## 5.5 Proportional Control

If the operator, instead of using an ON-OFF switch to control the power to the heaters, had a rheostat control, he would have much finer control of power to the furnace.

Provided such things as outside temperature and amount of metal in furnace was constant, he should be able to set the power level such that the temperature would remain at any desired level.

## EXPERIMENT 2 SIMPLE OPEN-LOOP PROPORTIONAL CONTROL

Patch the front panel of the PCS327 as in fig 10.

Using the SET VALUE control attempt to make the MEASURED VALUE meter indicate any desired value, noting the relative readings of both MEASURED VALUE and SET VALUE meters.

Apply a small disturbing voltage ±1.5V d.c to the LOAD DISTURBANCE socket and note any changes in meter readings.

## SUMMARY

With this arrangement a much smoother control of the furnace temperature is possible.

As long as the outside conditions are constant so is the MEASURED VALUE, but if the load is disturbed no corrective action occurs without the operator changing the SET VALUE.

## 5.6 Automatic Process Control systems

The two OPEN-LOOP systems so far considered have certain disadvantages as have been seen in the previous experiments. Proportional control enables a smooth adjustment of the system to be made but will maintain a particular DESIRED VALUE only for one particular set of operating conditions.

In the furnace example, if some metal is removed and no adjustment made to the power level, the actual temperature or MEASURED VALUE may well rise above the DESIRED VALUE.

The system now needs to be modified so that it can correct itself for any changes in operating conditions; this can be achieved by closing the loop.

