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DESCRIPTION OF THE SYSTEM USED AT DARESBURY TO PRODUCE TIMING PULSES FOR THE SYNCHROTRON RADIATION SOURCE USING ANALOGUE AND DIGITAL TECHNIQUES

by

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1. INTRODUCTION

The timing system for the Synchrotron Radiation Source at the Daresbury Laboratory is a complex system. The three machines comprising the facility have to be synchronised to the magnetic field in the booster magnets and the radio frequency field in the booster accelerating cavities. Satisfactory control and monitoring to meet this criterion is obtained by a combination of analogue and digital techniques. Computer control via CAMAC is used to select appropriate signals and to control time dependent signal relationships. The signals and their gated derivatives are distributed to relevant areas of the accelerator complex.

The Synchrotron Radiation Source comprises three machine sections. A 12 MeV linear accelerator, a booster synchrotron, and the radiation source itself: a 2 GeV electron storage ring. The process of filling the storage ring involves operation of all three machine sections, based on the repeated injection of beam from the booster into the storage ring and use of a beam stacking process to achieve a high current. When filling is complete, the storage ring energy is ramped up from the level at injection of 600 MeV to its final stored beam operating level of 2 GeV.

The timing system generates the fixed and variable trigger pulses required to time the injection, extraction, and beam transfer process involved in machine operation through to final beam stacking in the storage ring. The range of pulses generated include trigger pulses to all items of plant (e.g. the linac, r.f. system, the booster r.f. system and all pulsed magnets for injection and extraction) involved in machine operation. The timing system also provides the trigger pulses required for timing beam diagnostics, data read-out and display, and for locking oscilloscope displays to the machine injection and extraction process.

Trigger pulses are generated in a central timing system and are then fed through a pulse distribution system to items of plant in the three machines, and to the main machine control centres. Operator control and supervision is provided through the control computer network, and amongst its features includes facilities for setting the system to single or multi-bunch operation, setting the rate of injection into the storage ring during beam stacking and adjustment of injection level and slope in the booster to achieve maximum beam capture. The system also provides a computer controlled delay facility allowing variable machine triggers to be defined as computer controlled machine parameters.

The booster magnet power supplies are a resonant system operating at a nominal 10 Hz, and the booster a.c. field component provides the basic time reference for the system. One basic time reference, the booster injection pulse is derived from the booster magnetic field using a peaking strip to generate a low jitter timing pulse at the instant the booster field reaches a level corresponding to the required injection energy. This is adjustable within the range 10 to 15 MeV(1). A second basic time reference, again derived from the booster a.c. field component is the minimum field marker pulse. A backleg winding on the booster system reference magnet provides an a.c. signal which is the first derivative of the a.c. magnetic component. A zero crossing detector is then used to generate a low jitter timing pulse coincident with booster minimum field. These two basic timing pulses are used as the basis for timing all machine injection, extraction and transfer operations.

Pre-injection pulses derived from the booster injection pulse are used to trigger the booster r.f. system, the injection pulse is used to trigger the linac operations and the booster injection system. A booster extraction pulse derived from the minimum field pulse is used to trigger the booster extraction and S.R injection systems at booster peak energy. Most of these timing pulses are fed to plant via CAMAC delay modules so that the relative timing of the various machine sections can be controlled through the computer.

There is also provision to simulate these pulses from a crystal controlled clock when the Booster Dipole Magnets are not correctly energised.

2. THE BASIC TIMING SYSTEM

2.1 General Features

The major part of the timing system is housed in a central timing rack with an associated CAMAC control station, both located in the Plant Room containing the Booster Magnet Power Supplies. The basic system arrangement is shown in fig.1. Signals for the generation of basic timing pulses are derived from peaking strips, and a set of back leg windings mounted on a reference magnet energised by the Booster Magnet main current. (see figs. 26, 27, 28 and 29)

The main a.c. and d.c. field components in this reference magnet, particularly at low excitation are identical to those in the main booster system magnets and it provides a useful and convenient source for generating timing signals. Pole face windings providing orbit correction are not fitted to the reference magnet, and the reference field is less susceptable to injection or extraction equipment operation. This gives the immediate advantage that the timing signals generated in the reference magnet provide a more stable time reference for machine operation. Other advantages are that the peaking strips can be mounted in the magnet in a position corresponding to the beam orbit centre, and there is no radiation in the reference magnet, giving longer component life, and greater accessibility for calibration and maintenance. Also the timing rack can be sited local to the Reference Magnet giving less noise pickup due to shorter inter unit cables.

The reference magnet consists of equal section of "F" and "D" magnet blocks, with a set of identical peaking strips mounted in each section. Two back leg windings are wound round the back section of the magnet blocks.

The peaking strips and back leg winding signals from each F and D section are fed to identical timing system crates, each crate generating independently a complete set of system timing pulses. Either set of timing pulses can then be selected for machine operation by switching the output pulses from the selected crate to the main timing pulse distribution system. The second crate system then serves as a spare which can be switched from standby if a system fault occurs. The two systems also enable injection conditions to be studied in either type of magnet.

2.2 System Details(2)

A simplified block diagram of the timing system is shown in fig.2. A set of three peaking strips figs. 3 and 4 are mounted in the centre of each section of the reference magnet, on the beam orbit line, and parallel to the dipole field in the magnet. Each peaking strip has coaxial to it a bias coil which produces a flux in the peaking strip equal to the required injection field, but of opposite sense. Thus there is a flux sense change in the peaking strip when the dipole field in the magnet is equal to the required injection field. This generates a 50 mV pulse in the signal coil which is processed to give the injection pulse.

The two other peaking strips also have auxiliary bias coils coaxial to them, and energised to produce pulses at a discreet magnet flux at either side of injection field, these are used to compute the slope of the field at injection.

The back-leg of the magnet blocks have a winding round them which has a voltage induced into it proportional to the first differential of the magnet flux. Thus this waveform will be at zero at minimum and maximum flux in the magnet. This is fed to a sense conscious zero crossing detector and is processed to give the minimum field pulse.

In order to keep the physical size of the peaking strip bias coils small, and to enhance their field homogeneity the bias coils are only energised for 10 msec after minimum field to minimise their power dissipation, this is achieved via the peaking strip bias gate. A constant current computer controlled power supply feeds this bias gate which energises the peaking strip bias coils.

The four signals (minimum field, injection field and two pulses for slope measurement) so produced are fed to the timing rack for processing to standard levels. The signals are balanced about earth to give good common mode rejection. They are fed to the Signal Conditioning Module where an instrumentation amplifier converts the balanced signal to a single ended signal where it can be monitored. A differential amplifier to logic interface converts this to a logic pulse, which triggers a monostable driving an output circuit giving 50Ω line driving capability. This module also contains inhibit circuits to prevent spurious pulses being produced.

A signal of 499.6 MHz from the r.f. Master Oscillator is fed to the Orbit Clock generator module. This is detected and a signal indicating its presence is sent to the computer. If the Master oscillator signal is not present an internal source is used to drive the orbit clock generators.

The booster orbit clock is obtained by dividing the r.f. by 53, and this clock has a 1:1 duty cycle square wave and is fed to an output stage with the capability of driving 50Ω.

The storage ring orbit clock is obtained by dividing the r.f. by 160, and this clock has a 1:1 duty cycle square wave and is also fed to an output stage with the capability of driving 50Ω.

These clock signals are fed via a buffer with a 10 nsec rise time to other modules in the system, and to external equipment via the distribution system.

The timing pulses derived from the analogue magnet waveform are processed digitally to produce all the specified timing pulses. The digital processing has an accuracy of ± 1 clock period, and as the clock used is the booster orbit with a period of 106 nsec the derived pulses with the appropriate accuracy will still be locked to the booster orbit clock.

As regards the analogue magnet waveform, a cycle to cycle stability on the a.c. component of the magnet current of $1:10^4$ will produce a cycle to cycle jitter of 4 μsec on the injection pulse.

The pulses either side of injection are used to indicate the slope at injection in the $\dot{B}$ measurement module. A 10 MHz internal crystal clock is used to measure the time interval between the two pulses and this is presented as a binary number to the computer.

The simulator is transparent to the minimum field and injection pulses when the magnets are running normally, but if a pulse is missed on either input the unit output is changed to simulated pulses (generated by presetable counters fed by a 10 MHz crystal clock) which are synchronised to the magnet generated pulses whilst they are present. To return to the magnet generated pulses the conditions, as described in 10.1, must be fulfilled. Only when these conditions are met will the module switch from simulated to real pulses. A signal indicating this is sent to the computer which can inhibit the change over if erratic magnet excitation is expected. These pulses are fed via a buffer with a 10 nsec rise time to other modules in the system.

The booster injection pulse is generated by delaying the injection pulse so that its front edge coincides with the next booster orbit clock signal. The maximum delay will be 0.1 μ sec and in this time the injection field will increase by less than 1 μ tesla which is small compared to the injection field of approximately 15 m tesla.

The booster peak field pulse is generated by measuring the time between consecutive minimum field pulses and generating a pulse at half this time after the second minimum field pulse. This is done on separate systems with alternate pairs of pulses to give a peak field pulse on each cycle. The booster orbit clock is the time reference, thus giving a booster orbit clock locked output.

The booster pre-injection pulse is generated by measuring the time between minimum field and injection pulses and generating a pulse a pre-determined number of booster orbits before injection on the next cycle. This is done on separate systems with alternate pairs of pulses to give a booster pre-injection pulse on each cycle. The booster orbit clock is the time reference, thus giving a booster orbit clock locked output.

The Minimum field pulse is not processed in any manner.

The pulses are fed to buffers and thence to the distribution system.

The period and frequency module is fed with injection pulses and the period measured with respect to an internal 10 MHz crystal clock. The result is presented as binary information to the computer.

The binary information is reciprocated digitally and presented as binary information to the computer giving magnet frequency information.

The SRS injection rate is normally 10 Hz, but a facility to vary this is provided by the cycle rate selector. The cycle rate selector module is fed with information from the MCR, via the computer, as to the cycle rate requested. It generates an enable signal covering a set of timing pulses (i.e. from the start of minimum field to the finish of peak field) and via a gated buffer module allows the selected sets of pulses to be fed to the distribution system.

In multi bunch operation the booster has a stream of electron bunches from the linac injected into it, therefore the booster orbit path is full of electron bunches. In normal operation these are extracted over three orbits of the booster to completely fill the storage ring. Three orbit extraction is necessary because of the approximate three to one ratio of the booster to storage ring orbit path lengths.

Single turn extraction from the booster can be obtained thus filling one third of the storage ring.

A further refinement of this is single bunch operation where the output from the linac is reduced to a single bunch, which is 2 nsec long, by means of two choppers. This single bunch is accelerated in the booster and fed into the storage ring where it will produce a burst of synchrotron radiation down the beam lines at 320 nsec intervals. It is also intended that multi/single bunch operation be achieved where a number of discreet electron bunches are circulating in the storage ring at any one time, thus giving bursts of synchrotron radiation at subintegers of 320 nsec.

This is described in more detail in a Technical Design Note(3) and Preprint(4).

The booster magnet waveform obtained from the shunt which is used to monitor the booster magnet current is combined with the minimum, pre-injection, injection and peak field pulses in a buffer module, and the resultant composite waveform is fed direct to the control room for indication of correct functioning.

Pulses from the Timing Rack are sent to two distribution centres, the booster instrumentation room, and the storage ring controls gantry. The booster instrumentation room distribution point feeds the main control room machine physics racks and the control consoles with timing pulses. Racks in the booster instrumentation room are fed with pulses, as well as computor controlled delay modules with a single input and four independently controlled delayed outputs. The outputs of these units control the linac and its gun, the booster injection pulsers, and the booster extraction pulsers. Non delayed pulses are also supplied for diagnostics and oscilloscope trigger pulses. The timing pulses to the storage ring using a delay module feed the storage ring injection pulsers. Undelayed pulses are supplied for diagnostics and oscilloscope trigger pulses.

A set of timing pulses is also sent to the Basement Viewing Station for Beam diagnostics and scope triggering.

2.3 System Outputs and Specification

The distributed timing signals have the following time relationship:-

1.	Booster Orbit clock	A booster orbit period square wave phase locked to the master oscillator.
2.	Storage Ring Orbit clock	A storage ring orbit period square wave phase locked to the master oscillator.
3.	"D" Injection Pulse	A pulse at injection field in the "D" section of the reference magnet, not locked to the booster orbit clock.
4.	"F" Injection Pulse	A pulse at injection field in the "F" section of the reference magnet, not locked to the booster orbit clock.
5.	Booster Minimum Field Pulse	A pulse at the minimum field of the booster magnet waveform.
6.	Booster Pre-Injection Pulse	A pulse which can be present between minimum field and injection to a resolution of one booster orbit, normally set 1 msec before injection.
7.	Booster Injection Pulse	A pulse at injection field locked to the booster orbit clock.
8.	Booster Peak Field Pulse	A pulse mid-way between booster minimum field pulses, locked to the booster orbit clock.
9.	Booster Gated Minimum Field Pulse	Booster Minimum Field Pulse gated for selected cycle rates.
10.	Booster Gated Pre-Injection Pulse	Booster pre-injection pulse gated for selected cycle rates.
11.	Booster Gated Injection Pulse	Booster injection pulse gated for selected cycle rates.
12.	Booster Extraction Pulse	Booster peak field pulse gated for selected cycle rates. Single bunch operation incorporates a facility for a delay of a selected number of storage ring orbits after booster storage ring coincidence.

The primary pulses occur on every cycle of the booster magnet waveform i.e. at 10 Hz. The gated derivatives can be at 1:10, 2:10, 5:10 and 10:10 of this and there is also a single shot and off facility.

All distributed signals are short-circuit proof, and have an amplitude of +10 V on open-circuit and +5 V when correctly terminated in 50Ω. All pulse signals have a width of 50 μsec, and the clock signals have a 1:1 duty cycle. The rise and fall times are 10 nsec.

2.4 Supervision and Control

The facilities available in the complete timing system are:-

<u>Digital</u>

1. Indication that the booster and storage ring clocks, which are derived by division of the radio frequency are being obtained from the real R.F. and not the unit internal r.f. clock.

2. Enable D timing system, enables appropriate gated buffers to route D timing pulses to the distribution system.
3. Enable F timing system, enables appropriate gated buffers to route F timing pulses to the distribution system.
4. Indication that D timing pulses are real, that is, derived from the reference magnet.
5. Indication that F timing pulses are real, that is, derived from the reference magnet.
6. Inhibit change-over of D and F timing systems from simulated to real timing pulses if the magnets are liable to be unstable.
7. Indication of $\dot{B}$ at injection of the D timing system, this includes enable and valid information.
8. Indication of $\dot{B}$ at injection of the F timing system, this includes enable and valid information.
9. Selection of cycle rate of distributed pulses at, 1:10, 2:10, 5:10, 10:10, 0:10 (OFF) with single shot and selection valid information.
10. Delay of booster extraction pulse by up to 255 storage ring orbits after booster, storage ring coincidence for single and selected bunch operation, an enable signal is also required.
11. Indication of booster magnet period with valid signal.
12. Indication of booster magnet frequency with valid signal.

Analogue

1. D level, current in main bias coils of D peaking strips.
2. D level, indication of current in main bias coils of D peaking strips.
3. D separation, current in auxiliary bias coils of D peaking strips.
4. D separation, indication of current in auxiliary bias coils of D peaking strips.
5. F level, current in main bias coils of F peaking strips.
6. F level, indication of current in main bias coils of F peaking strips.
7. F separation, current in auxiliary bias coils of F peaking strip.
8. F separation, indication of current in auxiliary bias coils of F peaking strips.
9. Composite waveform showing time relationship between distributed timing pulses and booster magnet current.

3. PEAKING STRIPS

The peaking strips are rods of high permeability Molybdenum Permalloy, mounted in an alumina tube. A signal coil is wound round the centre of this and the assembly mounted in a glass tube. This is then mounted in the bias coil, a solenoid to magnetically bias the peaking strip (see figs. 3 and 4).

