig. 2.10 . Normally the output of a preset thumb-wheel switch is at logical 0 (ground level) and the transistor is in cut-off state. As soon as the BCD counter counts up to the value shown in the thumb-wheel switch a logical 1 signal (+5V) is sent to the base of the buffer transistor (via the output of the thumb-wheel switch) and since the buffer transistor is connected as an emitter follower the same signal also appears at the output of this buffer. The GR 110 NIXIE tube displays in decimal digit the count value in the BCD counter so that the operator knows at every moment how far he has gone through a specific group of measurement.

A feedback exist between the buffer output and the reset input of the BCD counter so that the BCD counter is also reset by the output of the thumb-wheel switch. As soon as the BCD counter is reset to zero, the AND gate action of the thumb-wheel switch changes its output level to logical zero resulting a narrow positive going pulse called preset output (see Fig. 2.10) at the output of the buffer transistor. This preset output is fed to Gate A1 and in combination with the delayed PC signal at the input of Gate A1 it produces a narrow negative going output pulse at Gate A1. This pulse is coupled to the input of Gate A3 via diode D_{11} and an RC differentiator.

2.7 Power Supply (see Fig. 2.11)

Although the system control is housed in a double width NIM module the control circuits are powered by a power supply different from the NIM power supply specifications in order to meet the power requirement of the printing mechanism and the display unit. The gas filled display tube (NIXIE) requires a 170 volts power supply at its anode circuit while the +24 volts supply is needed to supply power to solenoid driver of the mechanical register and printing mechanism in the line printer and also to the relay to operate the RF and Motor Control Unit. No voltage regulation is needed for these power supplies.

On the contrary a good voltage regulation is provided for +5 volts and +2.6 volts power supplies. The +5 volts supply is needed to supply power to digital IC's and the LED indicators while the +2.6 volts supply is provided for the print driver circuit in Fig. 2.8 . Both supplies are protected against short circuit through a current limiter in the voltage regulation loop. In order to minimize the temperature effect on semiconductor components in the regulating loop, a differential pair with 3 separate transistors IC is used. In this way temperature stability of voltage regulation is much improved.

Voltage regulation is achieved by comparing the output voltage with the reference diode D_{32} which has a Zener voltage of 5.6 volts. A base to emitter voltage drop of 0.6 volt at Q_{29} will provide the necessary 5 volt reference voltage at the base of Q_{26}, the inverting input of the differential pair. The noninverting input of the differential pair is directly connected to the output voltage. In this way the output voltage is compared with the reference +5 volts. If an error signal, a difference between the output voltage and reference voltage, occurs, this error signal will be amplified by Q_{25} and drives the series pass transistor Q_{24} in such a way that the error signal between the two inputs of the differential pair Q_{26} and Q_{27} becomes zero. To get a good common mode-rejection, the differential pairs are emitter-coupled through a constant current source provided by Q_{28} and R_{75}

Diode D_{31} will conduct when the output terminal is shorted to ground and will hold the potential at the base of Q_{29} at ground level. Consequently, Q_{29} will be cut-off and no current is supplied to the base of Q_{26} and since the collector of Q_{26} is directly connected to the base of Q_{25}, the short of colloector current of Q_{26} will make the darlington pair Q_{25} and Q_{24} totally cut-off and no current is supplied through the series pass transistor Q_{24} preventing the bridge rectifier D_{33} and transformer T_1 from damage incurred from short circuiting.

Resistors R_{76} and R_{77} form a voltage divider providing reference voltage to darlington pair Q_{30} and Q_{31} in such a way that a regulated voltage of + 3.2 volts exists at the collector of Q_{30}.

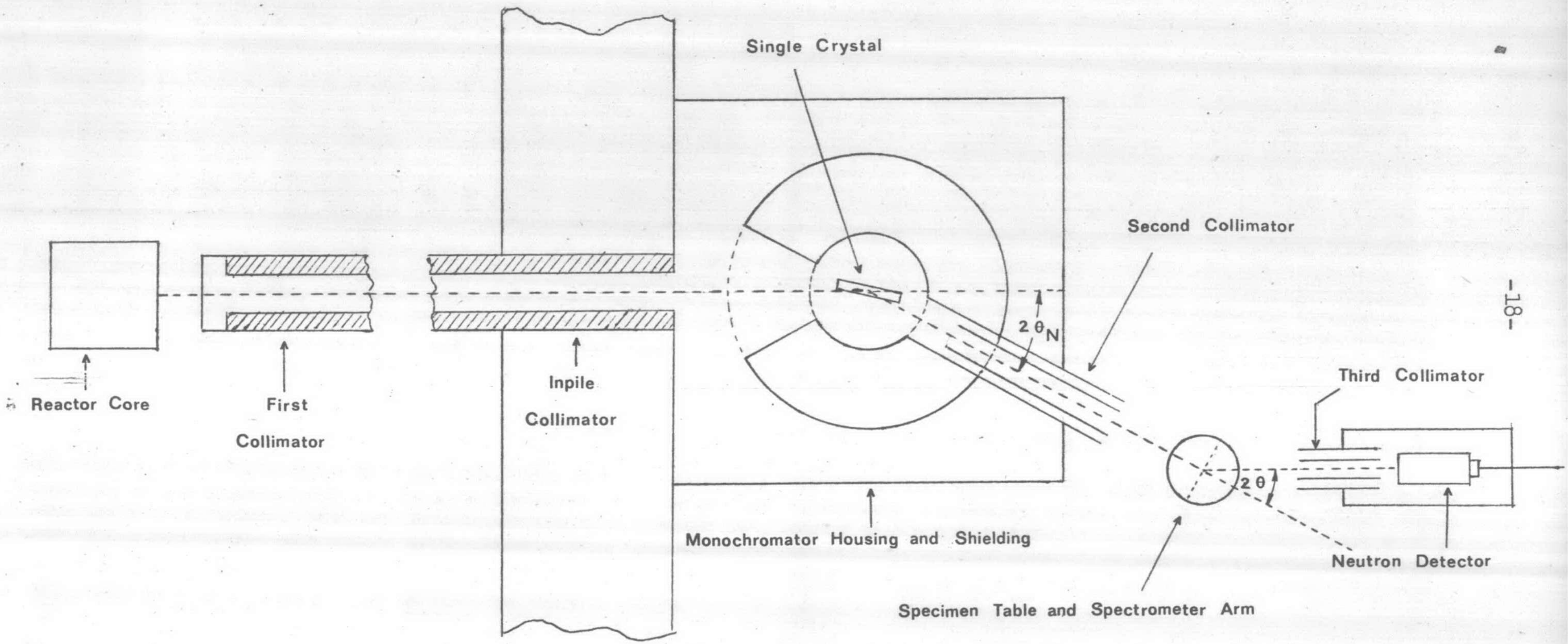


Fig. 2.1 A Diagram of Neutron Spectrometer[1]