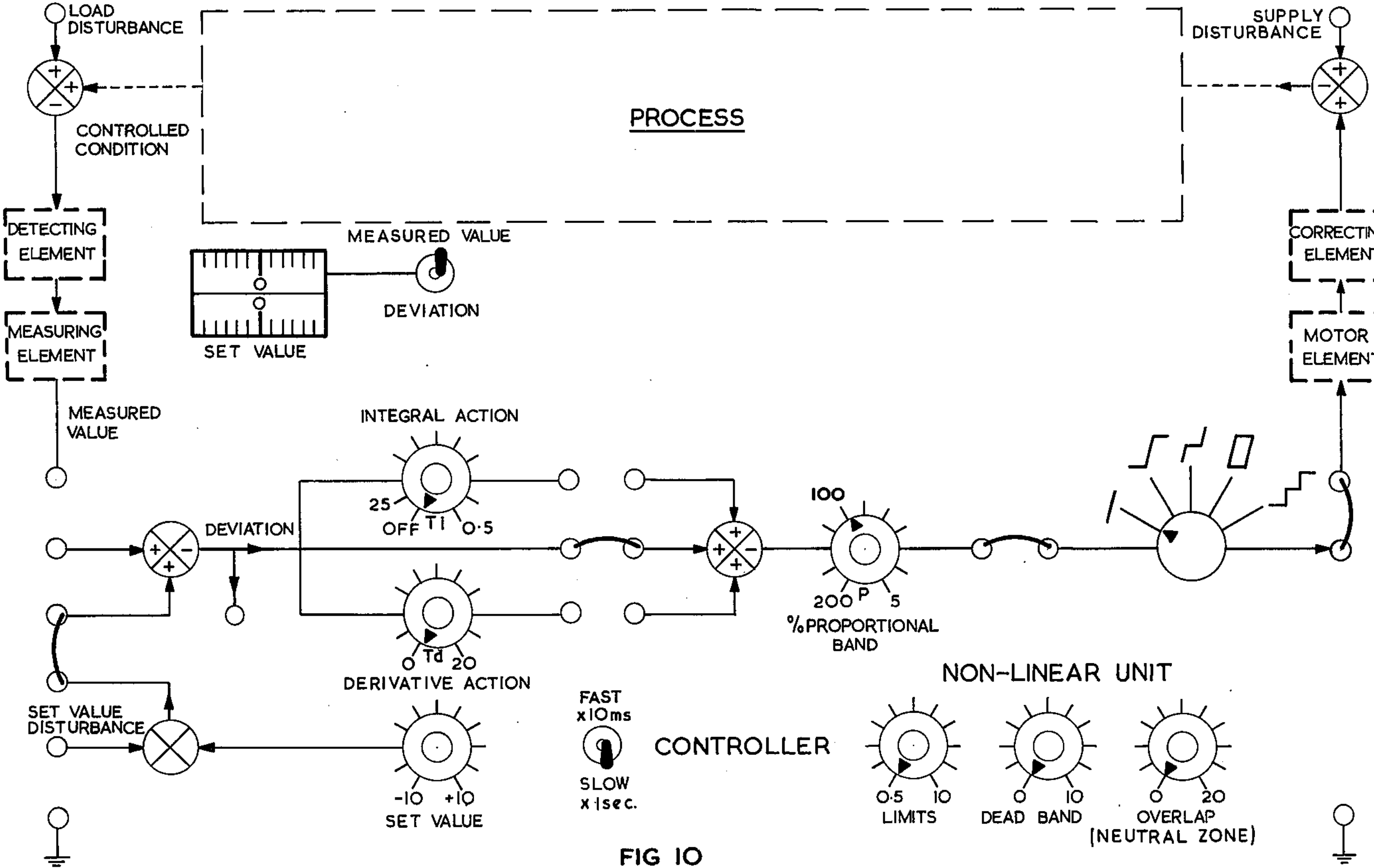

LOAD DISTURBANCE
CONTROLLED CONDITION
DETECTING ELEMENT
MEASURING ELEMENT
MEASURED VALUE
PROCESS
SUPPLY DISTURBANCE
CORRECTING ELEMENT
MOTOR ELEMENT
MEASURED VALUE
DEVIATION
SET VALUE
DEVIATION
INTEGRAL ACTION
25
OFF
Ti
0·5
DERIVATIVE ACTION
0
Td
20
100
200
P
5
%PROPORTIONAL BAND
SET VALUE DISTURBANCE
-10
+10
SET VALUE
FAST x10ms
SLOW x·1sec.
CONTROLLER
NON-LINEAR UNIT
0·5
10
LIMITS
0
10
DEAD BAND
0
20
OVERLAP (NEUTRAL ZONE)

FIG 10

### 5.7 The Closed-Loop Control system

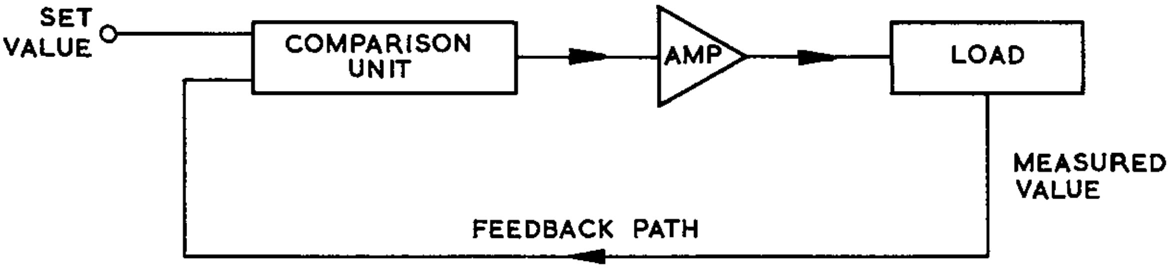


FIG 11

Fig 11 shows the basic elements of a CLOSED-LOOP system.

There are three main features of such a system. A comparison is made between the SET VALUE and the MEASURED VALUE to produce a DEVIATION.

DEVIATION = MEASURED VALUE - SET VALUE

The DEVIATION operates the system and there is a POWER GAIN between the DEVIATION and the LOAD.

With such a system as this, once the operater has fixed the SET VALUE, he is no longer required. Any change in operating conditions that cause the MEASURED VALUE or value of the controlled condition to change, produces a deviation which adjusts the system to correct for the new operating condition.

As there is now a feedback path from the load back to the input, this system is now a CLOSED LOOP.

Patch the front panel of the PCS327 as in fig 12.

Set all controls and switches as indicated.

With the meter switch at MEASURED VALUE make adjustments of SET VALUE CONTROL and note the corresponding changes on the SET VALUE and MEASURED VALUE meters.

Repeat with the meter switch at DEVIATION.

Apply to the LOAD DISTURBANCE socket a voltage of approx 1.5V note the changes in both MEASURED VALUE and DEVIATION meter indications.

## SUMMARY

When a change in the SET VALUE is made the MEASURED VALUE changes, but somewhat slower than the set value, and the measured value is not the same as the set value.

For any set value there is an appreciable DEVIATION present.

When a load disturbance is applied, both the MEASURED VALUE and the DEVIATION change.

The delay in the change of the MEASURED VALUE is due to lags in the process.