There are four molybdenum Permalloy strips each 25mm long and 0.023mm dia. in the alumina tube which has the 200 turn signal coil wound on it. The bias solenoid has a main winding of 5 layers of 80 turns and an auxilary winding of one layer of 80 turns.

The two sets of three peaking strips and their bias coils are mounted in the "D" & "F" reference magnet sections. The main bias coil is energised to produce a field in the peaking strips equal and opposite to that in the booster magnets (and thus the reference magnet), to match the linac energy for optimum injection conditions. Thus when the cyclic field in the booster reaches this value the resultant field in the peaking strip will reverse sharply and due to its square magnetic characterisation a pulse will be induced into the signal coil. This pulse will be at the time for correct injection into the booster. The auxiliary bias coils are energised to "buck" and "boost" the main field, and produces pulses ± 0.5m Tesla each side of the main injection pulse. These are known as the ± injection pulses, and are used to compute the slope at injection or $\dot{B}$.

3.1 Details

The peaking strip signal coil generates a pulse when the field in the peaking strip reverses polarity, that is at zero flux in the peaking strip. The bias coils produce an equal and opposite flux to that which it is required to detect in the magnet where the peaking strips are mounted. Thus by variation of the bias coil current (within the limits of power dissipation) any field in the reference magnet can be detected.

The details of the bias coils are as follows:

	Main Coil	Auxilary Coil
Turns	400	80
Length	3.8 cm	3.8 cm
Mean diameter	0.94 cm	1.27 cm
Wire	27 S.W.G.	27 S.W.G.
Number of layers	5	1
Inductance	295 μH	24 μH
Field produced in peaking strip	13.2 mT/Amp	2.64 mT/Amp

3.2 Method of Calibration

The method of calibration was to mount the peaking strip and bias coil in a magnet in which the field can be varied and measured. The reference magnet with a temporary 0-30 A d.c. power supply to produce the field, and a Lawson Rush rotating coil magnetometer to monitor the field was used. With zero field in the magnet a low voltage A.C. was fed to the auxilary bias coil (0.15V 50 Hz, mains via a variac and transformer) thus producing pulses from the signal winding at 10 msec intervals i.e. each time the auxilary excitation reversed and passed through zero. (see fig.5)

A known excitation was applied to the reference magnet, and the current in the main bias winding was adjusted to give the same 10 msec spacing of the peaking strip pulses. It was then known that the main bias coil current was producing a field in the peaking strip equal and opposite to that produced by the reference magnet. By this method the peaking strips were calibrated over their operating range.

4. BACK LEG WINDINGS

These consist of coils wound round the back leg of the iron forming the reference magnet. (see fig.1)

4.1 Circuit Operation

The voltage induced in them will be the first differential of the magnet field and with the aid of a zero crossing detector it is used to generate minimum field pulses (peak field pulses could also be generated by this method if it were not for disturbing influences to the magnetic field caused by the extraction beam-bump).

The windings each consist of 5 turns of coaxial cable wound round the magnet, the inner of the cable forming the winding, the outer forming an earthed electrostatic screen. At normal running of the magnets the output voltage is 30 Vp/p approximately.

5. PEAKING STRIP BIAS POWER UNIT

This is a double constant current amplifier built in a double NIM module. A ± 10V signal fed into either channel will drive ± 2 A into the peaking strip bias coils, a monitoring amplifier gives ± 10V out for this range of current.(see fig. 6, 26 and 27)

5.1 Circuit Operation

The circuit consists of a high gain differential amplifier feeding a high current amplifier. This drives the load, and the voltage across a shunt in series with the load is fed back to the input to maintain constant current. A monitoring amplifier connected across the shunt provides an analogue signal for the control system.

6. PEAKING STRIP BIAS GATE

If a continuous current is passed through the peaking strip bias coils overheating occurs. This unit built in a single width NIM Module overcomes this by shunting the bias current away from the coil at all times except for the period from minimum field to 10 msec later (see figs. 7, 26 and 27).

6.1 Circuit Operation

The minimum field pulse triggers a 10 msec monostable which via a peripheral driver cuts off a transistor which is in parallel with the bias coil. As the supply to the bias coil is a constant current this does not change the validity of the monitoring. The bias coil current is thus diverted through the transistor for 90% of the time, thus reducing the coil dissipation.

7. SIGNAL CONDITIONING

This double width NIM module accepts signals from the back leg winding and peaking strips on the reference magnet and conditions them to 50 µsec wide T^2L compatible pulses. (see figs. 8, 26 and 28)

7.1 Circuit Operation

Low level (< 100 mV) signals from the three peaking strips and a 30Vp/p sinusoid from the back leg winding are each fed to separate AD521 instrumentation amplifiers where the differential signals are converted to single ended, to enable them to be monitored. The inputs are also fed to NE521 comparators with T^2L outputs, these signals trigger 74123 monostables which generate a 50 µsec wide pulse which drives the output circuit consisting of a 2N 2894 which will feed a 50 Ω terminated cable. There are also gating logic circuits driven from the minimum field pulse to eliminate spurious pulses.

8. QUAD FANOUT BUFFERS

These are extensively used in the timing system for the distribution of pulses. Built in a single width NIM module they consist of four identical circuits which have an input of 5V into 50Ω and each generate four outputs with less than 10nsec delay and rise time which feed 5V into 50Ω. The outputs are short circuit proof and there is provision for a collective inhibit.(see figs. 9, 26, 27, 28 and 29)

8.1 Circuit Operation

The input signal is fed via a termination to a gate which also has the inhibit signal fed to it. The output of this gate feeds a discreet component amplifier which drives four emitter followers which feed the four outputs.

9. $\dot{B}$ MEASUREMENT

This unit built in a single width NIM module measures the time interval between injection - and injection + pulses. It displays the time in μsec and feeds it to the computer in binary format. The slope is in usec per m Tesla (see figs. 10, 26 and 28).

9.1 Circuit Operation

A crystal oscillator at 10 MHz provides an accurate clock source to measure the time interval between the two pulses, which are 1m Tesla apart. Two counters are used, one in B.C.D. to drive the local display, and the other in binary to provide the same information for the computer.

10. SIMULATOR

This unit built in a single width NIM module accepts real minimum field and injection pulses, and relays them to the subsequent modules. If however either of the pulses are not present it generates its own pulses to simulate them. When real pulses are restored they are interogated with respect to continuity and timing before being reinstated (see figs. 11, 26 and 28).

10.1 Circuit Operation

When running normally the unit is transparent to the real pulses. A 10 MHz crystal clock generates minimum field and injection pulses by means of preset counting and coincidence circuits. The timing of these pulses is continuously being corrected so that when there is a change-over to simulated pulses there will be minimum disturbance. The incoming real pulses are continuously checked for period (< 110 msec = healthy) if this is violated by either pulse the unit switches to simulatd pulses. When the real pulses are restored the following conditions must be satisfied before automatic changeover occurs.

A. Minimum and Injection Field Pulses must be less than 110 msec period
B. Injection must be less than 10 msec after minimum field
C. Real pulses must be less than 10 msec after simulated pulses
D. There must be 99 pulses satisfying A and B
E. The unit must not be externally inhibited

Only then will the unit switch from simulated to real pulses.
Indication of this is transmitted to the computer control system.
The output pulses are 50 μsec wide and will drive 50Ω.
Red and Green LED's on the front panel indicate if the output pulses are simulted or real.

11. ORBIT CLOCKS

The r.f. to excite the cavities of the SRS is 499.6 MHz and the orbit frequencies of the booster and storage ring are $\frac{1}{53}$ and $\frac{1}{160}$ of this respectively. Circuits in fast logic are used to generate sub-multiples of this primary frequency. It is built in a single width NIM module. Input is 499.6 MHz and outputs are the two orbit frequencies.

The r.f. fed into the module is detected and this determines the source of the inputs for the two dividing circuits, real r.f. or internally generated from a 125 MHz crystal oscillator output multiplied by four. (see figs. 12, 26 and 27)

11.1 Booster Orbit Clock Circuit Operation

Divide by 53 is achieved by means of a variable modulus divider with ratios of 10 and 11, it is cascaded with a divide by 5 counter to divide by 53. The divide by 5 counter output is high for 2 counts and low for 3 counts. This is fed to the modulus control of the variable modulus counter in such a manner that it divides by 10 for 2 counts and then divides by 11 for 3 counts thus giving a total division of (10 x 2) + (11 x 3) = 53. This is fed to an output stage to give a square wave capable of driving 50Ω.

11.2 Storage Ring Orbit Clock Circuit Operation

Divide by 160 is achieved by means of a divide by 16 counter cascaded with a divide by 10 circuit to give a total division of 160. The output is arranged to be a square wave capable of driving 50Ω.

There is a wavetrap on the 499.6 MHz input to by-pass any spurious signals which may be fed to it.
Red and Green LED's indicate if the internal r.f. or the Real r.f. is driving the unit.

12. ORBIT GATE

This single width NIM module synchronises the injection pulse to the booster orbit clock to maintain the time consistancy of the injected beam. Its inputs are the injection pulse and the booster orbit clock. (see figs. 13, 26 and 28)

12.1 Circuit Operation

Injection pulses are fed to the data input of a bistable, and booster orbit clock pulses are fed to the clock input of the same bistable. Therefore the injection pulse is transferred to the bistable output on the front edge of the next booster orbit clock pulse. This triggers a monostable which feeds the output circuit which feeds a 50 µsec pulse into 50Ω. A second monostable is used to inhibit and reset the bistable, it also drives a green LED on the front panel, which indicates correct operation.

13. PEAK FIELD GENERATOR(5)

This unit built in a single width NIM module produces peak field pulses digitally midway between minimum field pulses and locked to the booster orbit clock. The inputs are minimum field pulses and the booster orbit clock. (see figs. 14, 26 and 28)

13.1 Circuit Operation

Minimum field pules are fed into the unit and the time interval between them is measured by counting the number of booster orbit clock pulses divided by two between them. On the following magnet cycle this count is compared to a counter fed with normal rate booster orbit clock pulses. Thus coincidence will occur at a time equal to half the magnet period in the previous cycle due to the clock period relationship. This is done using two time interval counters on alternate cycles to give a pulse out on each cycle. This pulse is fed to an output circuit to give a 50 µsec pulse suitable for feeding 50Ω. A Green flashing LED on the front panel indicates correct operation.

14. PRE INJECTION PULSE GENERATOR(5)

This unit in a single width NIM module has fed to it minimum field, injection pulses and booster orbit clock pulses. It produces a pre-injection pulse which is locked to the booster orbit and has a presetable advance of 10 msec or to the minimum field pulse whichever is the least. (see figs. 15, 26 and 28)

14.1 Circuit Operation

The circuit operates by measuring in a counter the time from minimum to injection field in units of booster orbit time, and then interrogates this counter on the following cycle of the magnets with a counter which already contains a preset count equivalent to the advance required. (Thus coincidence will occur at a time equal to the advance required). Two counters are used for minimum to injection field time alternately, so that a pre-injection pulse is produced on every magnet cycle computed from information obtained during the previous cycle. This is fed via a 50 µsec, 50Ω output circuit to the system. A flashing Green LED on the front panel indicates correct operation.

15. QUAD OR BUFFER

This module is similar to the quad fanout buffer but it has an exclusive OR facility on two sets of inputs, and contains circuits for selecting the input signals. There are four channels each having two 5V 50Ω inputs and four 5V 50Ω outputs. There is a facility for adding in an analogue waveform and monitoring the combination of analogue and digital waveforms. (see figs. 16, 26 and 29)

15.1 Circuit Operation

Two input signals per channel are terminated and fed to a gate. The appropriate signal is selected and fed via a discreet component amplifier to four emitter followers which feed the four outputs on each channel. If however both sets of inputs are selected an exclusive OR gate inhibits the buffer outputs. The magnet waveform derived from a shunt in series with the main booster magnet current is fed to a differential amplifier whose input is also fed with pulse signals from the four pulse channels in the buffer. These signals are normally minimum, pre-injection, injection and peak field pulses, thus the output from the differential amplifier will be a composite waveform showing the timing pulses in relation to the magnet waveform for diagnostic purposes. This composite waveform is fed to the control room. (BM ACPI).

16. CYCLE RATE SELECTOR

The cycle rate selector built in a single width NIM module has minimum field and peak field pulses fed to it with digital information from the computer. Its output is an inhibit signal which disables a quad buffer to eliminate pre-selected sets of timing pulses. (see figs. 17, 26 and 29)

16.1 Circuit Operation

The start of the minimum field pulse is fed via select gates to the 1:1 and single shot circuits, and via dividers of ratio 1:2, 1:5 and 1:10 to three further select gates. The required cycle rate is selected and a bistable is preset at the required cycle rate. This bistable is cleared by the end of every peak field pulse, thus the output is an enable pulse on the required cycles from the start of minimum field to the end of peak field.

There is also a 4 input exclusive OR gate to detect invalid states of cycle rate, this is fed to the computer. There are also indicators on the front panel to show that a valid cycle rate has been selected and which one it is.

17. EXTRACTION GATE

The orbit selector generates an output pulse a predetermined number of booster orbits after the start of a peak field pulse and a Booster beam/Storage Ring clock coincidence. It is built in a single width NIM module. (see figs. 18, 26 and 29)

17.1 Circuit Operation

Booster orbit clock pulses, peak field pulses, and booster beam/storage ring clock coincidence, and orbit select information are fed into this module. The booster orbit clock pulses are fed into an eight bit binary counter. This counter is enabled by the first booster beam/storage ring clock coincidence after the start of the peak field pulse. The binary output of this counter is compared to the predetermined count data from the computer. An output pulse is generated at parity and this is fed out via a 50μsec 50Ω output circuit.

This is the mode for single bunch operation, for multibunch operation the unit is transparent to peak field pulses.

18. BOOSTER MAGNET PERIOD/FREQUENCY METER

This device built in a size one NIM module measures the time between alternate consecutive input pulses presenting this in binary format with a resolution of 0.1 msec to the computer. (see figs. 19, 26 and 29)

Using a digital arithmetic circuit it computes a binary output of frequency with a resolution of 0.01 Hz for feeding to the computer.

18.1 Circuit Operation

Booster magnet generated pulses fed to a divide by two circuit open a gate to allow 10 KHz pulses to a binary counter which has been set to zero on alternate cycles. Thus the period of the magnet waveform is measured on alternate cycles. This information is fed to a memory and via buffers to the computer.

To generate the frequency information, the period information P is fed to a binary rate multiplier where:

$$\text{pulses out} = \frac{\text{P x pulses in}}{64 \times 64}$$

Therefore if it is arranged that the pulses out is equal to 244 and re-arranging:

$$\text{pulses in} = \frac{244 \times 64 \times 64}{P} \approx \frac{10^6}{P} \text{ within } 0.06\%$$

If the pulses into the multiplier are counted in a binary counter a reading proportional to frequency will be obtained.

This information is fed to a memory, and via buffers to the computer.

Max period 409.5 msec
Max frequency 40.95 Hz

19. PULSE DISTRIBUTION SYSTEM

Pulses from the timing rack are distributed to the three accelerators and their associated equipment, and to the main control room. CAMAC controlled delay modules are used where it is necessary for satisfactory operation of the equipent to delay individual injection and extraction equipment trigger pulses. (see fig. 1)

The main areas which receive pulses are:-

1. Linac and gun)
2. Booster injection)
3. Booster R.F.) Booster Instrumentation Room
4. Booster extraction)
5. Storage ring injection) Storage Ring Controls Gantry
6. Control Room
7. A Single Bunch) Basement Monitoring Station

20. POWER SUPPLIES

These are bought outside power units which are mounted in rack mounting chassis. There is indication of the presence of input and output voltages on each front panel. (see figs. 20 and 26)

Power unit 1

Mains input with +6V and +12V output

Power unit 2

Mains input with +6V, -6V and -12V output
-6V is derived from the -12V

Power unit 3

Mains input with +16 and -16V output. These supplies are not standard NIM, and are used to reduce dissipation in the peaking strip bias power units.

There is also a fan mounted at the bottom of the rack.