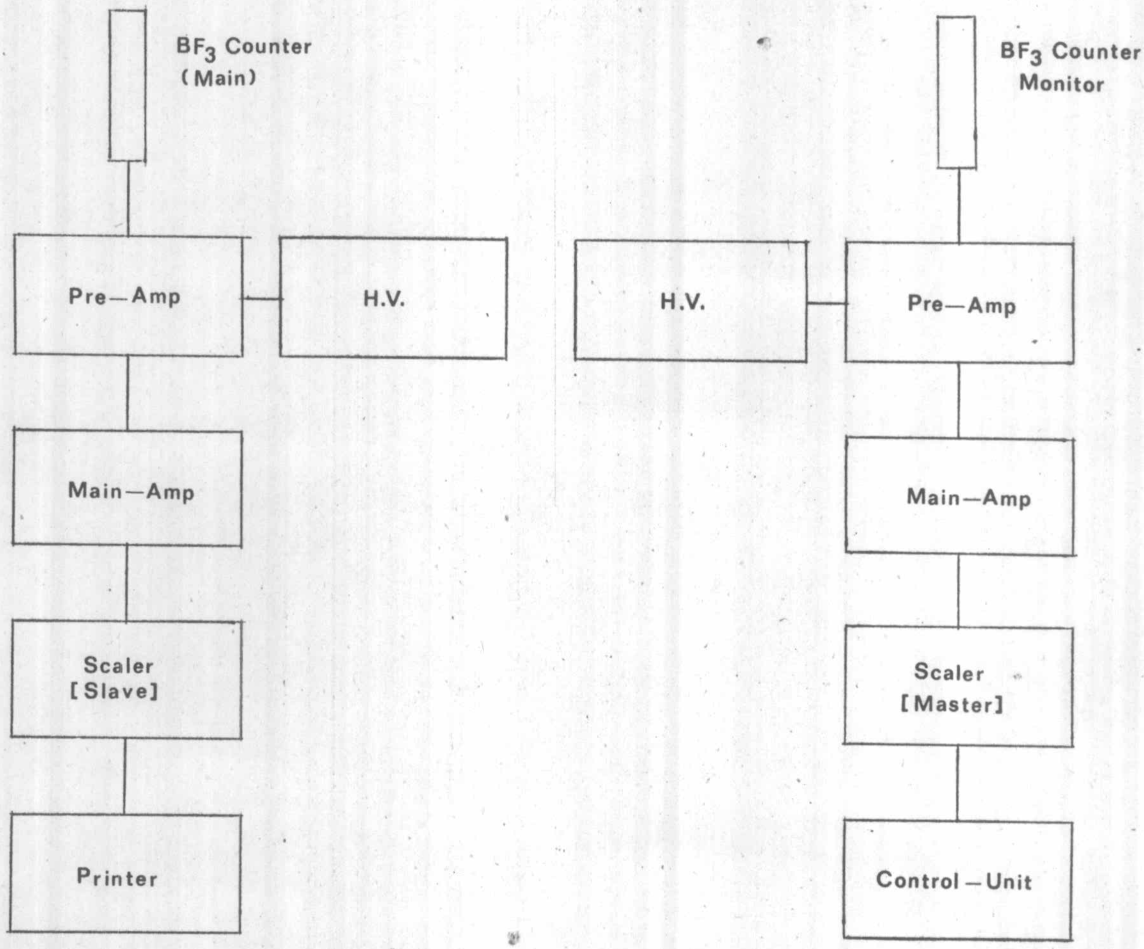


Fig.2.2 Block Diagram of Neutron Detection and System Control[1]