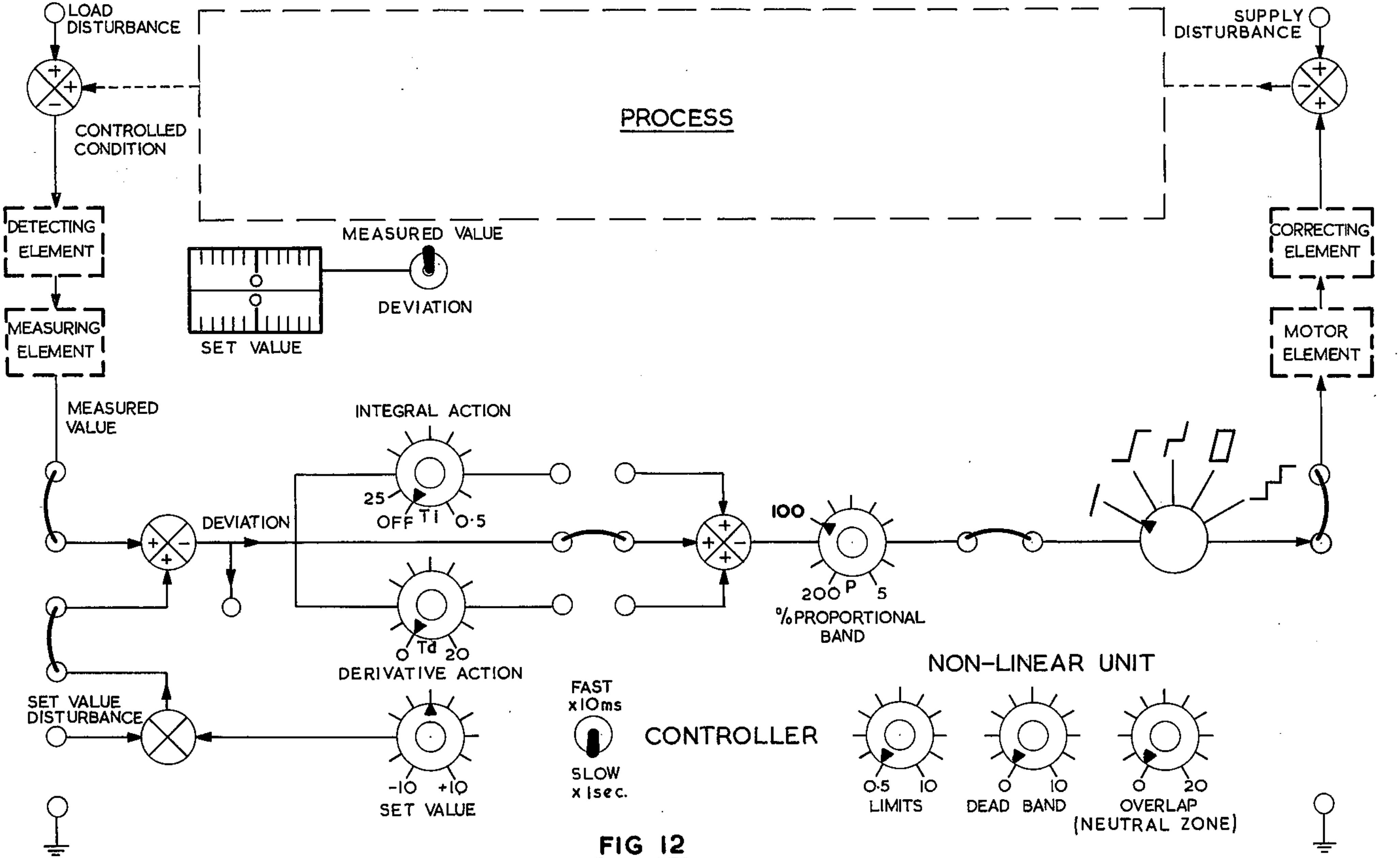

LOAD DISTURBANCE
PROCESS
SUPPLY DISTURBANCE
CONTROLLED CONDITION
DETECTING ELEMENT
MEASURING ELEMENT
MEASURED VALUE
SET VALUE
DEVIATION
CORRECTING ELEMENT
MOTOR ELEMENT
MEASURED VALUE
INTEGRAL ACTION
25
OFF
TI
0·5
DEVIATION
100
200
P
5
% PROPORTIONAL BAND
0
Td
20
DERIVATIVE ACTION
SET VALUE DISTURBANCE
-10
+10
SET VALUE
FAST x10ms
SLOW x1sec.
CONTROLLER
NON-LINEAR UNIT
0·5
10
LIMITS
0
10
DEAD BAND
0
20
OVERLAP (NEUTRAL ZONE)

FIG 12

## 5.8 Process Characteristics

As was seen in EXPERIMENT 3 the process may have built-in delays which can occur for a variety of reasons, but can be divided into two main types. These are the EXPONENTIAL LAG and the DISTANCE/VELOCITY or TRANSPORT LAG.

## 5.9 The Exponential Lag

Consider the case in fig 13 in which water is being transferred from the left-hand into the right-hand tank.

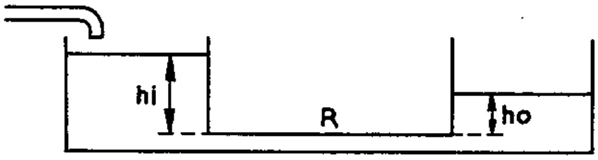


FIG 13

The water level in the LH tank is kept constant at hi and is transferred into the RH tank through a pipe of flow resistance R.

In such an arrangement the flow of water in the RH tank is proportional to the difference between the two levels and inversely proportional to the pipe flow resistance.

This means that when the RH tank is empty the flow rate is high because $h_i - h_o$ is large. As the tank fills the flow rate falls so that when a sudden increase in the contents is required, the increase is rapid at first and then gets slower.

The TIME CONSTANT of the system is the time taken for the output to reach 63% of its final value as shown in fig 14.