The diagram also shows the route of the mains supply from P.D.1 for the timing rack and booster control station 3.

21. SINGLE BUNCH COINCIDENCE CIRCUIT

This is a unitary NIM module, which detects coincidence between the Booster Orbit Clock and the Storage Ring Clock (these have a 160:53 relationship). The circuit uses ECL high speed logic and a standard TTL output pulse is produced at 16.96 μsec intervals (160 x 53 x RF period). This controls extraction from the Booster to obtain a Single Bunch in the Storage Ring. (see fig. 21)

21.1 Circuit Operation

Booster and Storage Ring Clock Pulses are both processed to give "short" pulses, and are fed to two inputs on a ECL gate. There is an output only when the pulses coincide, and this is interfaced to give a TTL output.

22. BOOSTER MAGNET WAVEFORM UNIT

This is built in a screened box with its mains power supply, and takes a differential signal from the Booster Magnet Current Shunt, and converts it to a single ended output signal. (see fig. 22)

22.1 Circuit Operation

The output from the shunt feeds the differential input of an instrumentation amplifier. The single ended output from this feeds three amplifiers connected as voltage followers.

23. BOOSTER R.F. PROGRAMME GENERATOR

This is a NIM module which has the Pre-injection Pulse for its input, and produces a variable length amplitude, and d.c. level output pulse to drive the Booster r.f. Amplifier. (see fig. 23)

23.1 Circuit Operation

The pre-injection triggers a monostable which has variable R.C. in its timing circuit. The output of the monostable is fed via a variable potentiometer to one input of a differential amplifier, whose other input is fed with a variable D.C. level. The output is taken from this amplifier which has a gain of unity.

24. CHOPPER GATE

This NIM module locks the Injection Pulse to Chopper One frequency divided by four. This gives a stable single bunch in the Booster. (see fig. 24)

24.1 Circuit Operation

Injection Pulses are fed to the input of a bistable which is gated with Chopper One pulses divided by four. The output of this bistable has a change of state at the required time, and this triggers a monostable to give the output.

25. D/F SELECTOR

This is in a screened box, it accepts computer control signals, and switches control and monitoring between the D and F sections of the Timing Rack. (see fig.25)

25.1 Circuit Operation

F and D enable signals from the computer control two relays which effect the change over from F to D or vice versa.

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(3) A Single Bunch "Ghost", Daresbury Technical Design Note DL/TDN/79/103

(4) A Single Bunch System for the Daresbury SRS, Daresbury Preprint DL/SCI/P371A (1983)

(5) Digital Generation of Timing Pulses, Daresbury Internal Report DL/TM/111 (1973)

FIGURE CAPTIONS

Fig. 1 The SRS Timing System Basic Organisation
Fig. 2 The SRS Timing System Basic Circuit
Fig. 3 Peaking Strips and Bias Coils
Fig. 4 Mounting of Peaking Strips
Fig. 5 Calibration of Peaking Strips
Fig. 6 Peaking Strip Bias Power Module
Fig. 7 Peaking Strip Bias Gate
Fig. 8 Signal Conditioning
Fig. 9 Quad Buffer
Fig. 10 $\dot{B}$ Measurement
Fig. 11 Simulator
Fig. 12 Orbit Clocks
Fig. 13 Orbit Gate
Fig. 14 Peak Field Pulse Generator
Fig. 15 Pre-Injection Pulse Generator
Fig. 16 Quad or Buffer
Fig. 17 Cycle Rate Selector
Fig. 18 Extraction Gate
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Fig. 20 Power Supplies
Fig. 21 Coincidence Circuit
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Fig. 23 Booster R.F. Programme
Fig. 24 Chopper Gate
Fig. 25 D/F Selector
Fig. 26 General View of System
Fig. 27 Upper Crate
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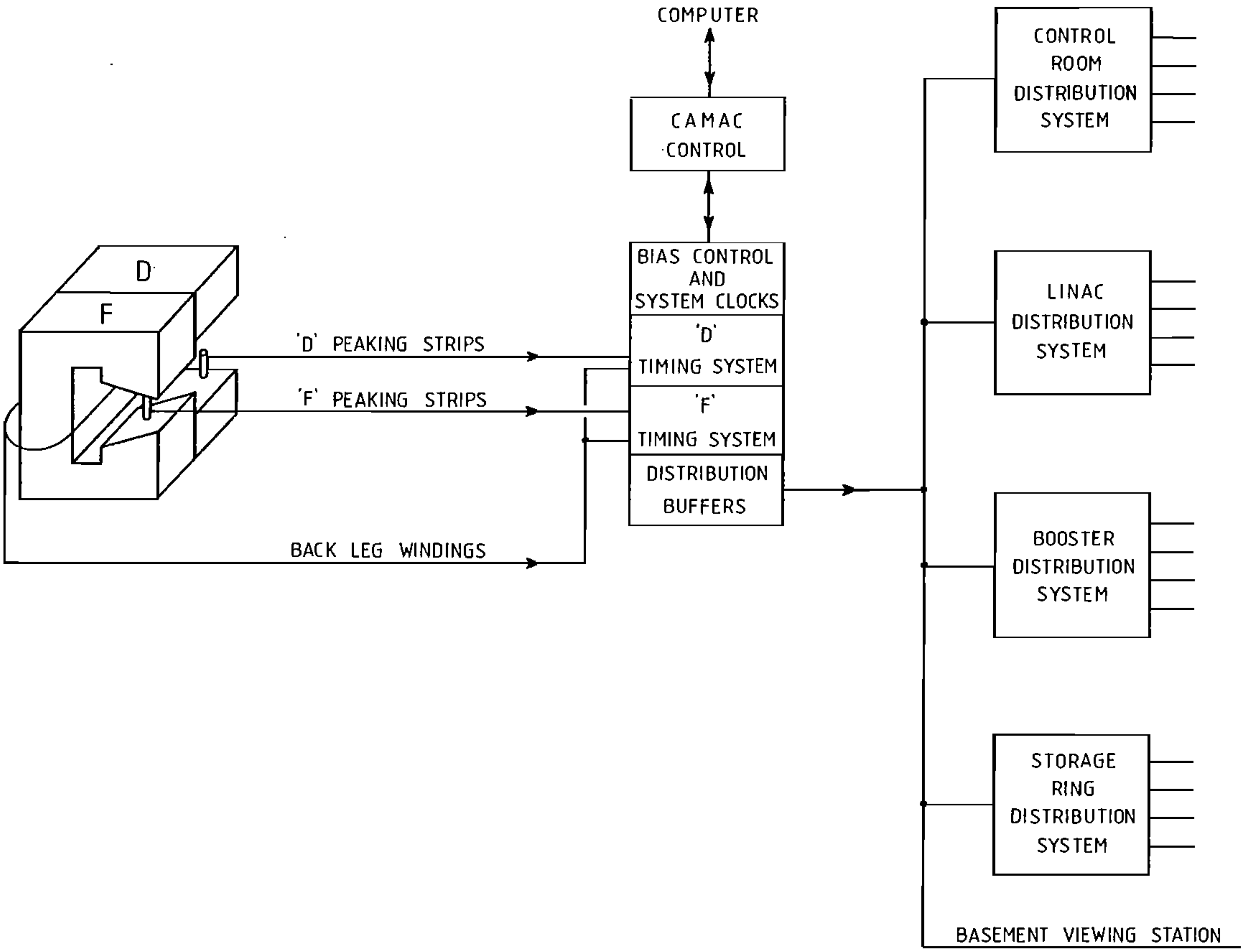
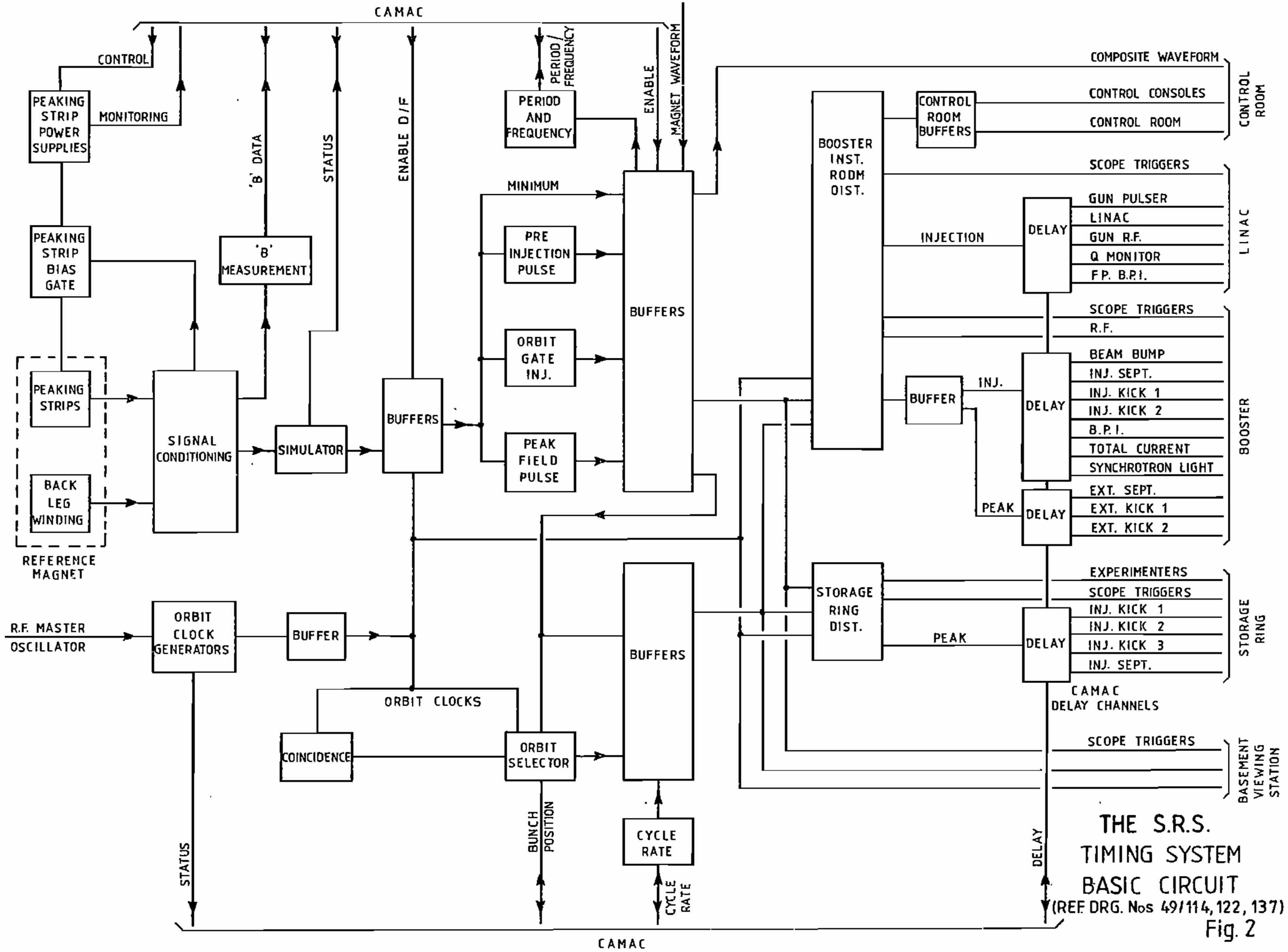
Fig. 29 Lower Crate

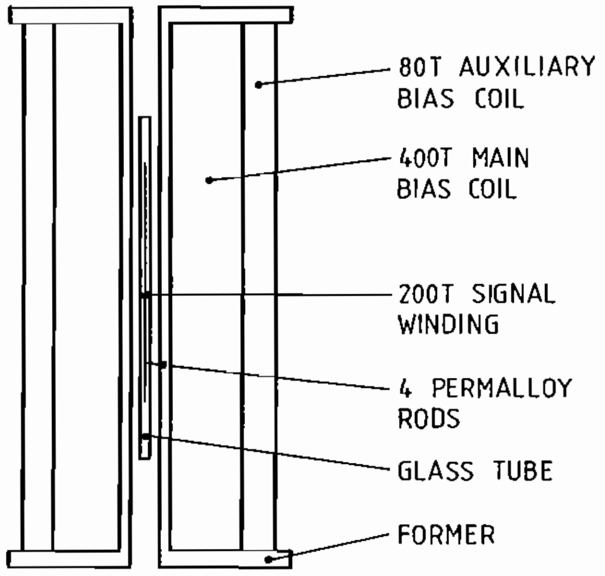


THE S.R.S. TIMING SYSTEM
BASIC ORGANISATION
(REF. DRG. Nos. 49/114, 122, 137)