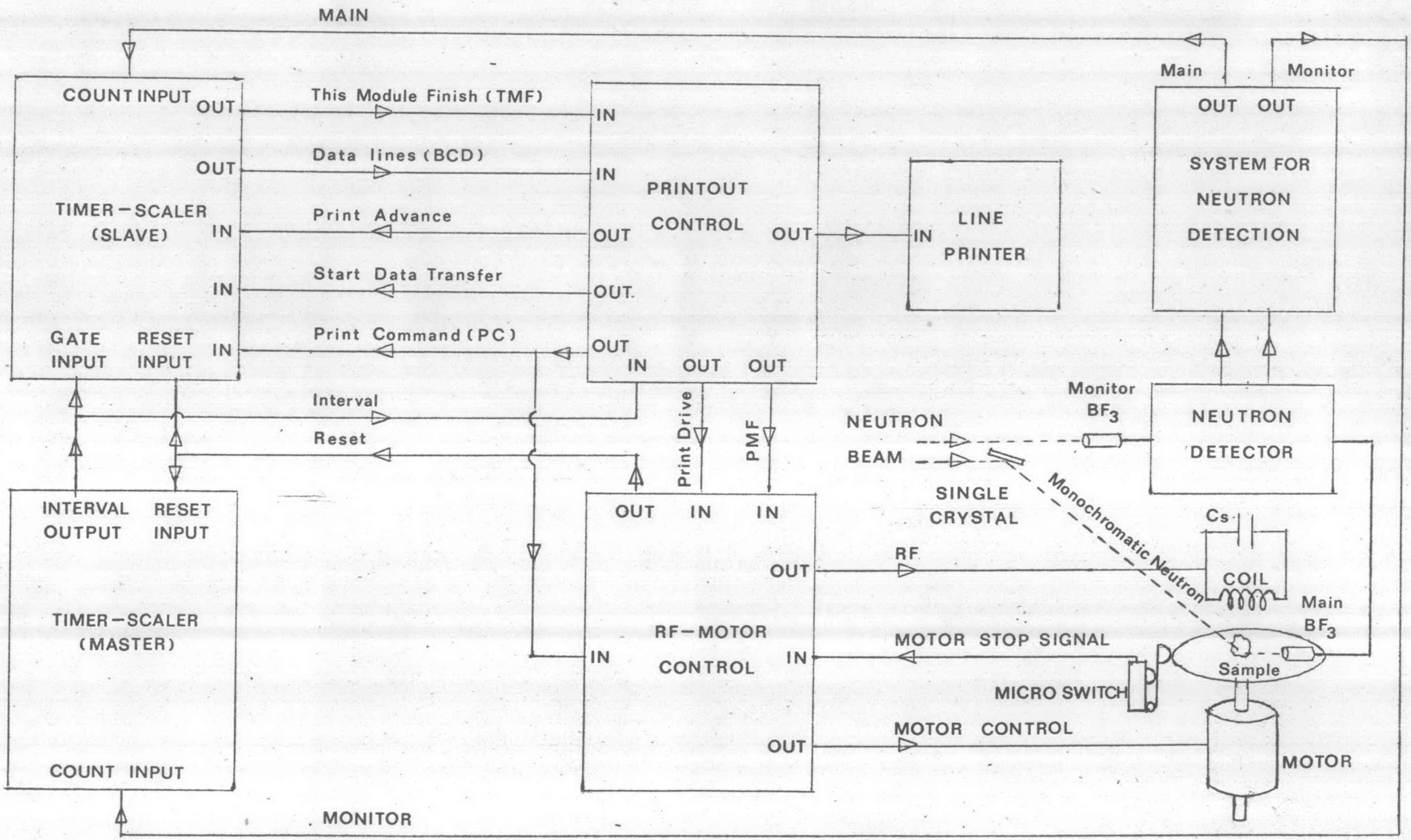


Fig. 2.3 Printout and System Control for Neutron Spectrometer

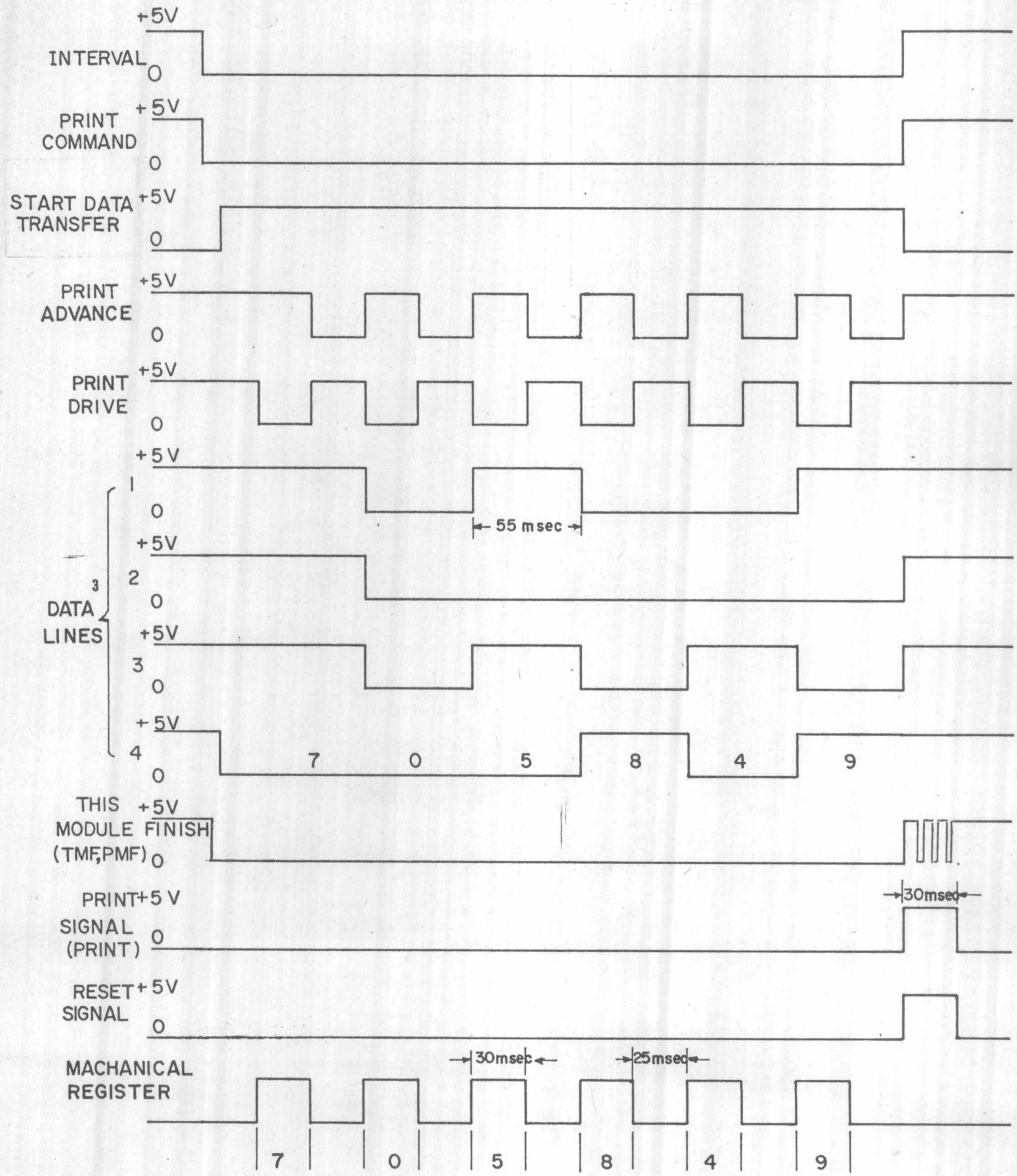


FIG. 2.4 Timing Diagram (Signal sequence for transferring data for 705849 from a printing scaler to the printout control)