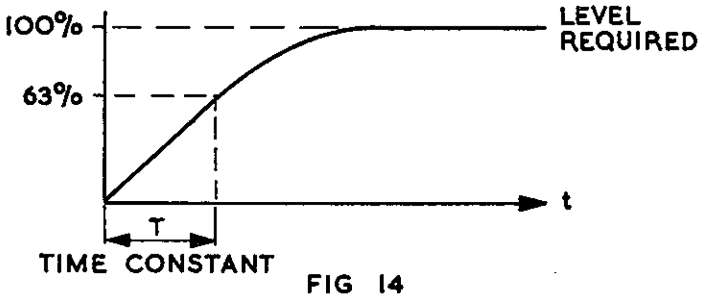


FIG 14

In practical processes the time constants can be anything from a few milliseconds to several hours.

## 5.10 Distance Velocity or Transport Lag

Consider a process which involves the control of water temperature in a storage tank, the temperature being measured in the outlet pipe from the tank. The water flows from the tank to the thermometer via the pipe and a change of temperature can occur in the tank sometime before it is detected by the thermometer.

This time interval is governed solely by the velocity of the water and the distance between the tank and the thermometer, and is known as the TRANSPORT LAG.

## 5.11 Closed-Loop Proportional Control

The system considered in Experiment 3 had one major disadvantage, namely that there was considerable DEVIATION present at all times. As the DEVIATION should operate the system, this implies that the sensitivity is too low.

In process control this sensitivity is defined in terms of PROPORTIONAL BAND. This is the range of values of DEVIATION that causes the controller output to cover its full operating range.

This is often expressed as a percentage such that 100% PROPORTIONAL BAND means that the full range of outputs of the measuring system causes the controller to operate over its full range.

Adjustment of the percentage of the PROPORTIONAL BAND varies the gain of the controller.

The following experiment will examine the effects of changes in percentage of the PROPORTIONAL BAND and the response of the system to disturbances.