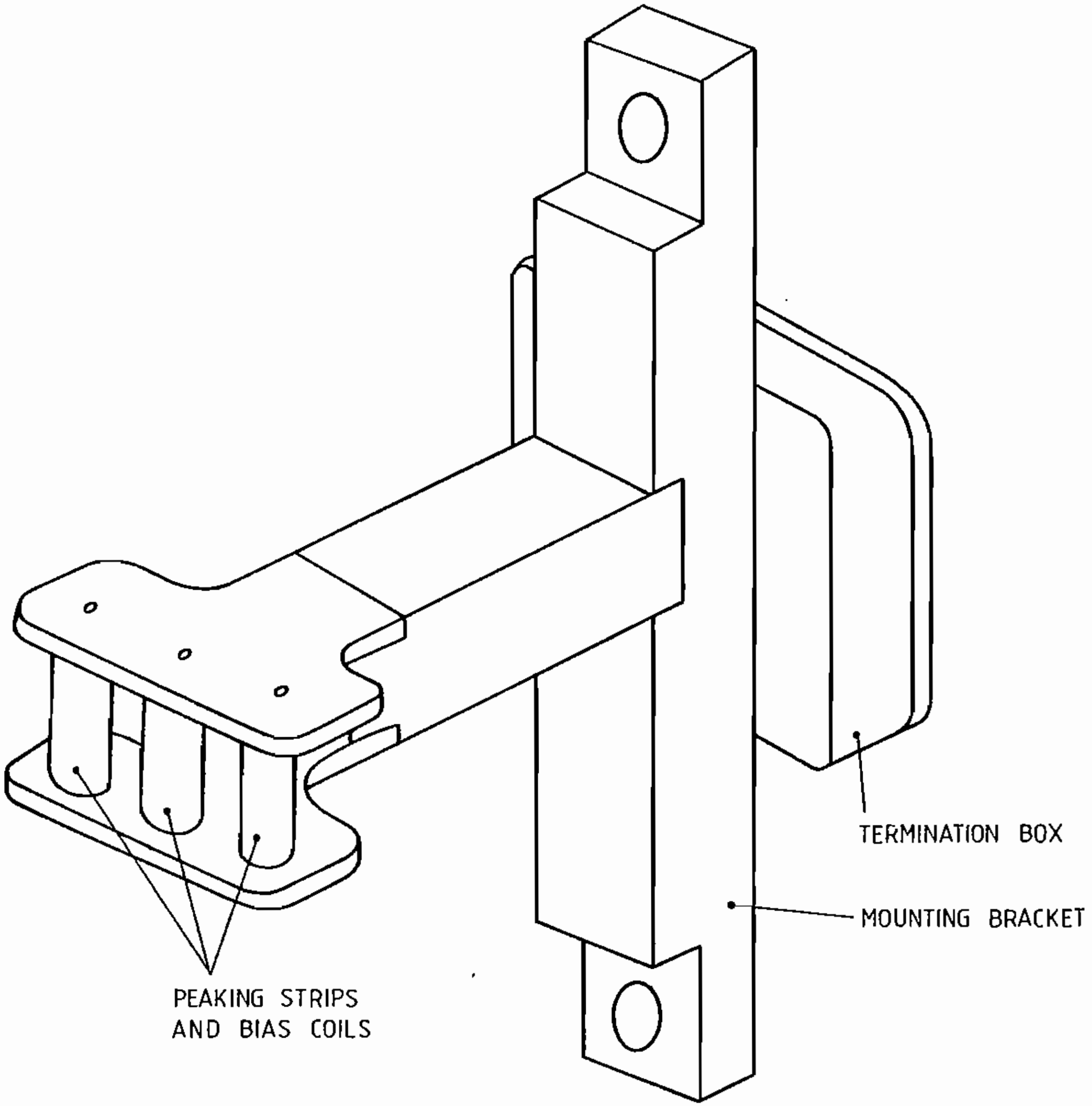
Fig. 1



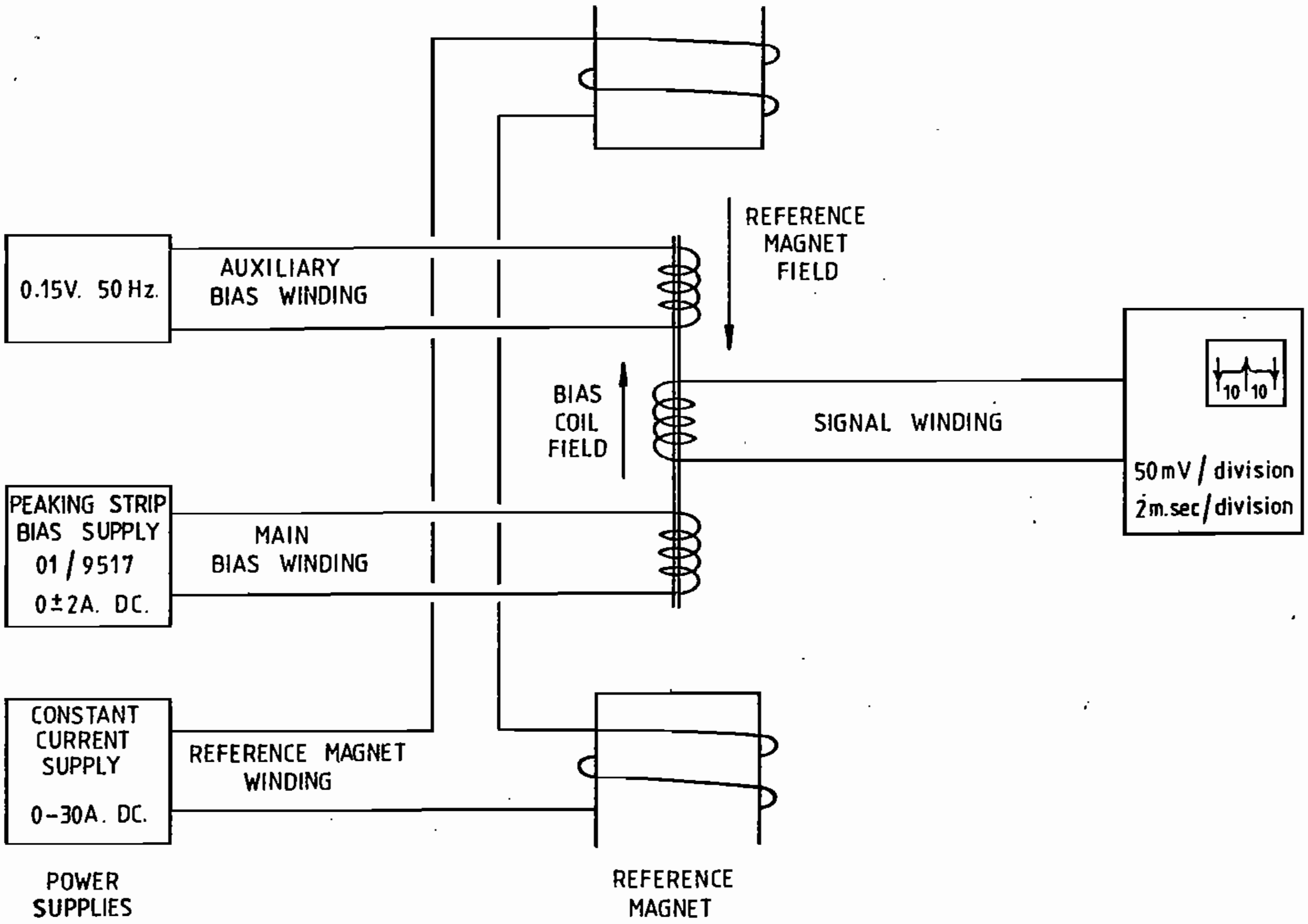
THE S.R.S.
TIMING SYSTEM
BASIC CIRCUIT
(REF DRG. Nos 49/114, 122, 137)
Fig. 2



PEAKING STRIPS
AND BIAS COILS
(REF. DRG. No. 43/669)
Fig. 3

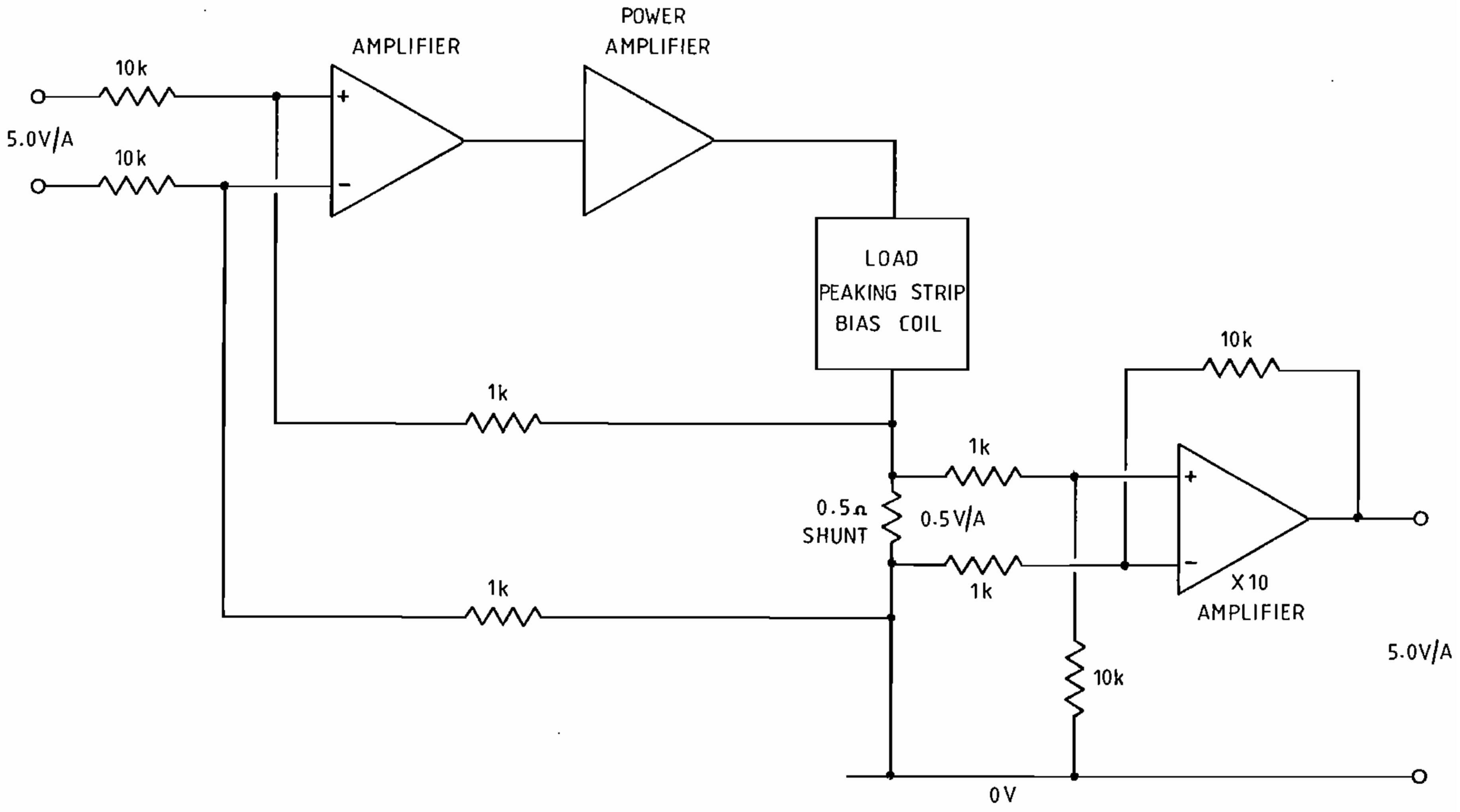


PEAKING STRIP MOUNTING
(REF. DRG. No. 43/669)
Fig. 4



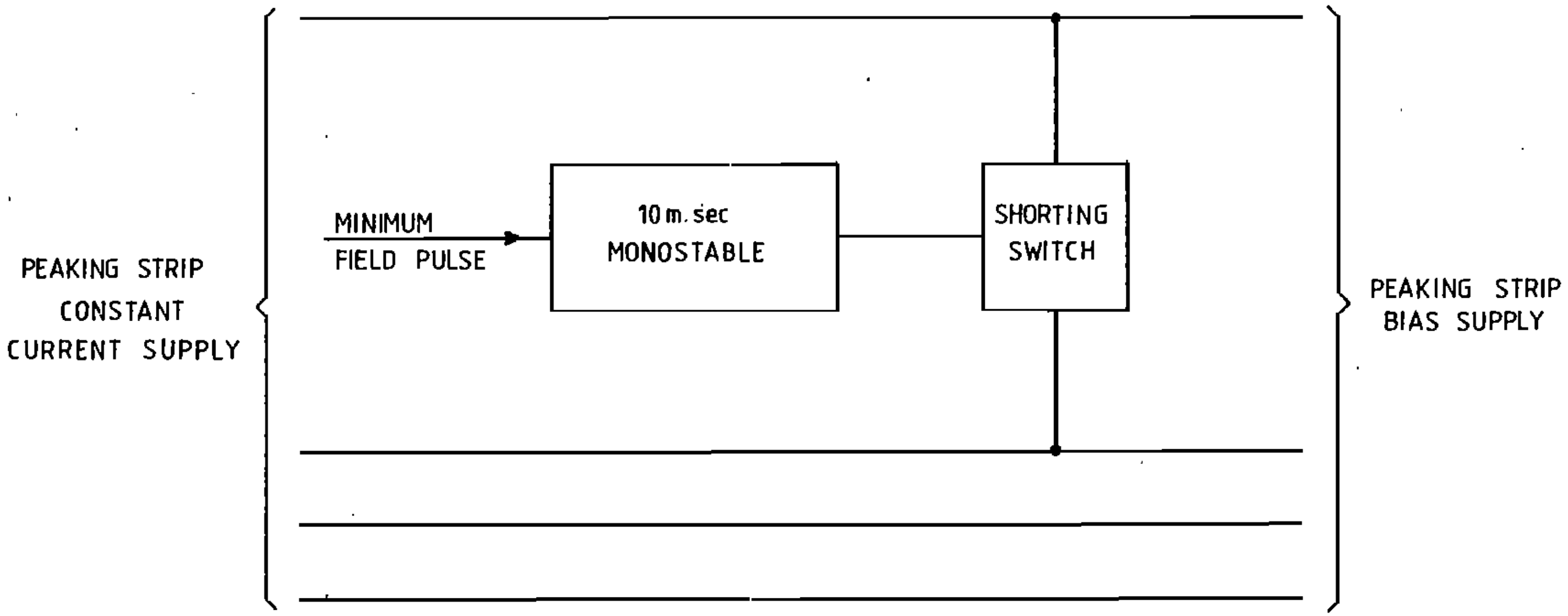
CALIBRATION OF PEAKING STRIPS

Fig. 5



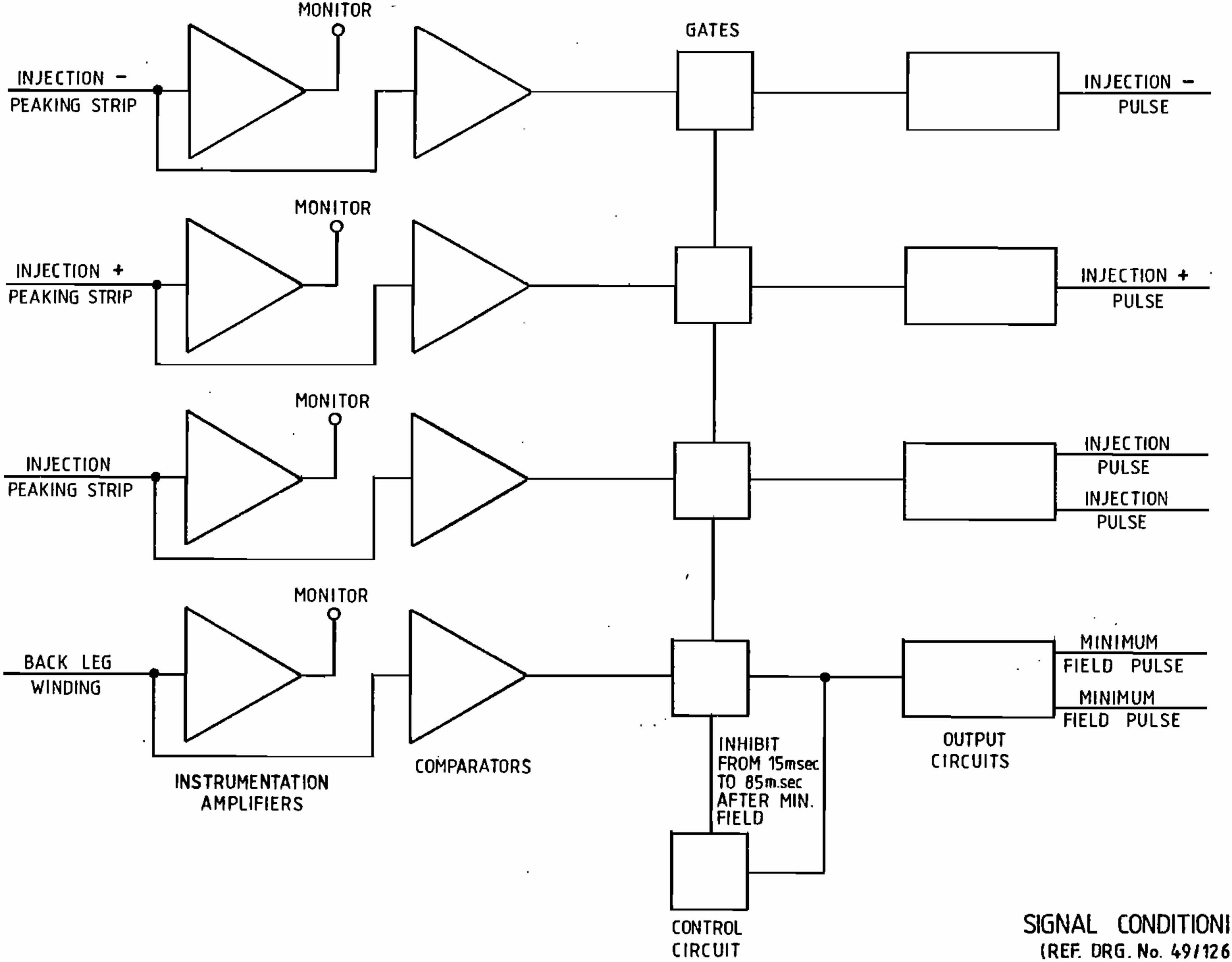
POWER MODULE EC.479
(REF. DRG. No. 49/140)