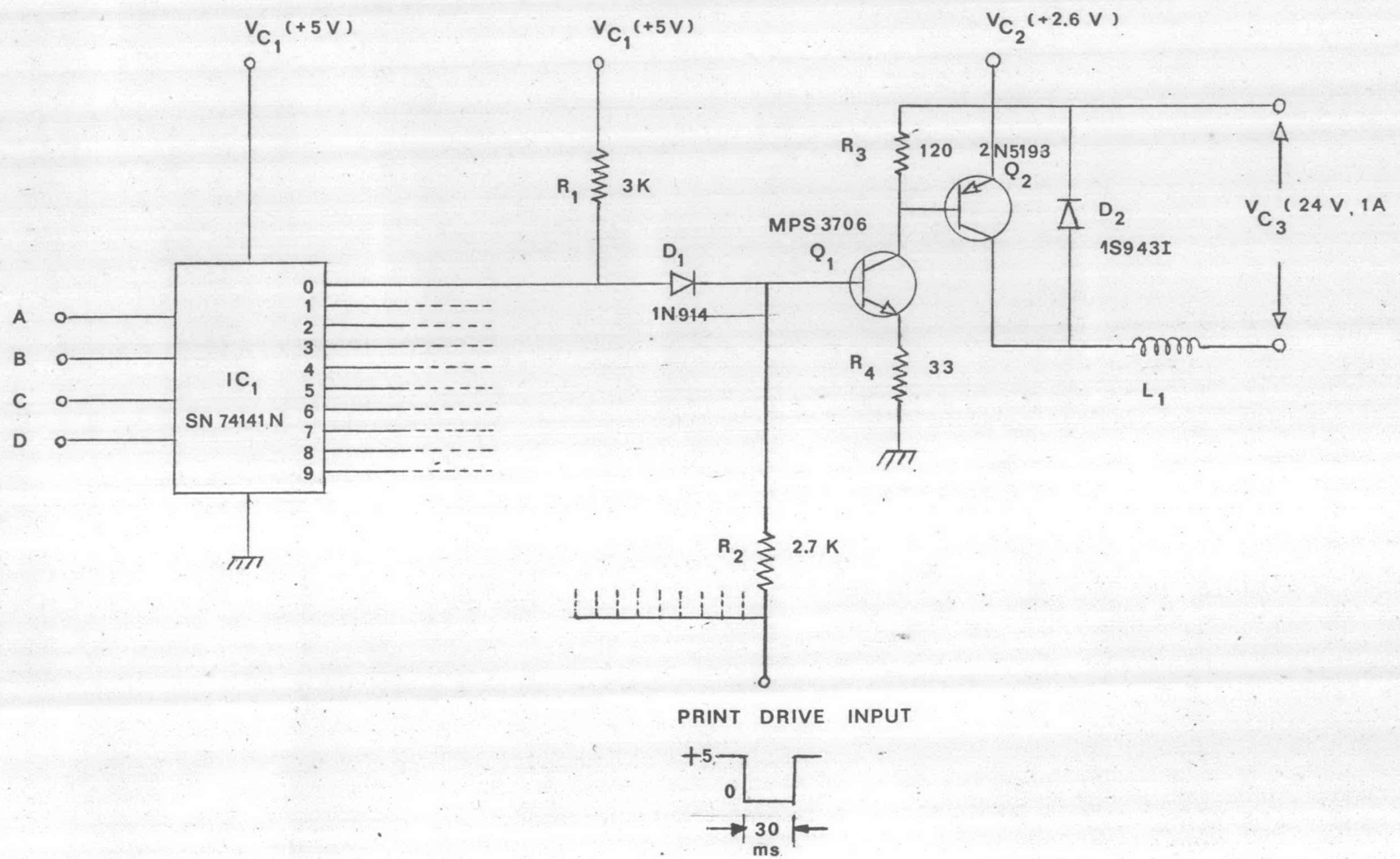


Fig.2.5 Print Driver Circuit

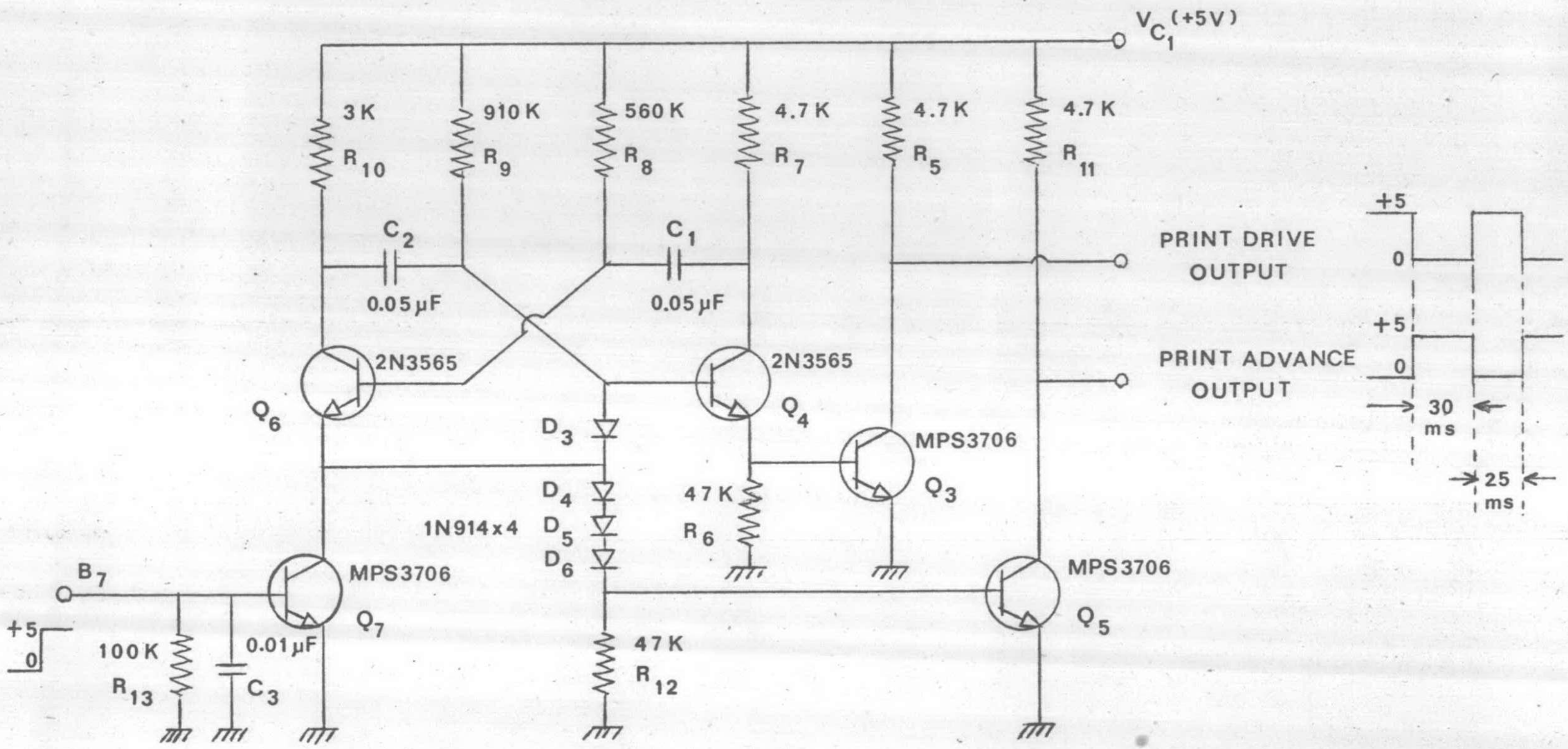


Fig.2.6 Printout Control Circuit

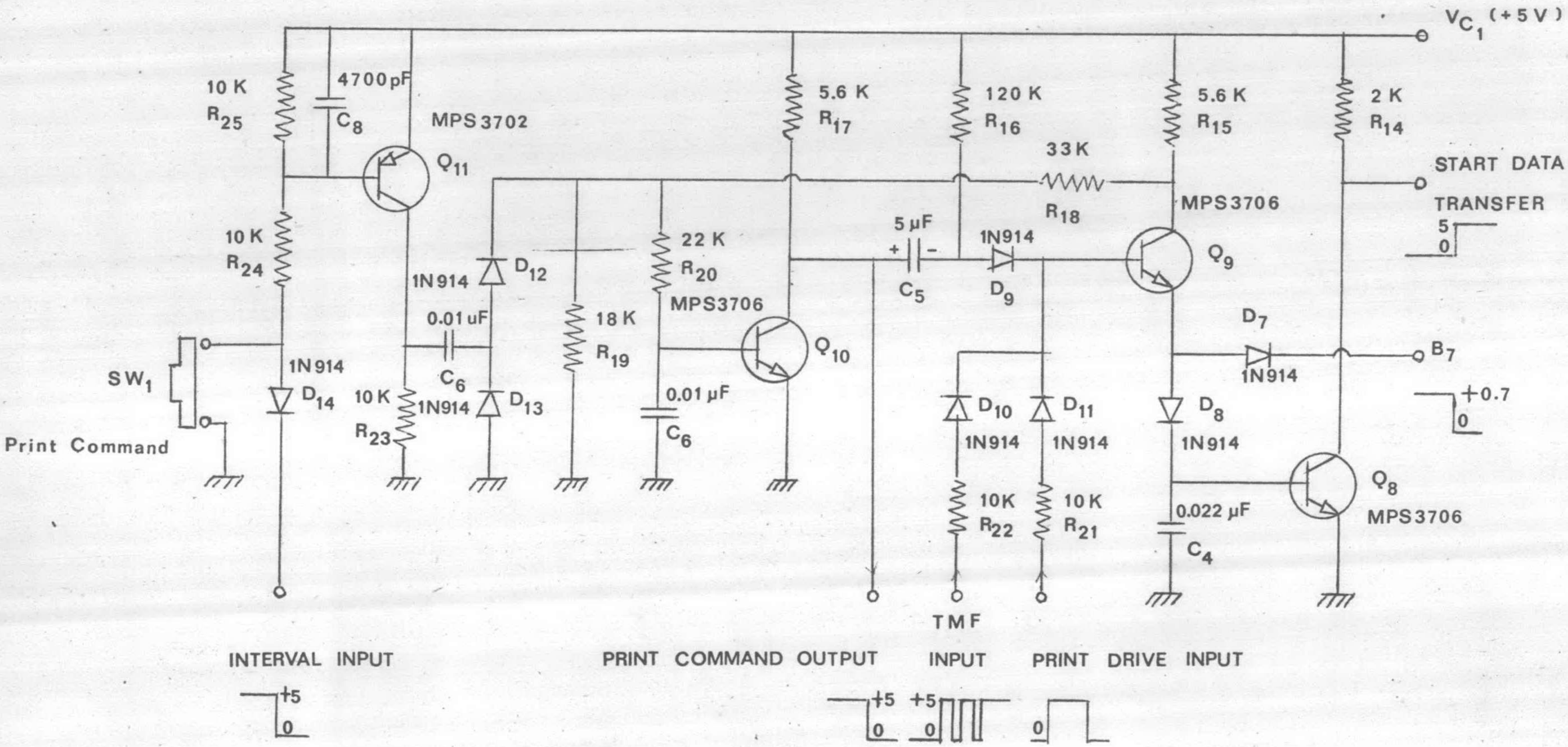