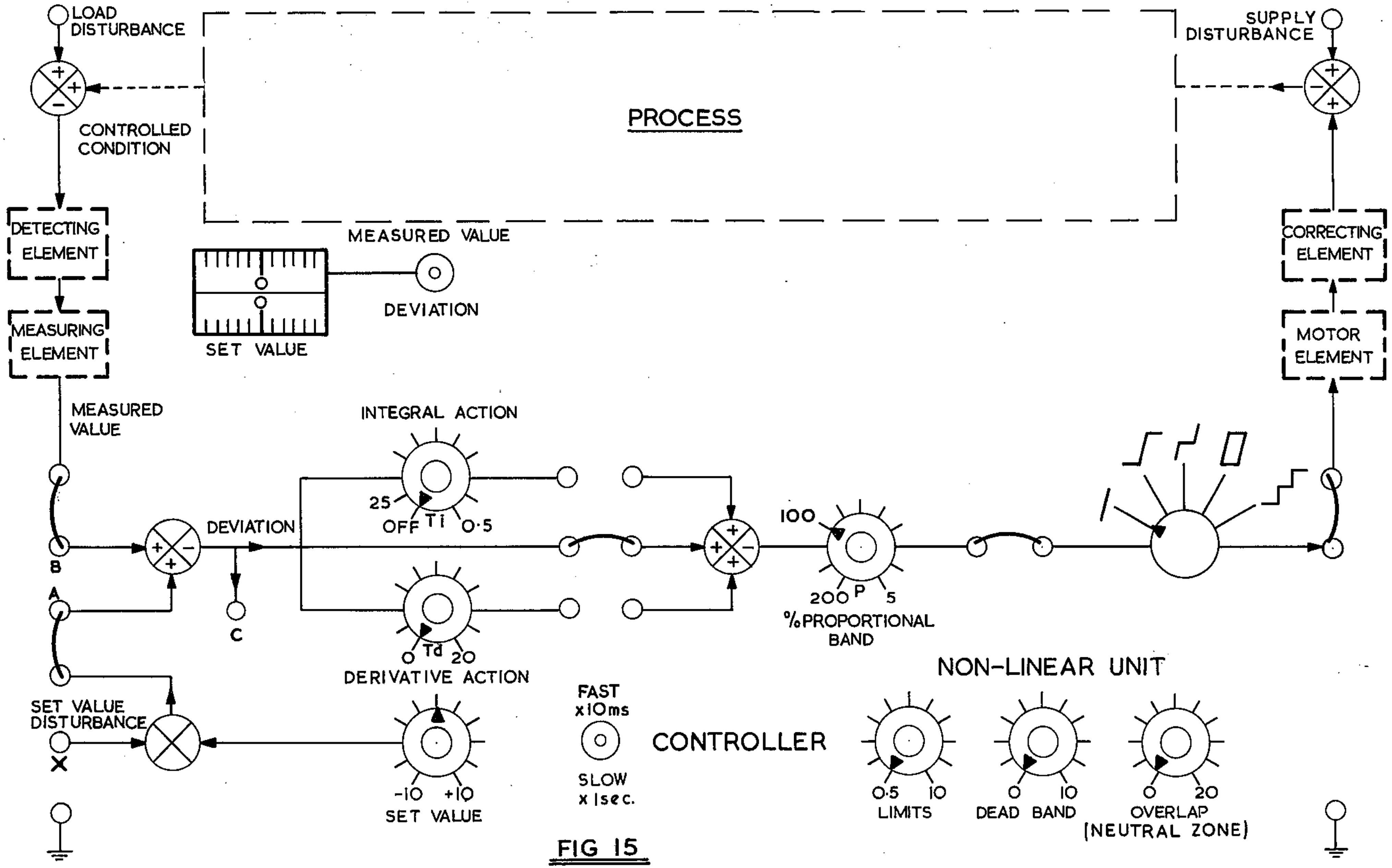

LOAD DISTURBANCE
CONTROLLED CONDITION
PROCESS
SUPPLY DISTURBANCE
DETECTING ELEMENT
MEASURING ELEMENT
MEASURED VALUE
DEVIATION
SET VALUE
CORRECTING ELEMENT
MOTOR ELEMENT
MEASURED VALUE
B
A
C
DEVIATION
INTEGRAL ACTION
25
OFF
Ti
0·5
DERIVATIVE ACTION
0
Td
20
100
200
P
5
%PROPORTIONAL BAND
SET VALUE DISTURBANCE
X
-10
+10
SET VALUE
FAST x10ms
SLOW x1sec.
CONTROLLER
NON-LINEAR UNIT
0·5
10
LIMITS
0
10
DEAD BAND
0
20
OVERLAP (NEUTRAL ZONE)

FIG 15

## EXPERIMENT 4 PROPORTIONAL CONTROL SYSTEM RESPONSE

Patch the front panel of the PCS327 as in fig 15.

Set all controls and switches as indicated.

Inject into the system at point X in fig 15 a square wave signal 5V p-p at 0.05Hz.

As these input disturbances are applied compare the readings of the MEASURED and SET VALUE meters.

Alternatively display on an oscilloscope the SET VALUE from point A in fig 15 and the MEASURED VALUE from point B, with both PROCESS and CONTROLLER switches at FAST, and input signal frequency 1.0Hz.

Switch the meter to DEVIATION or display from point C in fig 15 and note changes in DEVIATION as disturbances are applied. Note final settling points of both MEASURED VALUE and DEVIATION.

Repeat all the above tests with a percentage PROPORTIONAL BAND set at 50 and then 5.

## SUMMARY

As each step is applied the system responds as in fig 16.

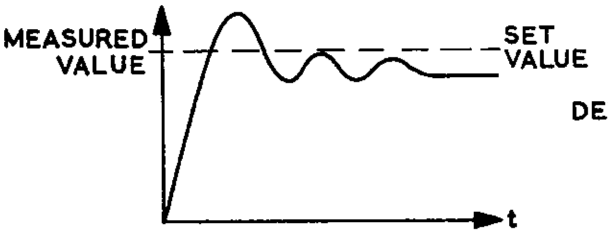


FIG 16

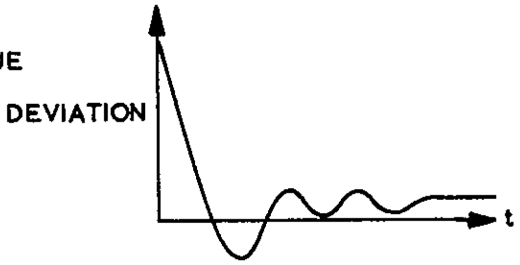


FIG 17

The system moves slowly towards the SET VALUE, overshoots, returns, and after a few oscillations settles so that the MEASURED VALUE is less than the SET VALUE as in fig 16. When it has settled there exists a considerable DEVIATION shown in fig 17. As the percentage PROPORTIONAL BAND is reduced, i.e the gain of the system is increased, the steady state DEVIATION is reduced and the system settles with its MEASURED VALUE much closer to the SET VALUE.

In order to reduce the steady state DEVIATION to zero, however, the gain must be increased to such a value that the system becomes completely unstable.

A compromise gain level must be used which maintains a stable system, but this gives a fairly slow response, a fair amount of overshoot, and a steady state deviation signal.

## 5.12 Integral Control

Experiment 4 has shown that with proportional control to maintain a stable system the gain level is such that the system is insentive to deviations below a certain level.

In an ideal system the MEASURED VALUE and SET VALUE should be the same and under steady state condition the DEVIATION should be zero.

What is required is an alternative signal to be fed into the main amplifier of sufficient size to provide an output if a steady state deviation exists.

Such a signal can be provided by an integrator which gives a constantly increasing output for a steady value input.

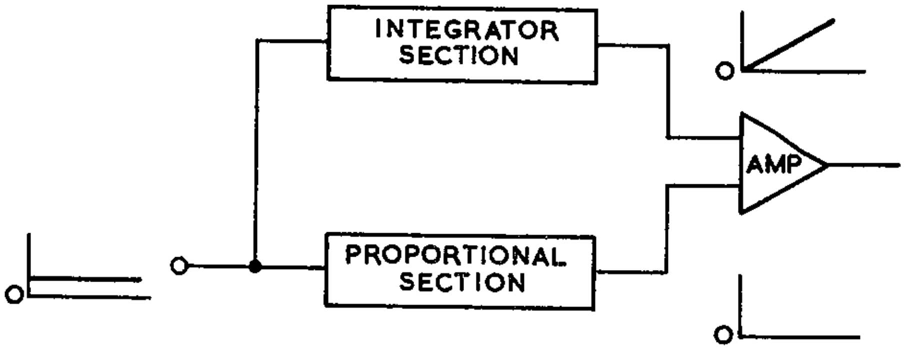


FIG 18

Fig 18 shows a controller arrangement consisting of two sections. The steady state DEVIATION is fed into both sections. The proportional section's sensitivity is such that it will give no output for a signal of this size but the integrators output is slowly increasing. Each output is added in the main amplifier and controls the system.