Fig. 6



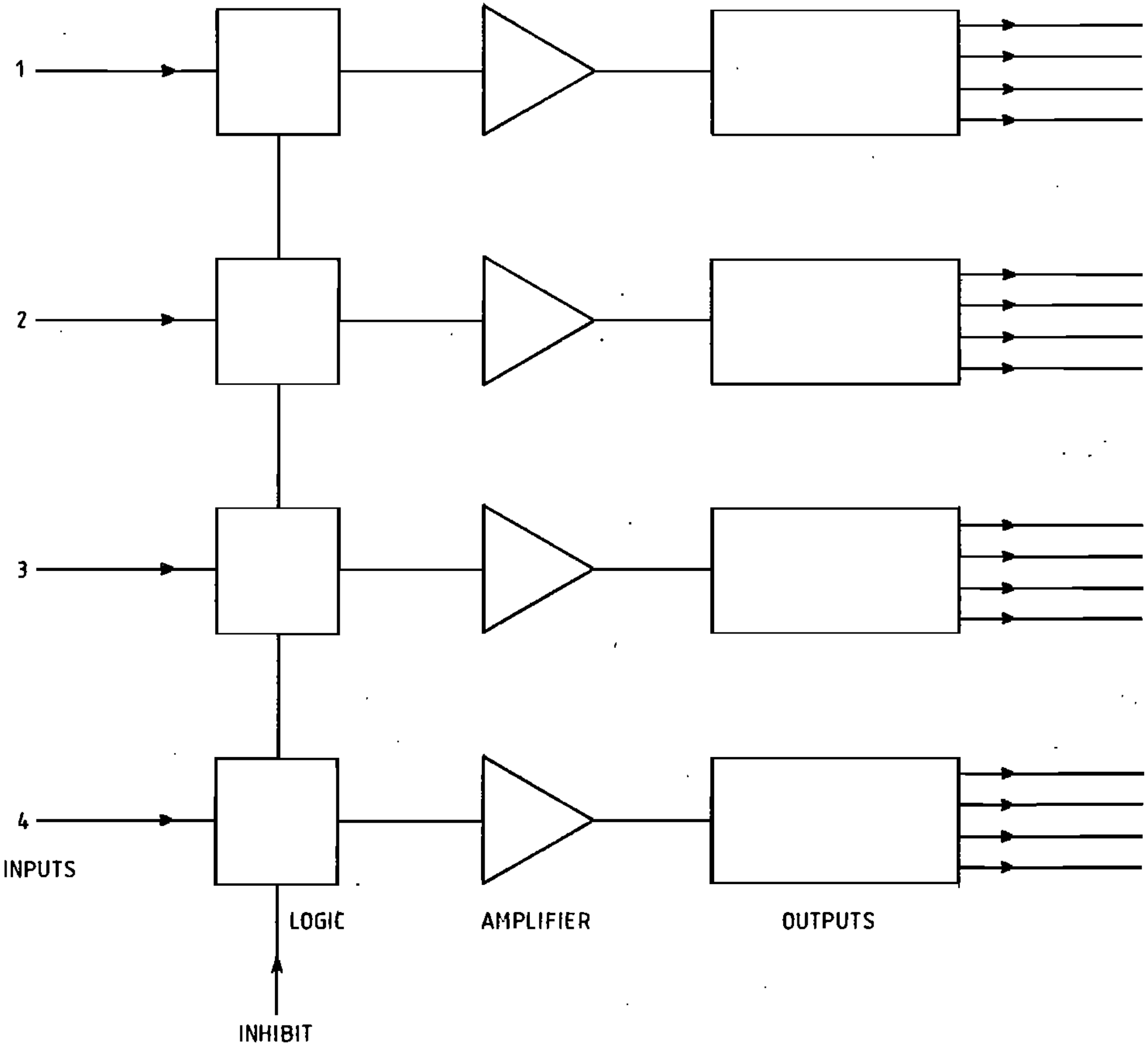
PEAKING STRIP BIAS GATE
(REF. DRG. No. 49/128)

Fig. 7

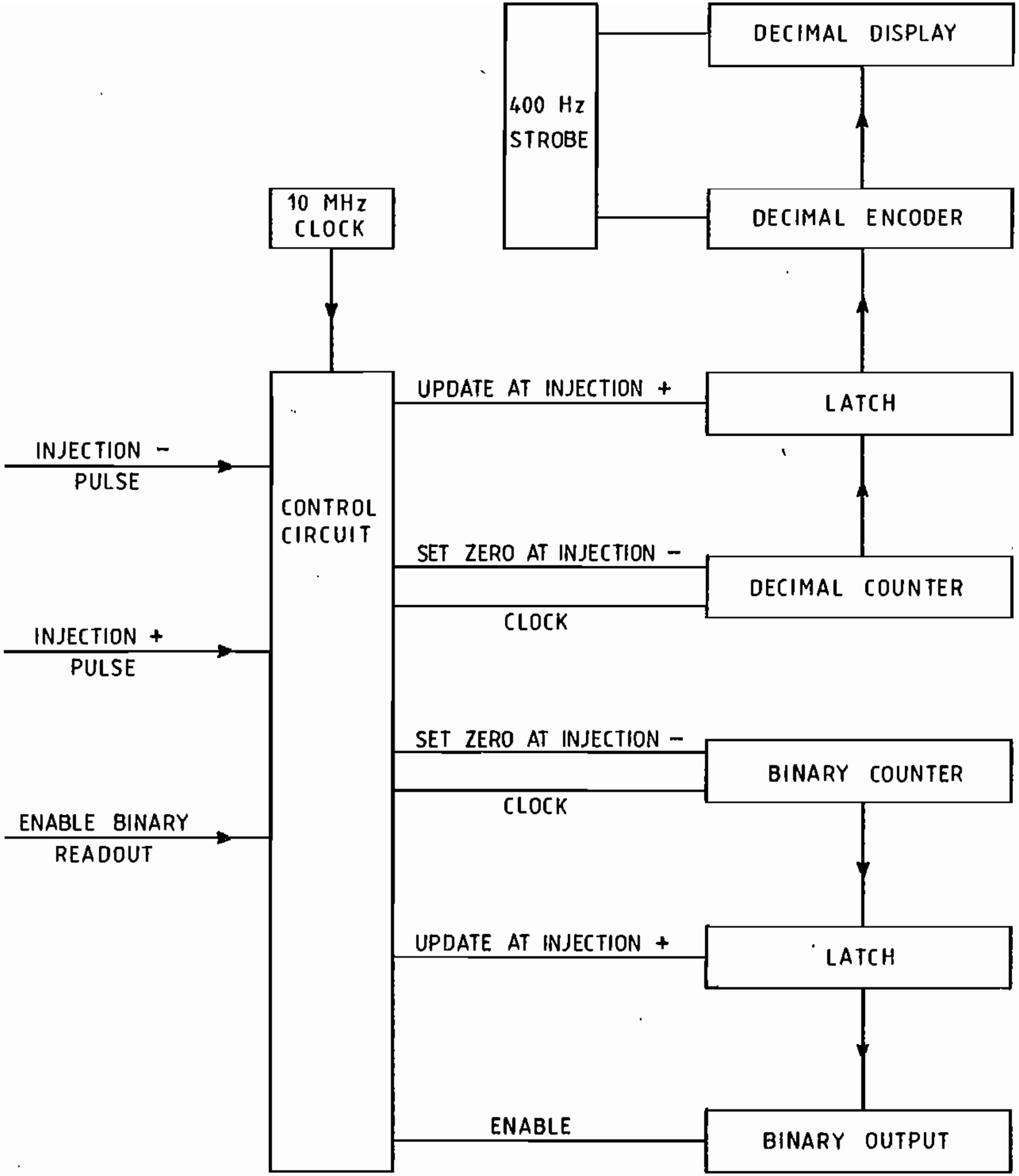


SIGNAL CONDITIONING
(REF. DRG. No. 49/126)

Fig. 8

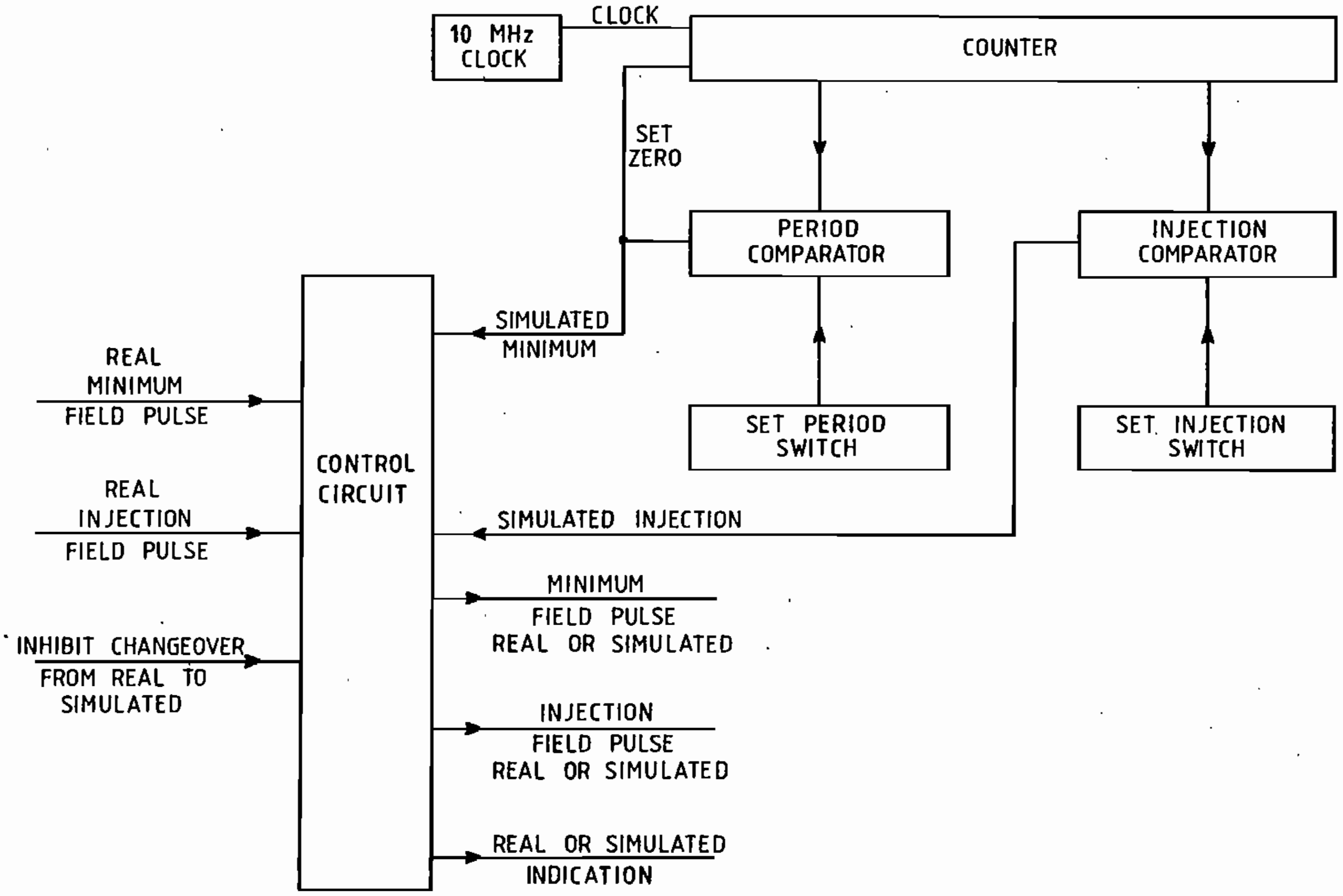


QUAD BUFFER
(REF. DRG. No. 49/124)
Fig. 9



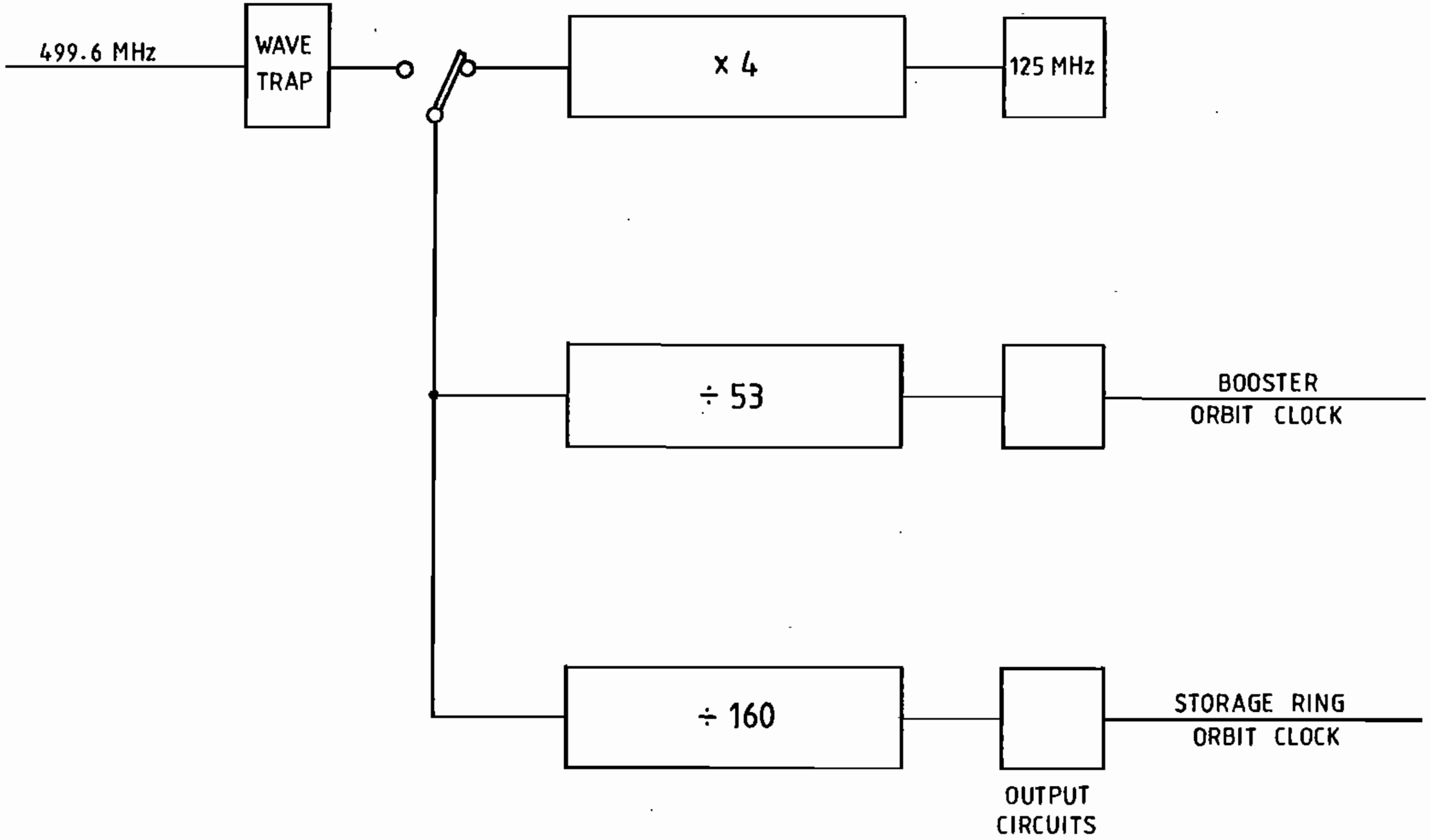
'B' MEASUREMENT
(REF. DRG. No. 49/136)

Fig. 10



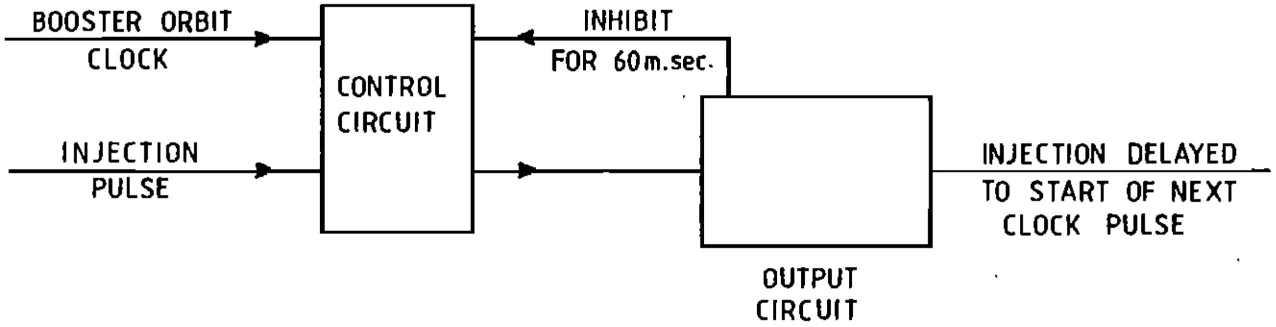
SIMULATOR
(REF. DRG. No. 49/135)