Fig.2.7 Printout Control Circuit

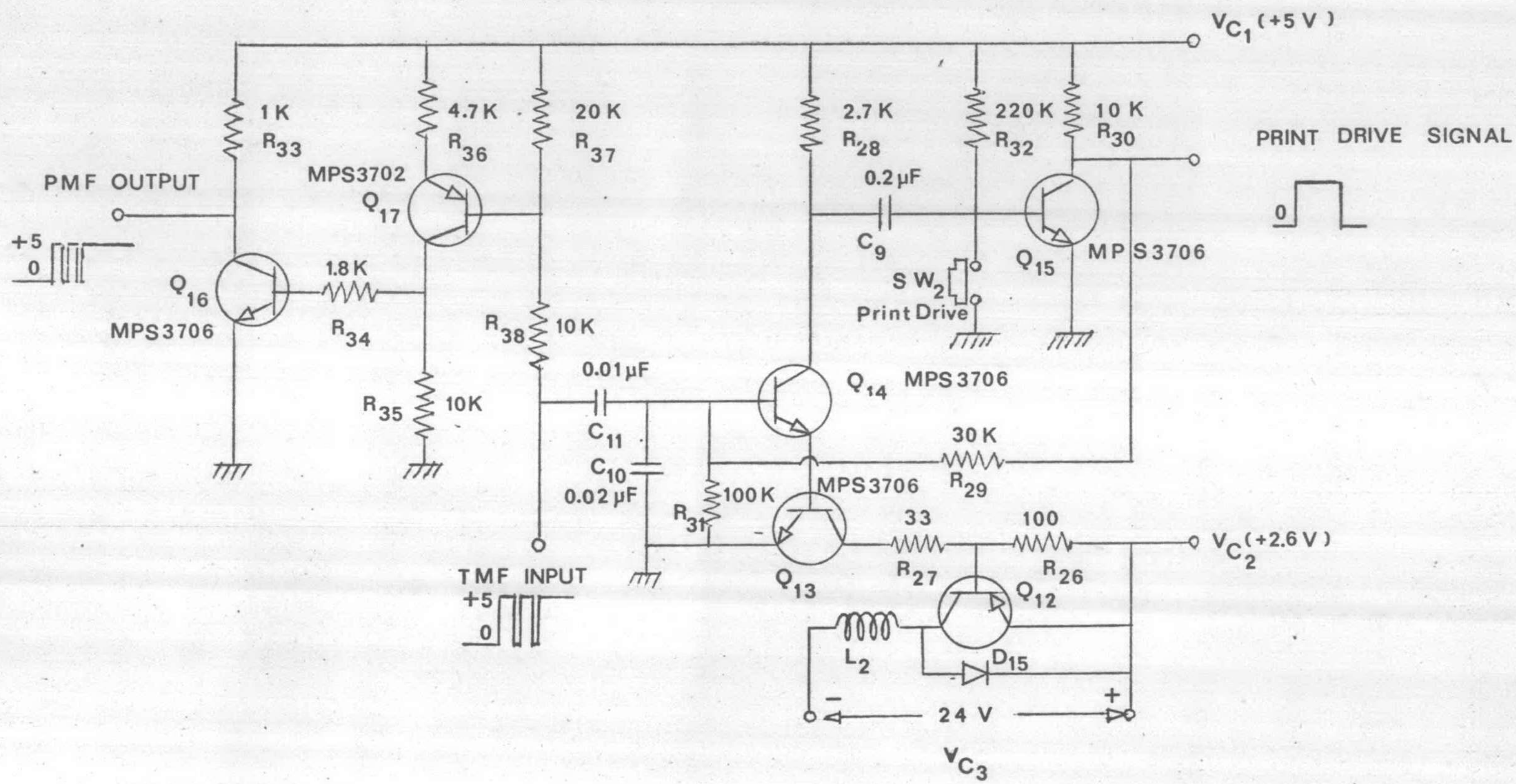


Fig. 2.8 Printout Control Circuit

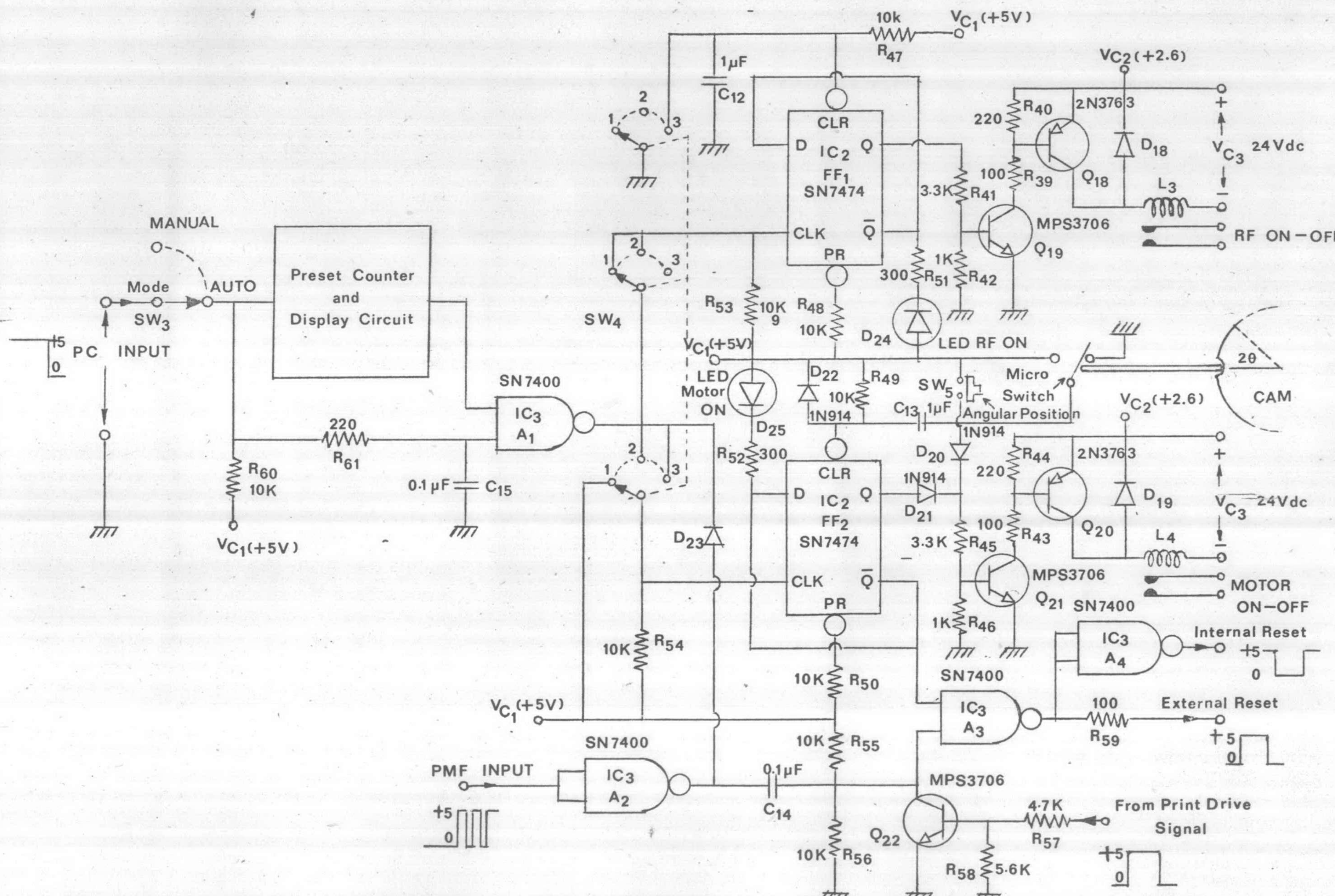


Fig.2.9 RF-Motor Control Circuit