DEVIATION = MEASURED VALUE - SET VALUE

Although the proportional section has ceased to give an output the integrator has not, so the controller will bring the MEASURED VALUE up to the SET VALUE and the DEVIATION should fall to zero. At this time the integrator output will remain constant.

Such an arrangement is known as a PROPORTIONAL + INTEGRAL CONTROLLER and should reduce any steady state DEVIATION to zero.

Patch the front panel of the PCS327 as in fig 19.

Set all switches and controls as indicated.

Apply to the SET VALUE DISTURBANCE socket a square wave of 5V p-p at 1.0Hz.

Adjust the proportional band control to 50 or until the system settles with about four overshoots only after each disturbance. Continuous oscillation should commence at a value of about 12.

Monitor DEVIATION socket A in fig 19 and slowly reduce the setting on INTEGRAL ACTION control until DEVIATION falls to zero after each disturbance. Note the number of overshoots before it settles. Note the output of the integrator socket B in fig 19 when system has settled.

Note the difference between MEASURED and SET VALUES.

Reduce INTEGRAL ACTION control to 10 and note the responses of system.

## SUMMARY

By suitable adjustment of the integrator section output the steady state DEVIATION can be reduced to zero. In consequence the MEASURED VALUE becomes much closer to the SET VALUE.

Too much integral term however causes the system to go into oscillation.

Generally speaking an increase in the integral term reduces steady state deviation but increases the time the system takes to settle.

## 5.13 Derivative Control

As was seen in Experiment 5 integral control improves the performance of the control system in some respects, i.e reduces steady state DEVIATION, but has the disadvantage of slowing down the overall response time.

If a system was required to follow a sudden change in SET VALUE this would give rise to a rapid change in the DEVIATION.

Although this deviation change is rapid the system responds rather slowly, so if at this time the controller output could be boosted the speed of system response should be improved.

If the deviation was differentiated, i.e its rate of change measured, and a signal produced proportional to this and then added to the signals from the proportional and integrator sections, some improvement should result.

Such an arrangement is shown in fig 20 and is known as a THREE-TERM CONTROLLER.