Fig. 11



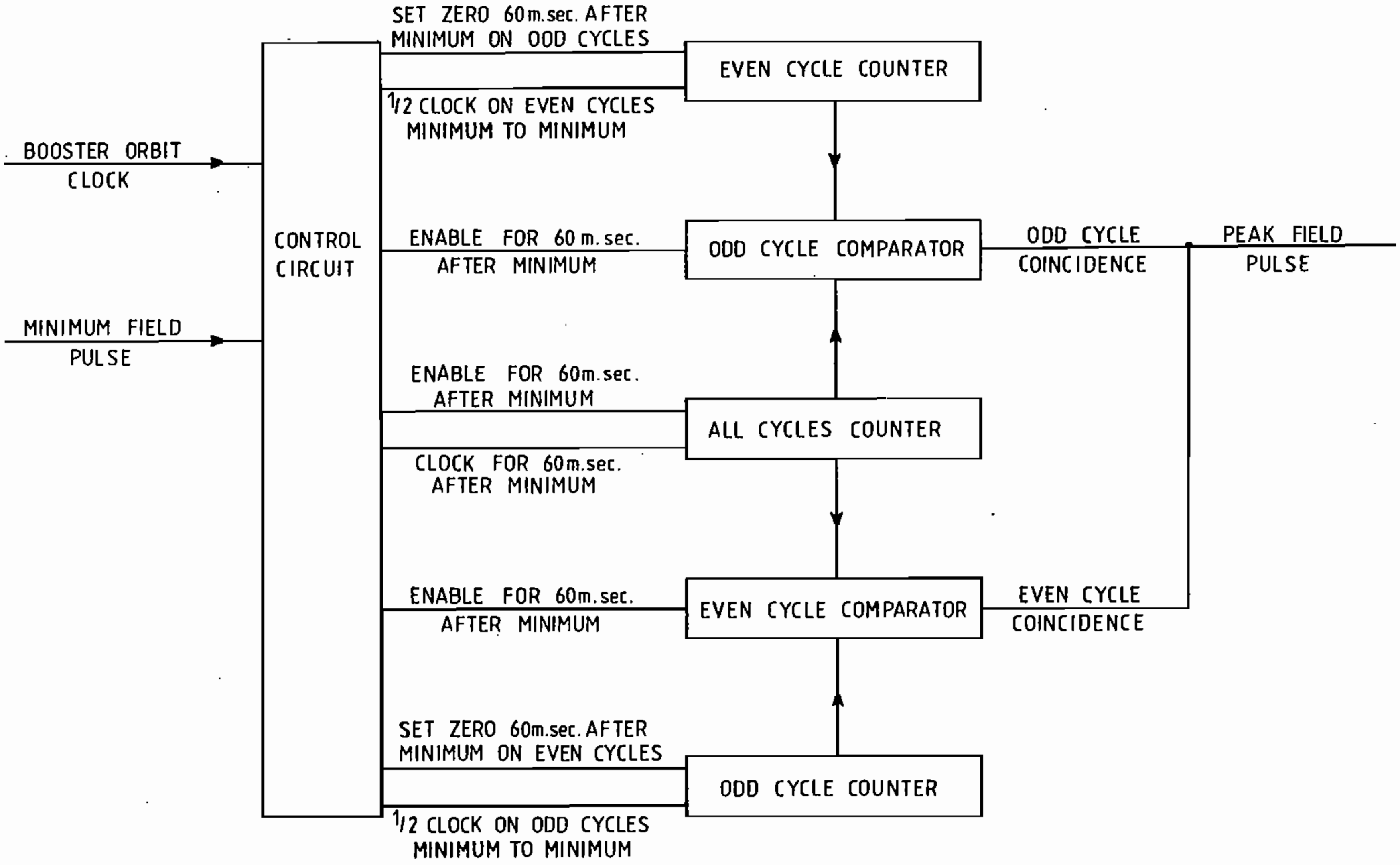
ORBIT CLOCKS
(REF. DRG. No 49/129)

Fig. 12



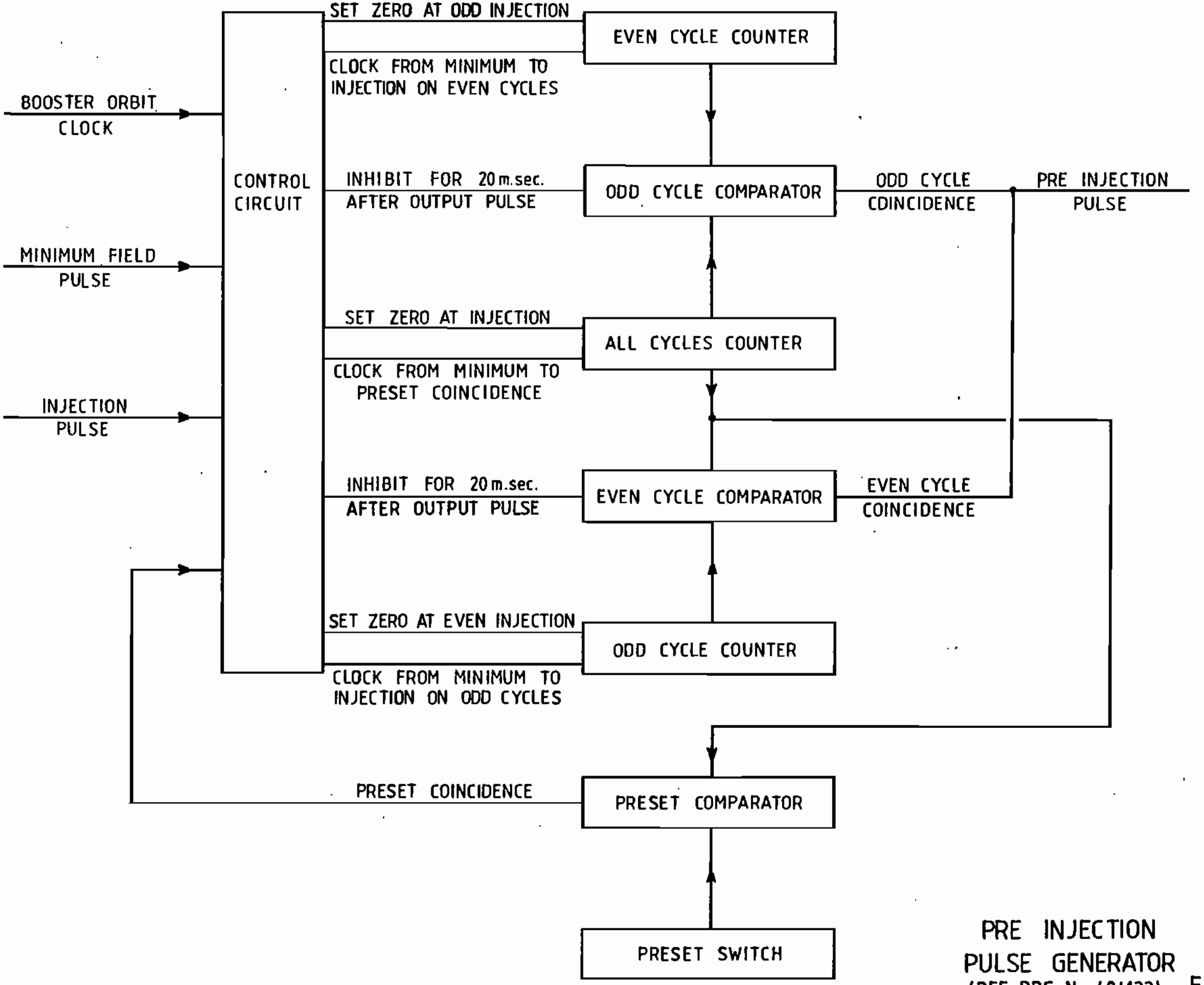
ORBIT GATE
(REF. DRG. No 49/127)

Fig. 13

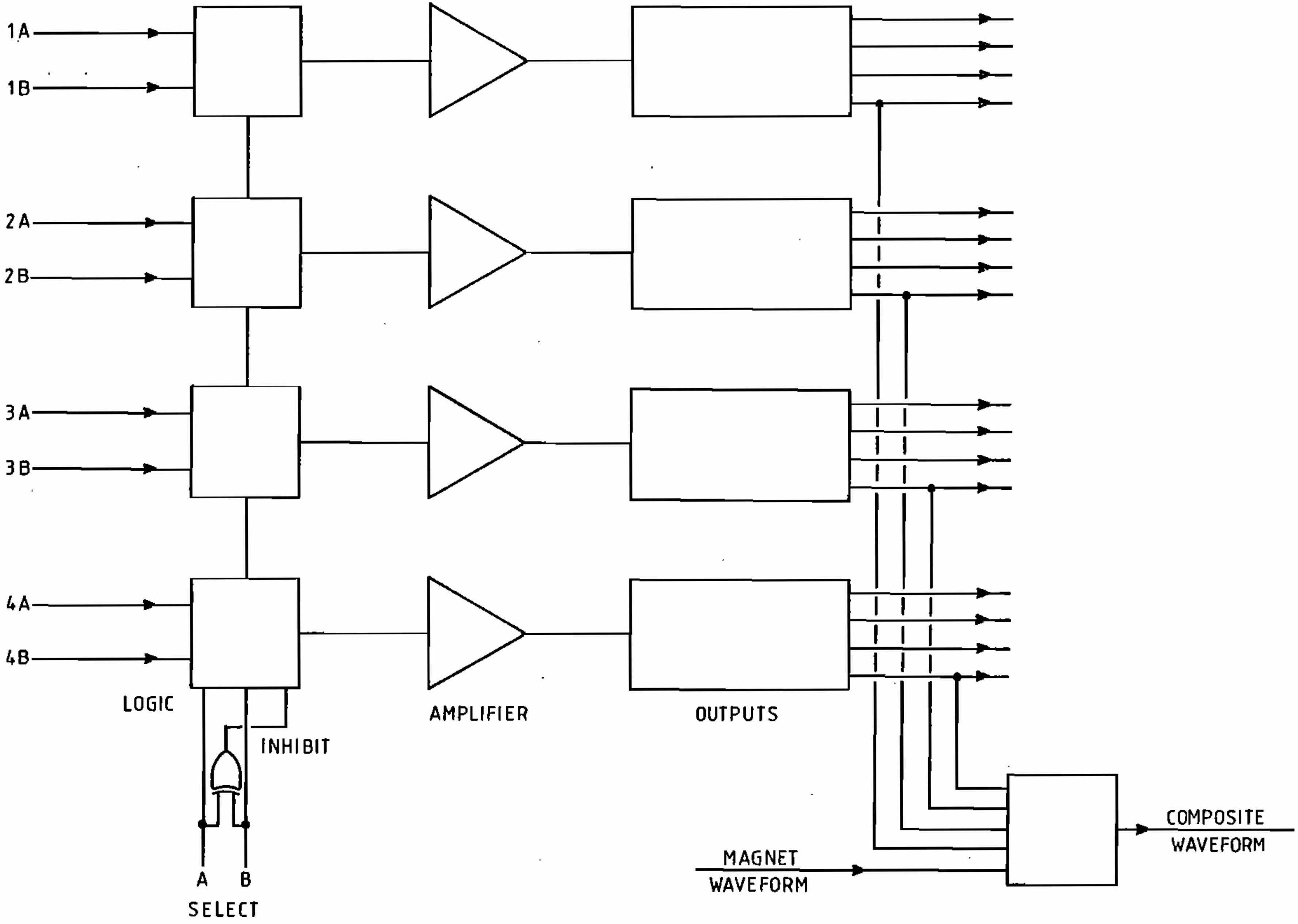


PEAK FIELD PULSE GENERATOR
(REF DRG No 49/134)