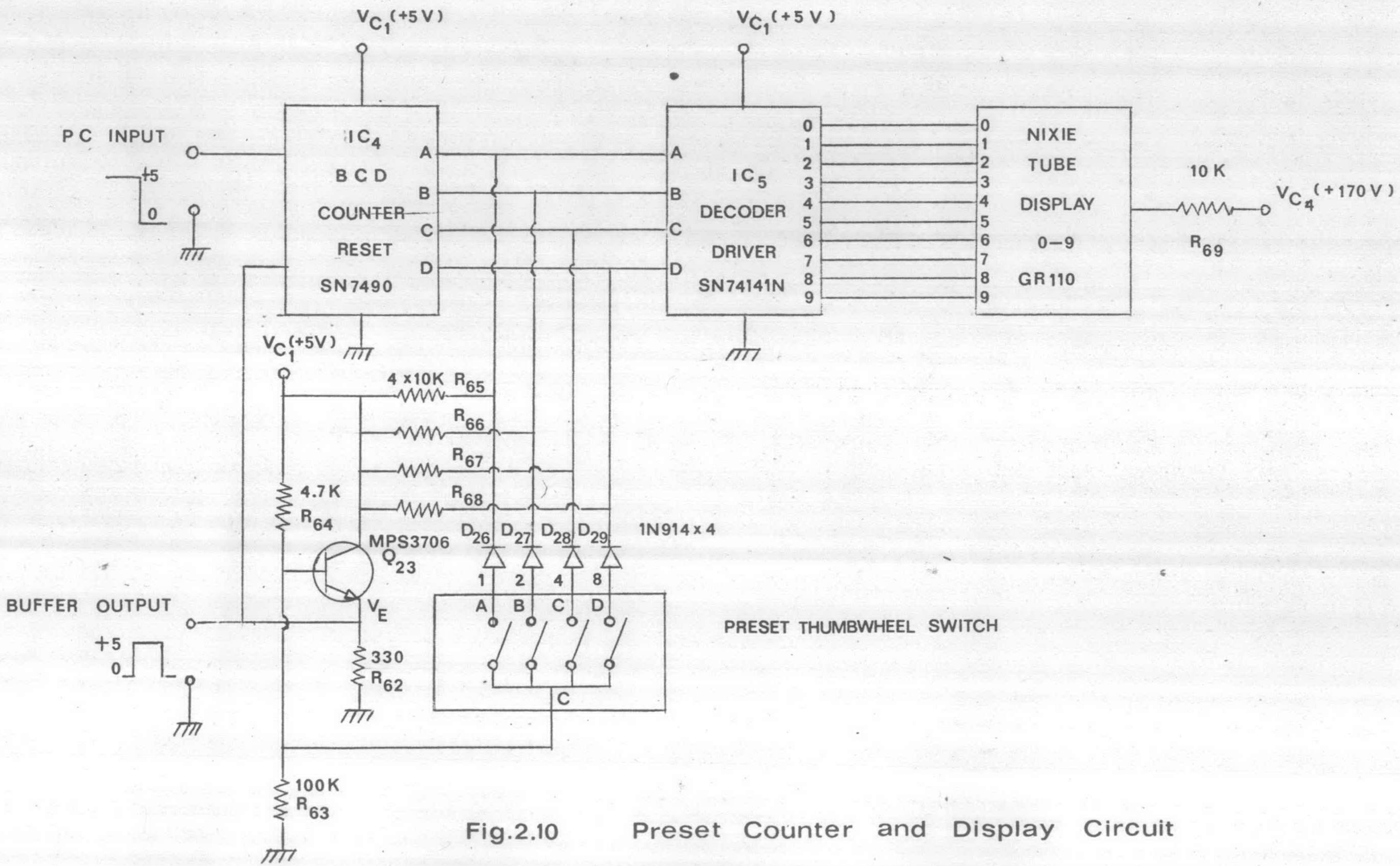


Fig.2.10 Preset Counter and Display Circuit

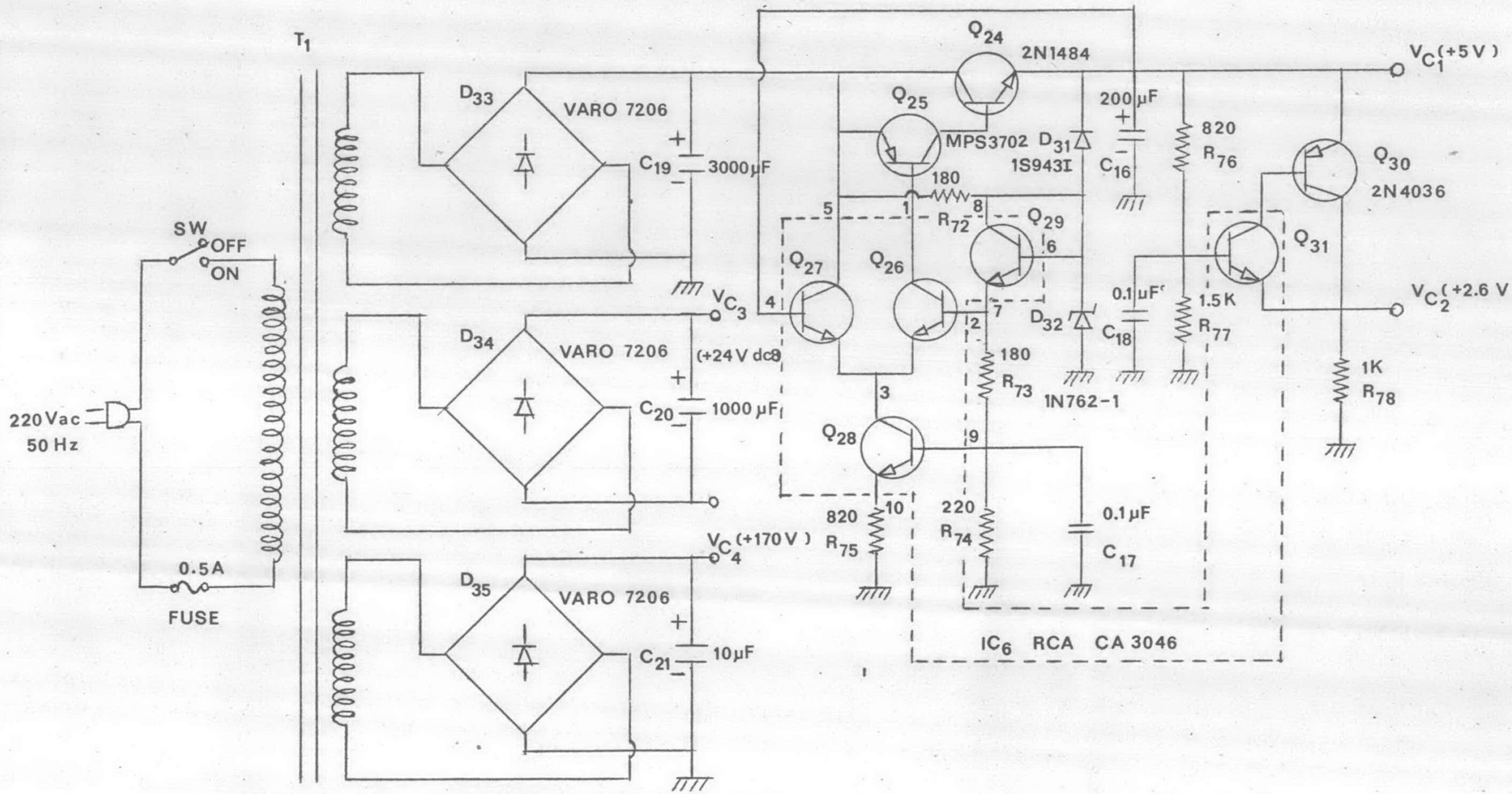


Fig. 2.11 Power Supply Circuit

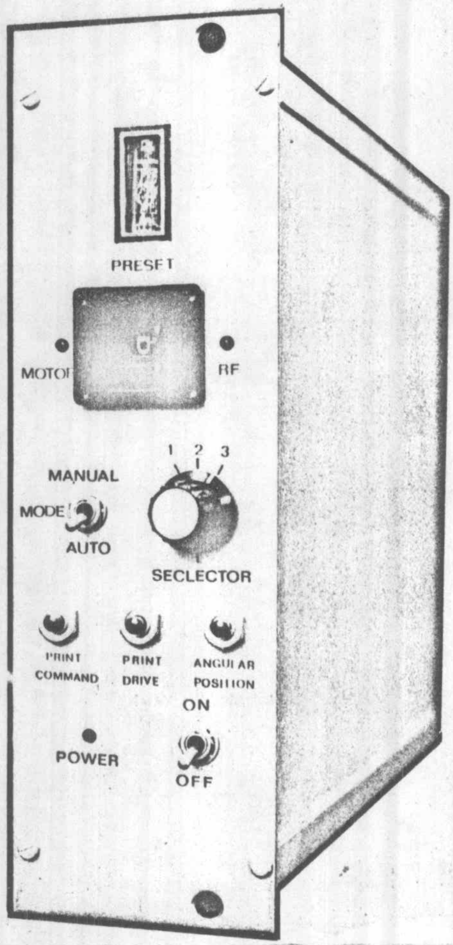