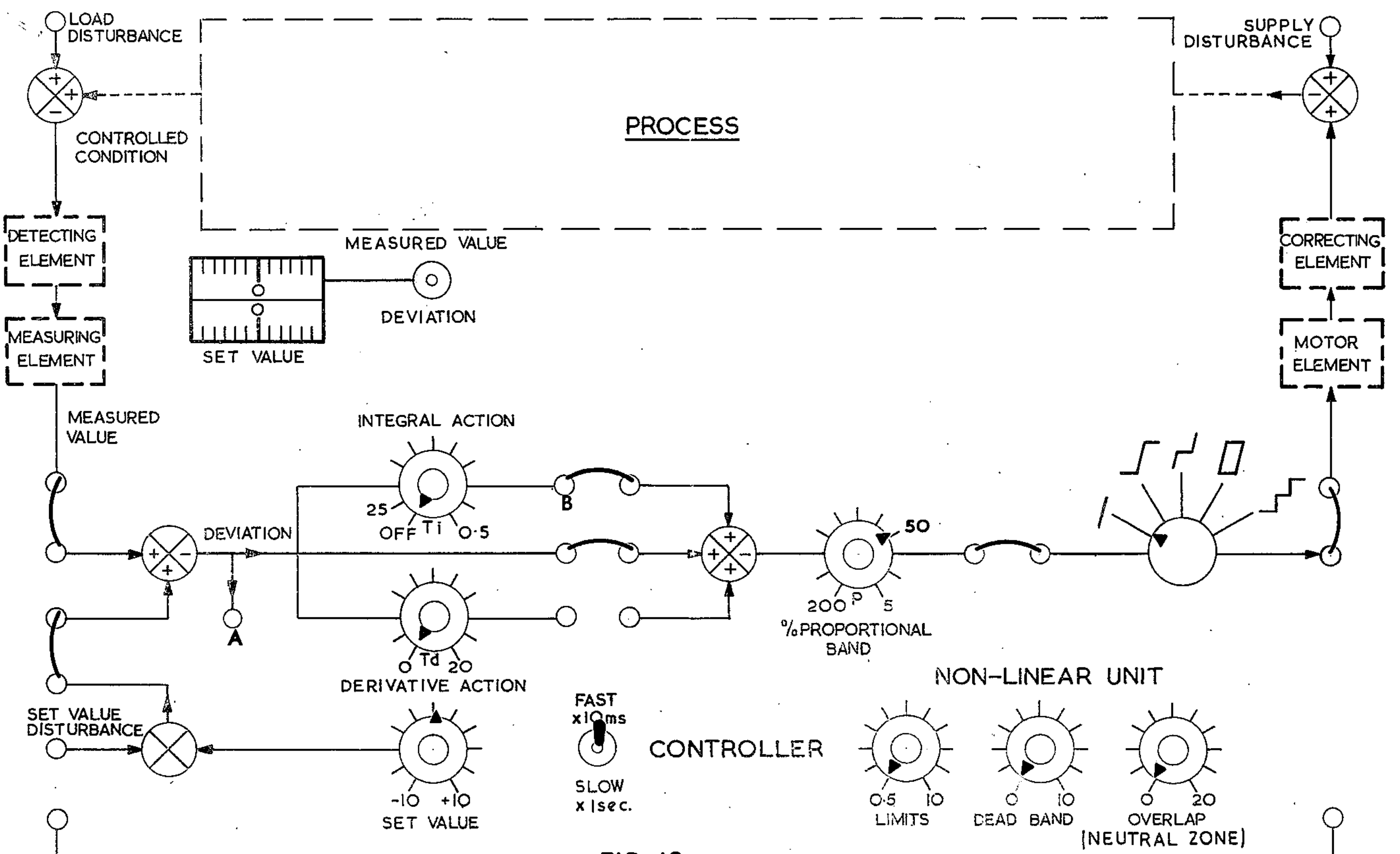

LOAD DISTURBANCE
CONTROLLED CONDITION
PROCESS
SUPPLY DISTURBANCE
DETECTING ELEMENT
MEASURING ELEMENT
MEASURED VALUE
DEVIATION
SET VALUE
CORRECTING ELEMENT
MOTOR ELEMENT
MEASURED VALUE
INTEGRAL ACTION
25
OFF
Ti
0·5
B
DEVIATION
A
0
Td
20
DERIVATIVE ACTION
200
P
5
50
%PROPORTIONAL BAND
NON-LINEAR UNIT
SET VALUE DISTURBANCE
-10
+10
SET VALUE
FAST x10ms
SLOW x1sec.
CONTROLLER
0·5
10
LIMITS
0
10
DEAD BAND
0
20
OVERLAP (NEUTRAL ZONE)

FIG 19

## EXPERIMENT 6 PROPORTIONAL + INTEGRAL + DERIVATIVE CONTROL

Patch the front panel of the PCS327 as in fig 21.

Set all switches and controls as indicated.

Apply to the SET VALUE DISTURBANCE socket a square wave input of 5V p-p at 1.0Hz. Adjust INTEGRAL ACTION until steady state deviation is zero.

After a disturbance note the steady state deviation and number of overshoots before the system settles.

Slowly increase the DERIVATIVE ACTION control and note the effect this has upon the system response. Also check if this has any effect upon the steady state DEVIATION.

### SUMMARY

Application of the DERIVATIVE TERM does not have any effect upon the steady state deviation but does reduce the settling time by reducing the number of oscillations.

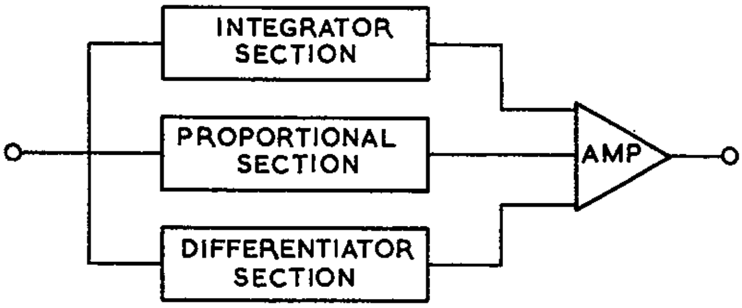


FIG 20

## EXPERIMENT 7 ADJUSTMENT OF 3-TERM CONTROLLER

Use the same circuit arrangement as for Experiment 6. Set the INTEGRAL ACTION TIME and DERIVATIVE ACTION TIME to OFF and 0 respectively with percentage PROPORTIONAL BAND 100%

Apply step input disturbance as before and adjust INTEGRAL ACTION TIME until steady state DEVIATION is zero.

Increase the DERIVATIVE ACTION until the MEASURED VALUE shows no signs of oscillation. Reduce the percentage PROPORTIONAL BAND until the best response of MEASURED VALUE can be obtained giving minimum overshoot and oscillation.

NOTE.

There are many combinations of the integral and derivative term settings which will give a stable control system, In practice there are methods of predicting the best settings for a particular system but these methods are beyond the scope of this section of the handbook. For the student wishing to know more about predicting the controller settings an alternative experiment is given in the appendix at the end of this book.