Fig. 14

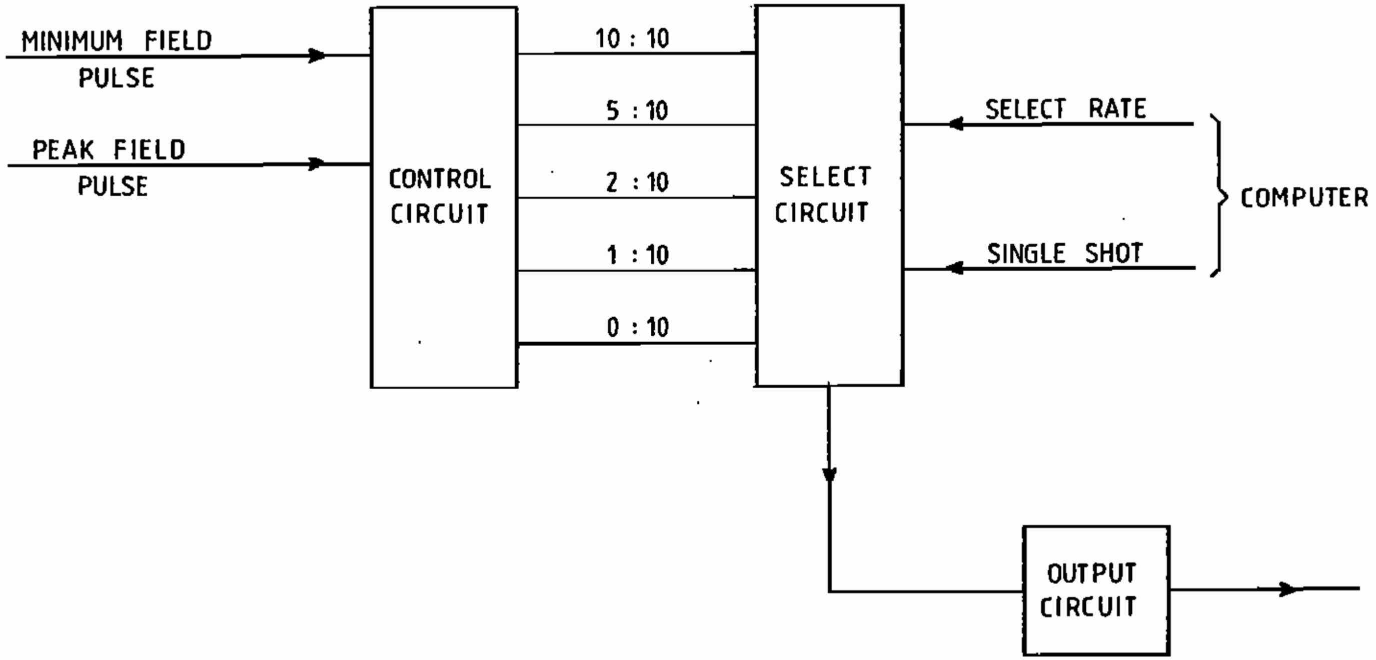


PRE INJECTION
PULSE GENERATOR
(REF. DRG. No. 49/133) Fig. 15



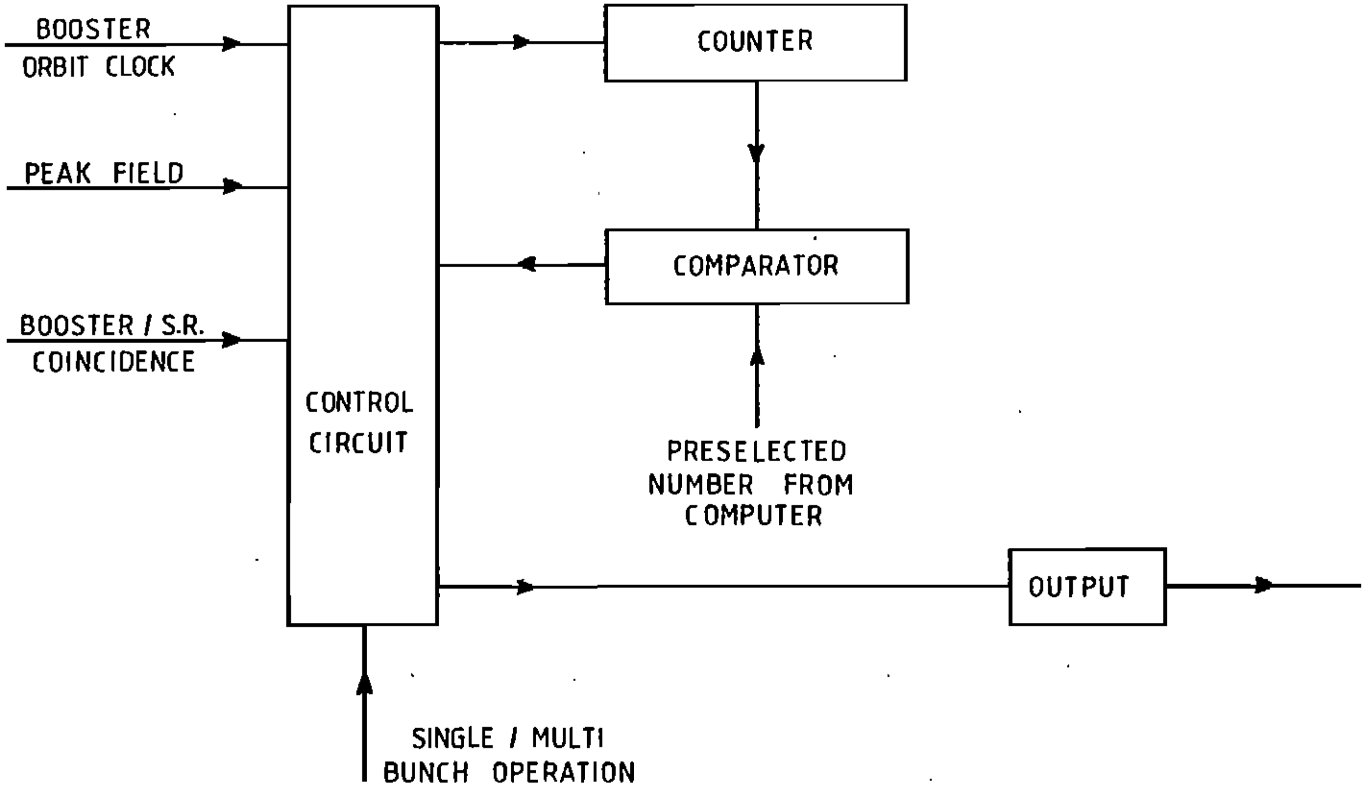
QUAD OR BUFFER
(REF. DRG. No. 49/123)

Fig. 16



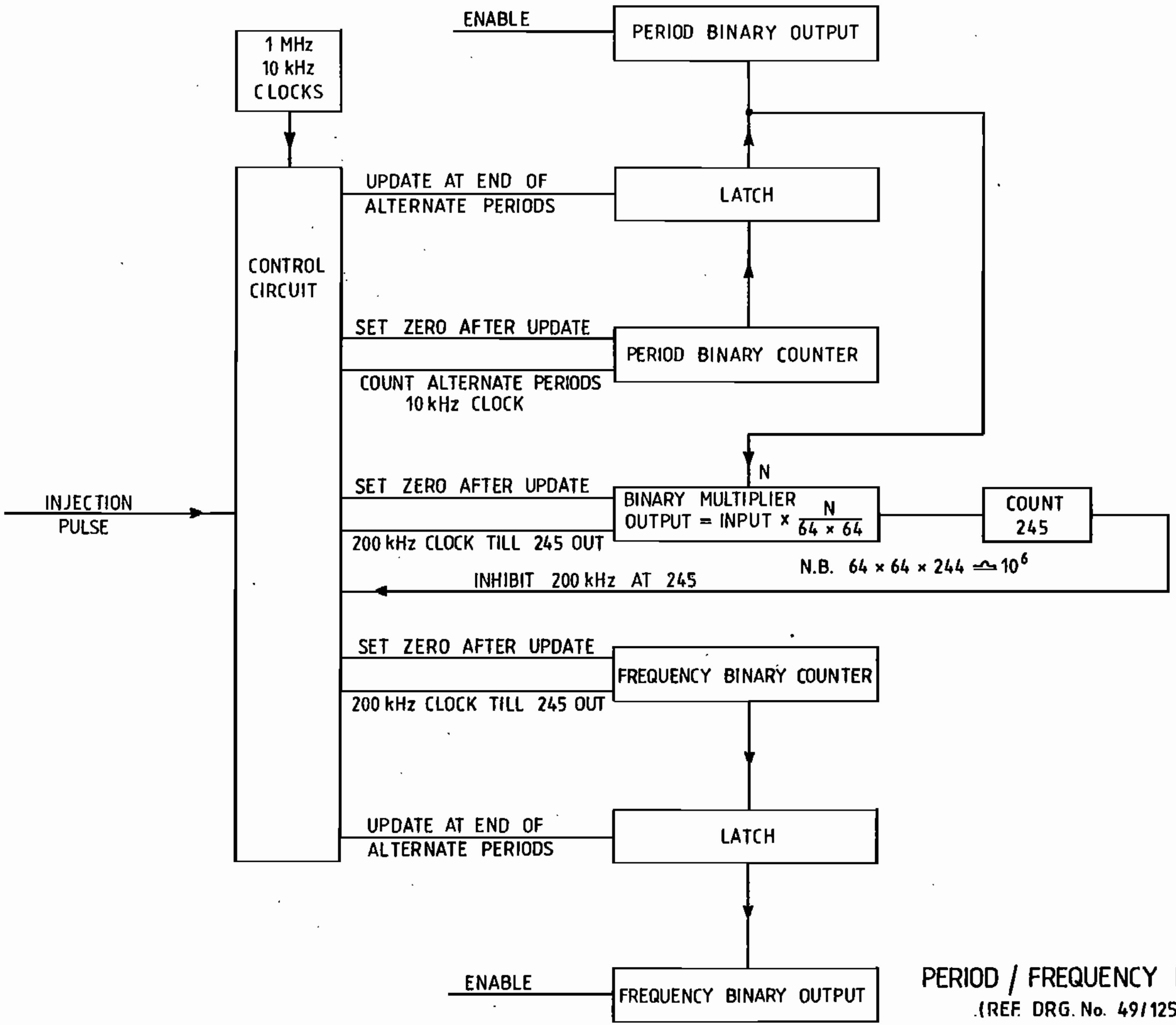
CYCLE RATE SELECTOR
(REF. DRG. No. 49/131)

Fig. 17



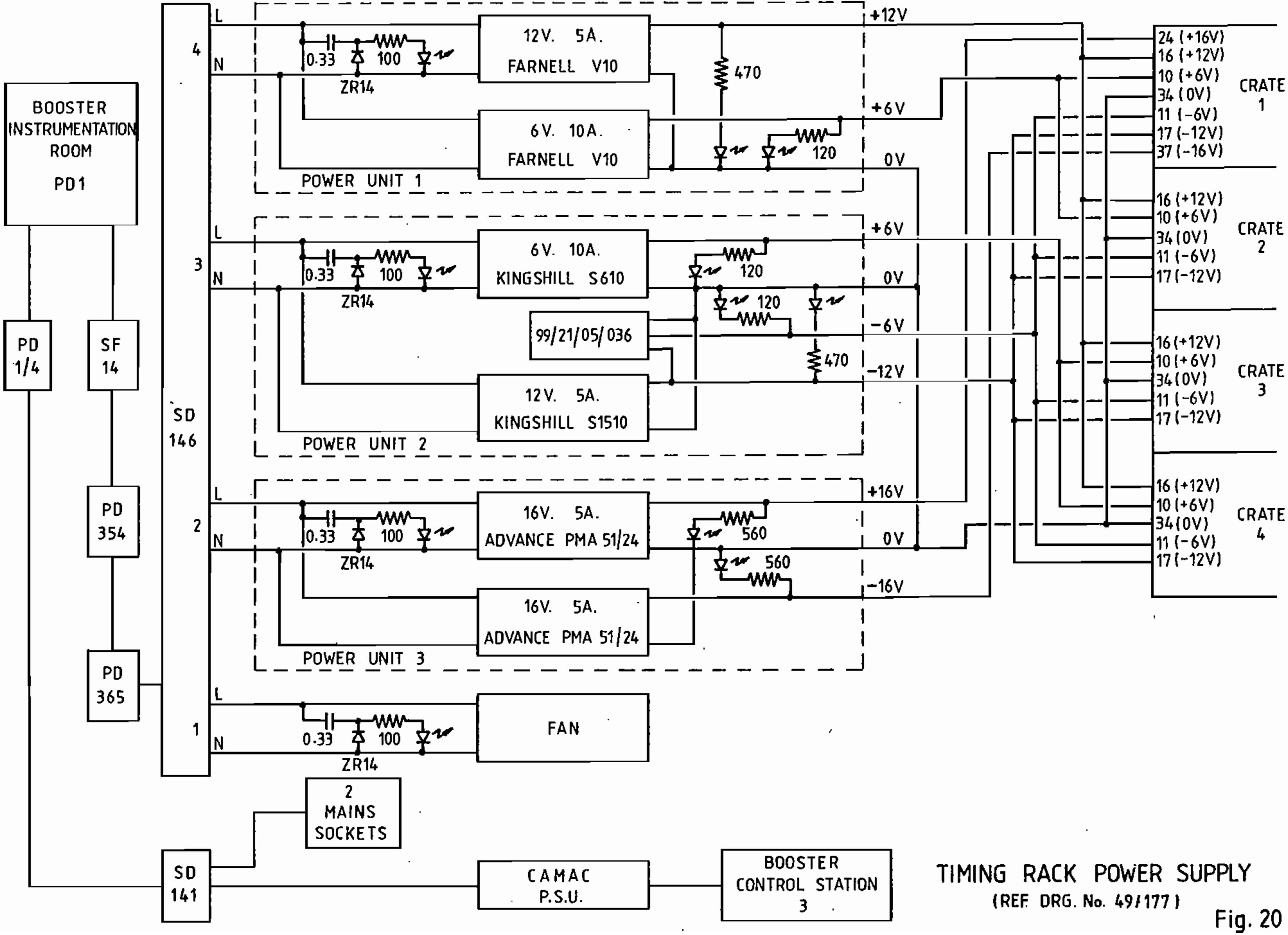
EXTRACTION GATE
(REF. DRG. No. 49/130)

Fig. 18



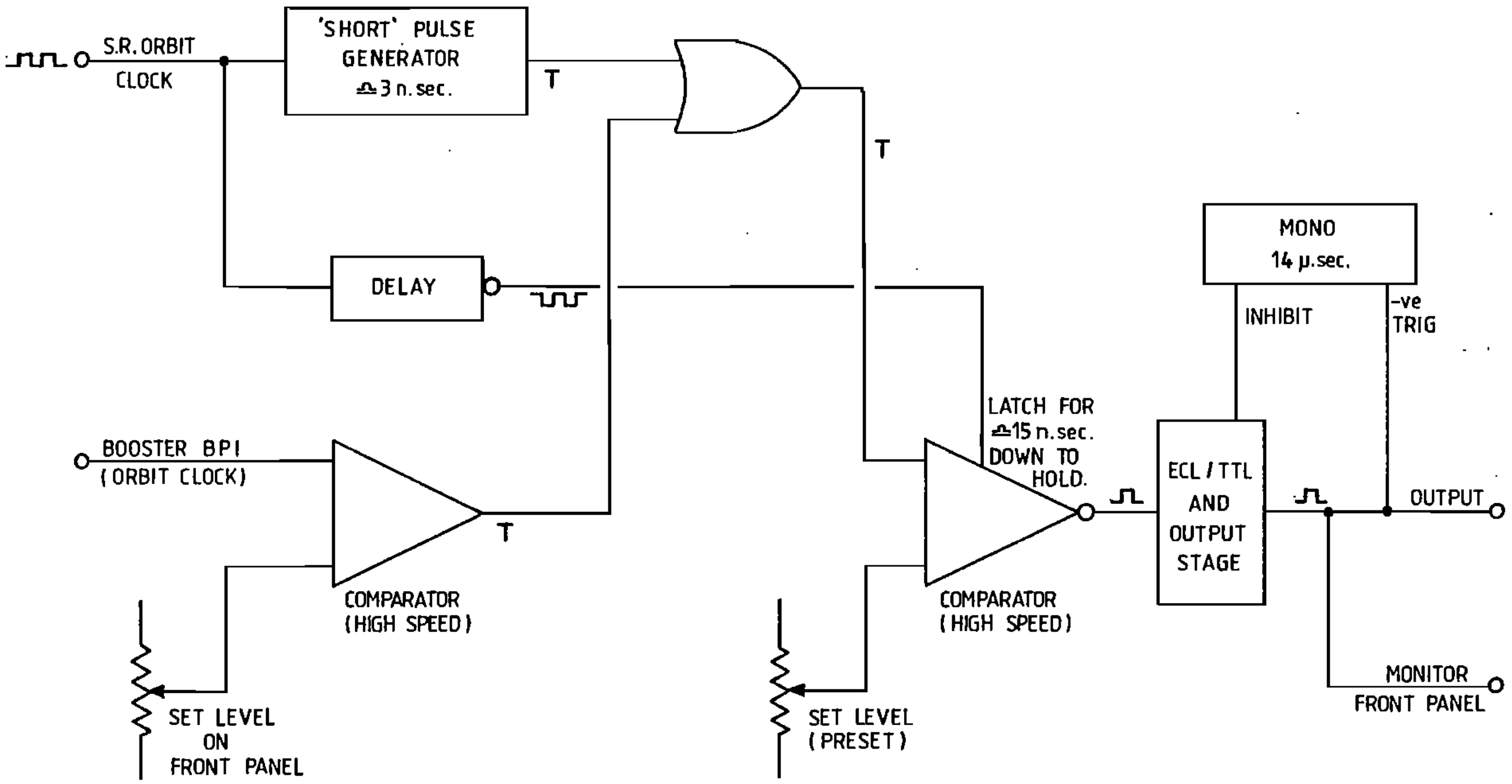
PERIOD / FREQUENCY METER
(REF. DRG. No. 49/125)

Fig. 19



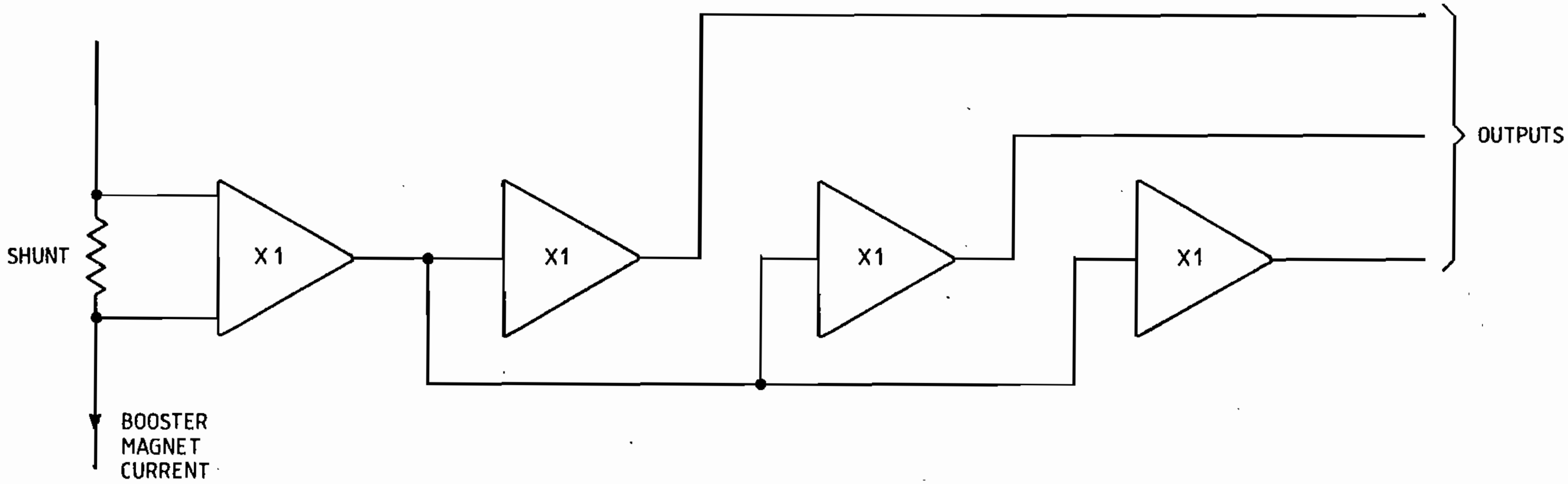
TIMING RACK POWER SUPPLY
(REF. DRG. No. 49/177)