Fig. 2.12 Printout and System Control Module for Neutron Spectrometer

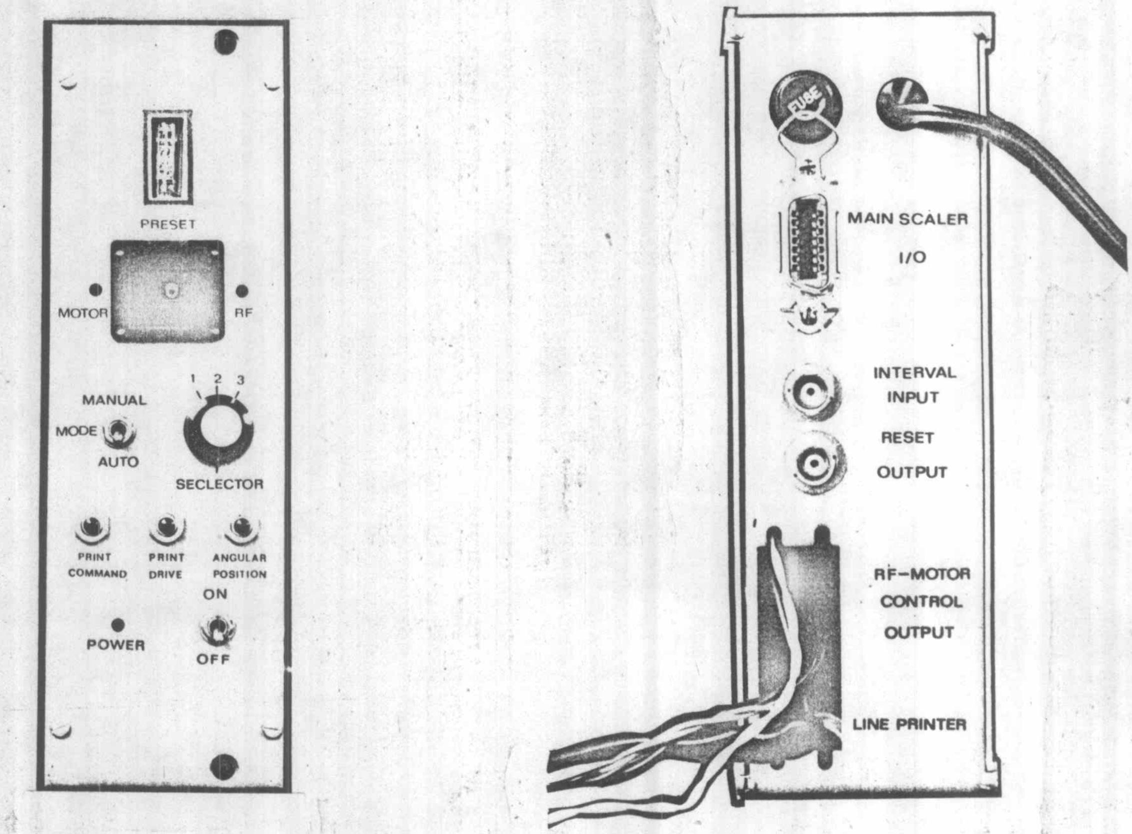


Fig. 2.13 Front and Rear Panels

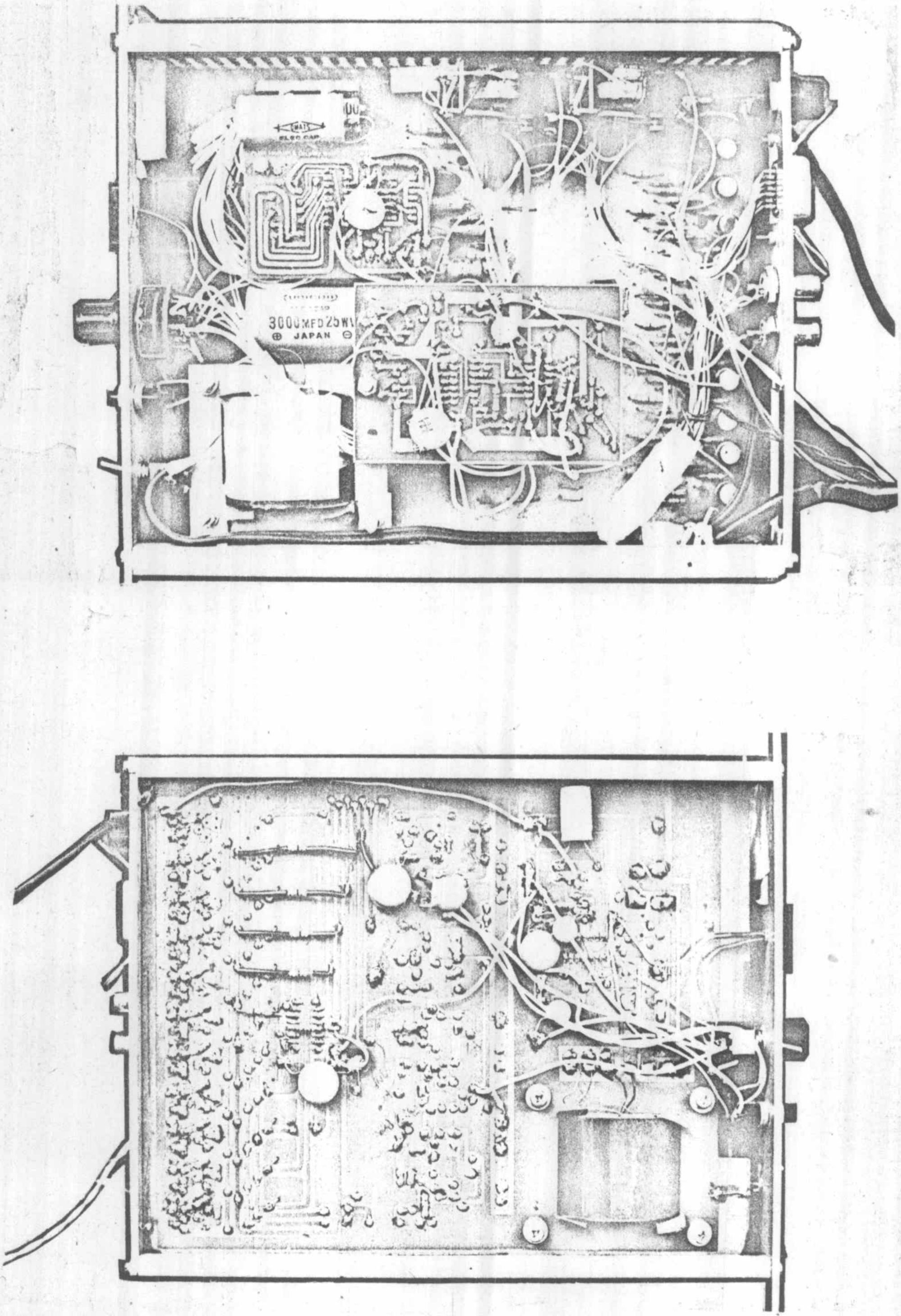


Fig. 2.14 Side Views of the Module

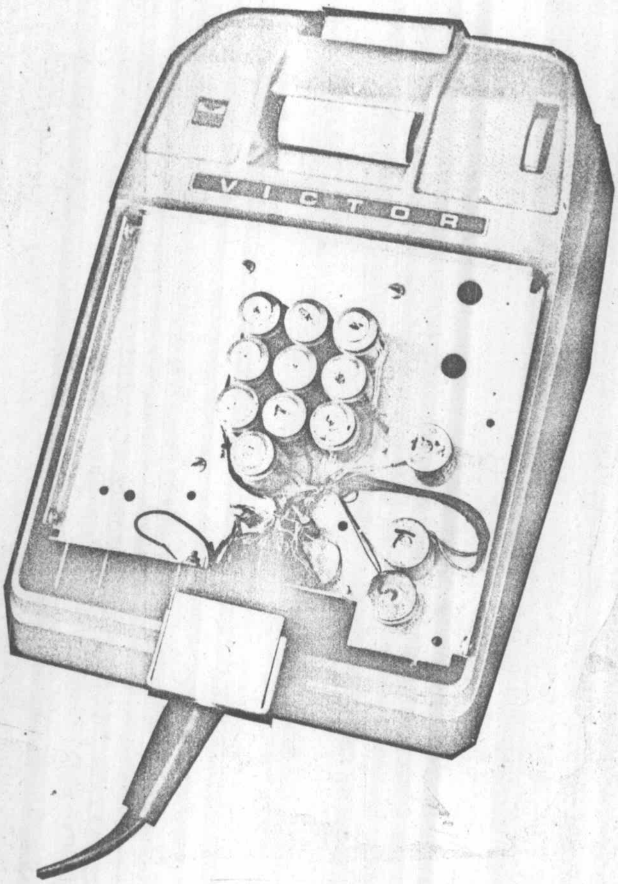


Fig. 2.15 Line Printer

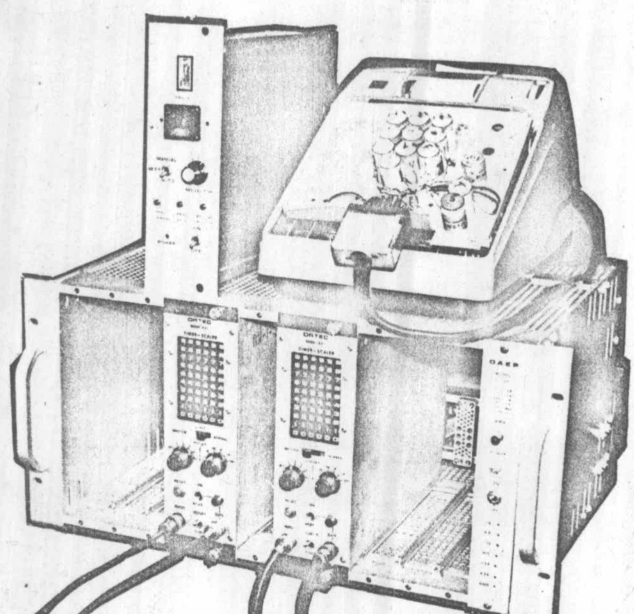


Fig. 2.16 . Set up of the Printout and System Control