Fig. 20



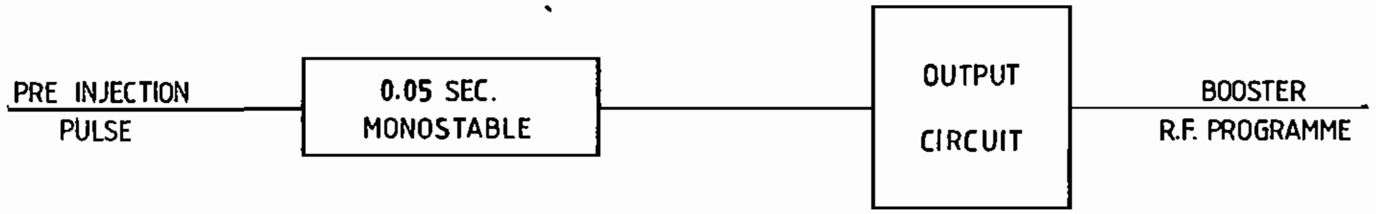
COINCIDENCE CIRCUIT
(REF DRG. No 49/175)

Fig. 21

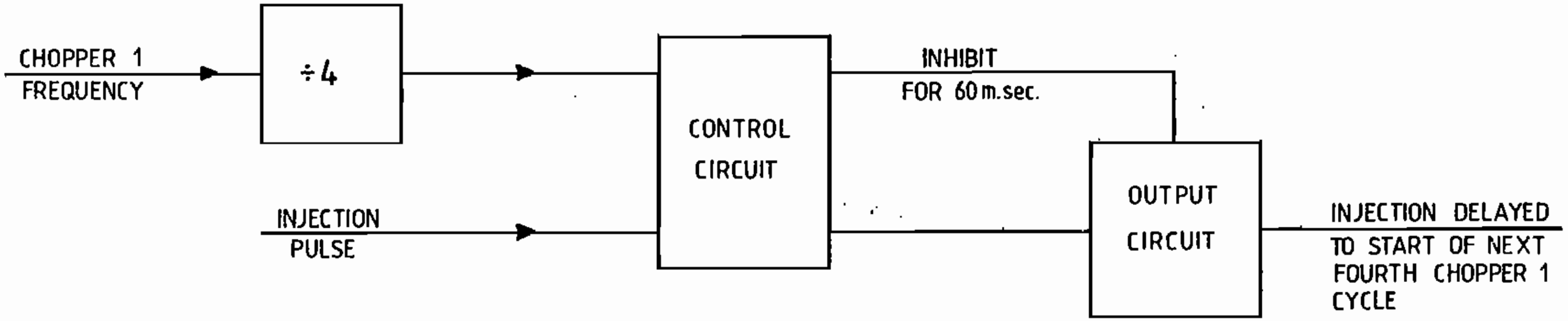


MAGNET WAVEFORM UNIT
(REF. DRG. No. 49/138)

Fig. 22

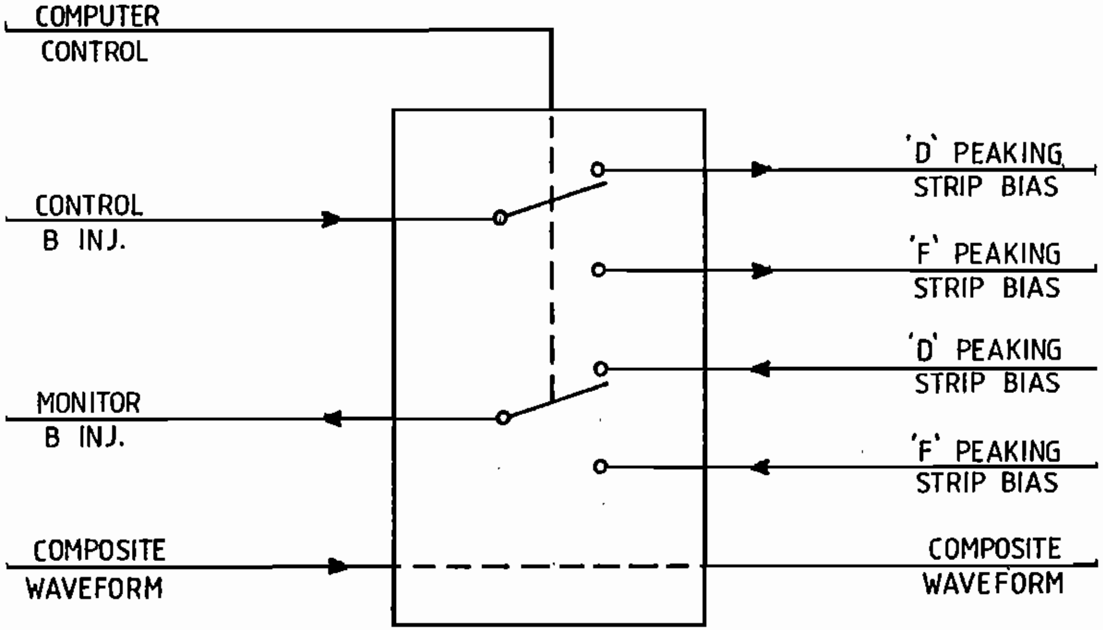


BOOSTER R.F. PROGRAMME
(REF. DRG. No. 49/174)
Fig. 23



CHOPPER GATE
(REF. DRG. No. 49/176)

Fig. 24



D / F SELECTOR
(REF. DRG. No. 49/139)

Fig. 25

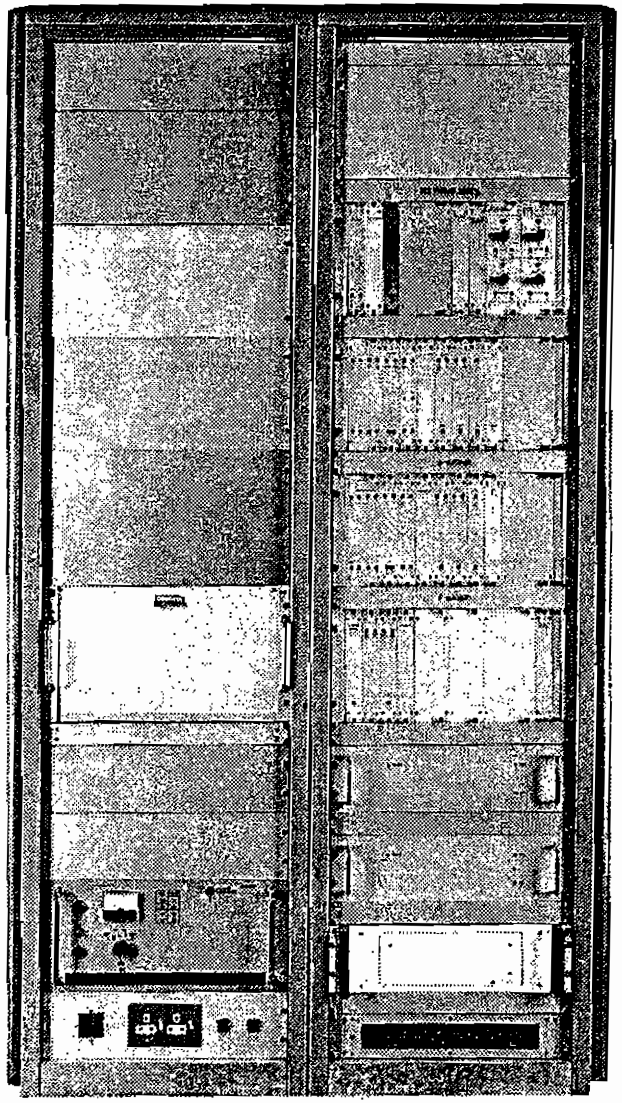


Fig. 26

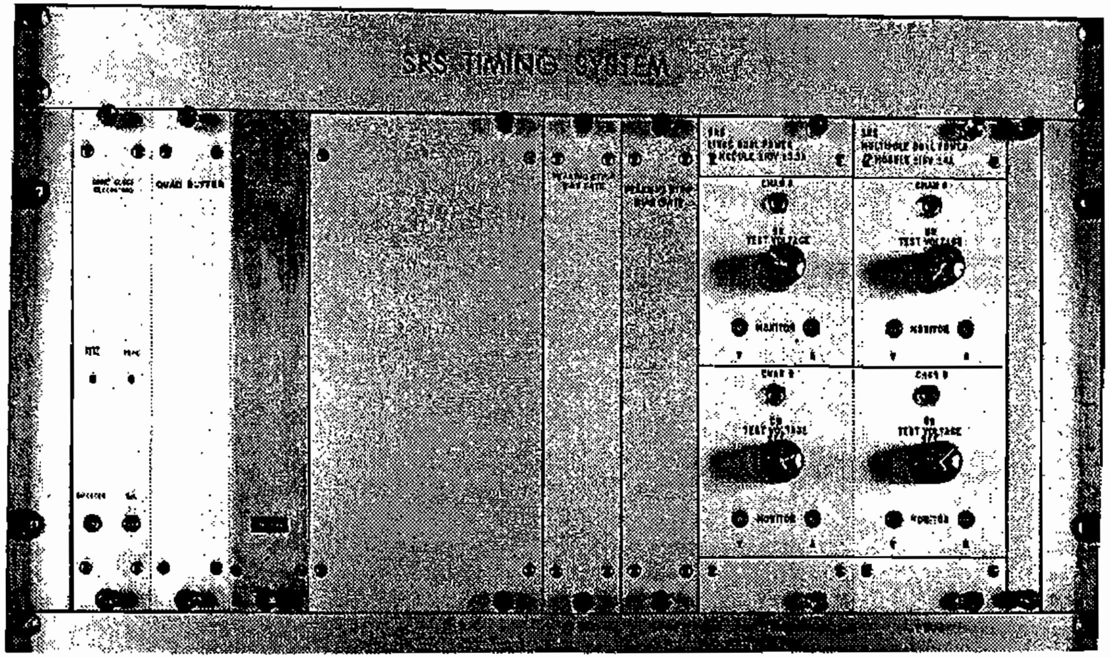

SRS TIMING SYSTEM
QUAD BUFFER
TEST VOLTAGE
MONITOR
TEST VOLTAGE
MONITOR
TEST VOLTAGE
MONITOR
TEST VOLTAGE
MONITOR

Fig. 27

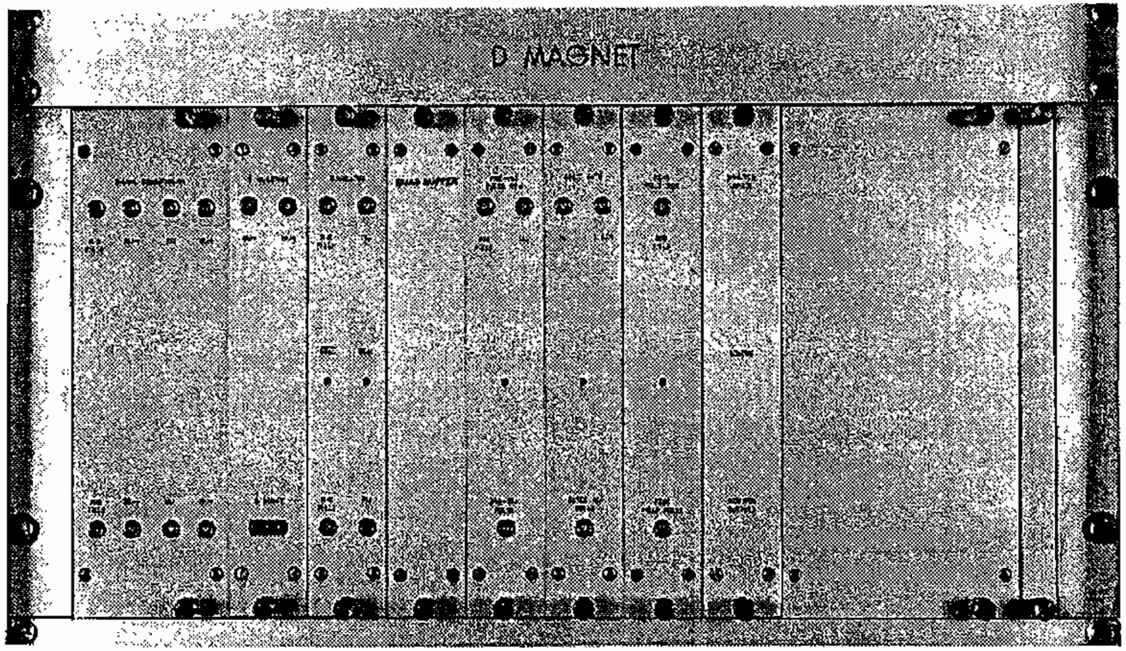


Fig. 28

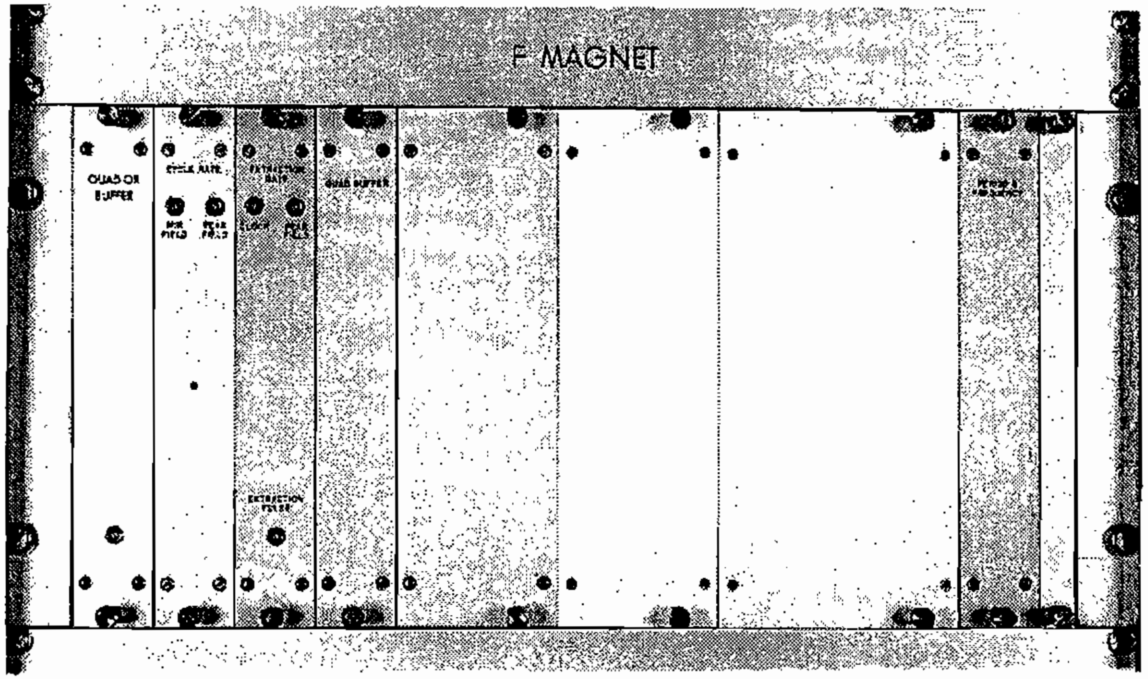

F MAGNET
QUAD OR BUFFER
CYCLE RATE
MIN FIELD
PEAK FIELD
EXTRACTION GATE
CLOCK
PEAK FIELD
EXTRACTION PULSE
QUAD BUFFER

Fig. 29