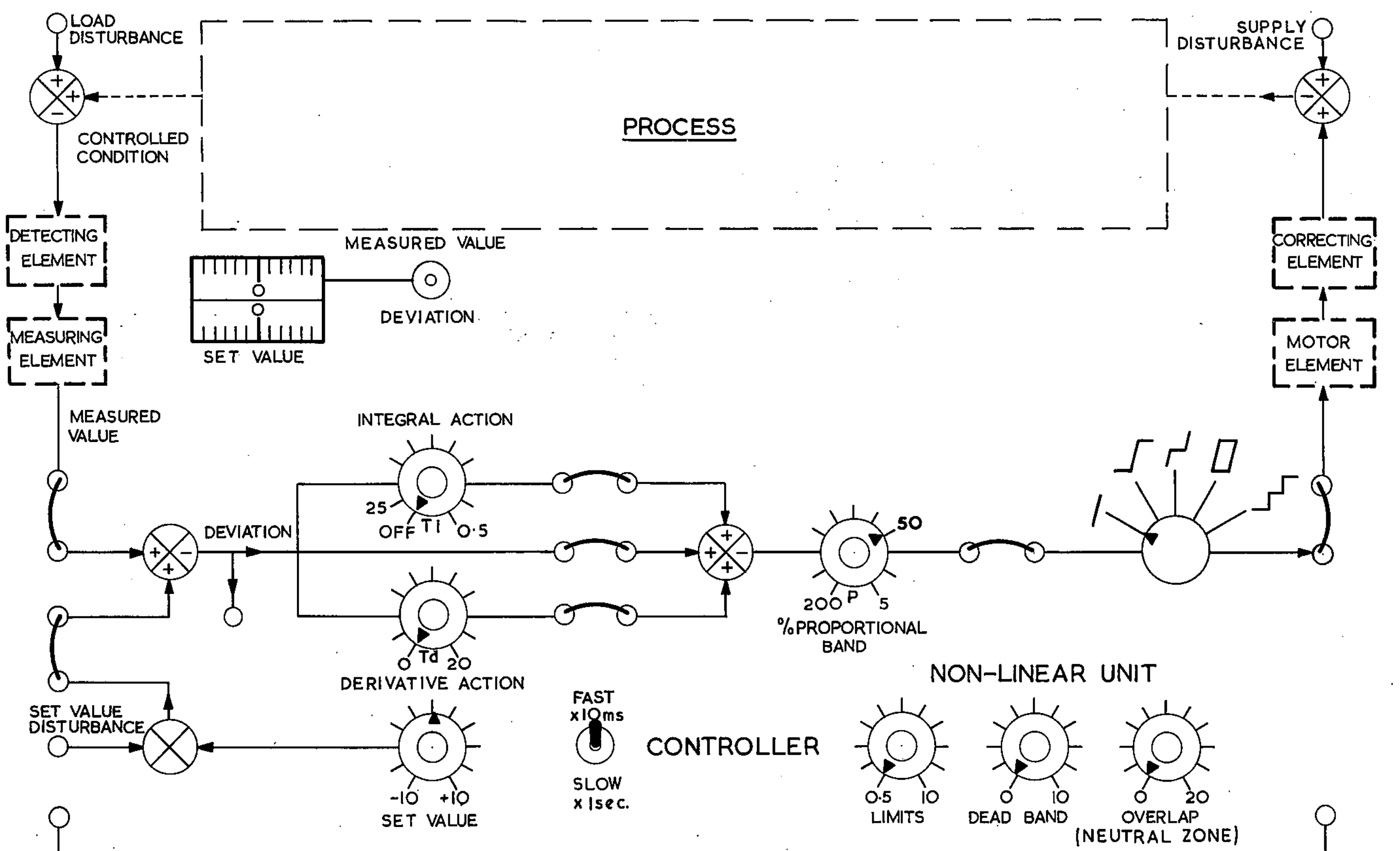

LOAD DISTURBANCE
PROCESS
SUPPLY DISTURBANCE
CONTROLLED CONDITION
DETECTING ELEMENT
MEASURING ELEMENT
MEASURED VALUE
0
0
SET VALUE
MEASURED VALUE
DEVIATION
CORRECTING ELEMENT
MOTOR ELEMENT
INTEGRAL ACTION
25
OFF
Ti
0·5
DEVIATION
50
200
P
5
% PROPORTIONAL BAND
0
Td
20
DERIVATIVE ACTION
SET VALUE DISTURBANCE
-10
+10
SET VALUE
FAST x10ms
SLOW x1sec.
CONTROLLER
NON-LINEAR UNIT
0·5
10
LIMITS
0
10
DEAD BAND
0
20
OVERLAP (NEUTRAL ZONE)

FIG 21

## 5.14 Effect of Limits of Proportional Control

### EXPERIMENT 8

In this experiment limits are placed upon the maximum level of output available from the controller section of the system and the effect upon the overall control is examined.

Patch the front panel of the PCS327 as in fig 22.

Set all controls and switches as indicated.

Apply a SET VALUE DISTURBANCE signal of 5V p-p square wave at 1.0Hz.

Monitor the MEASURED VALUE and note the variations in system response as the LIMIT control is adjusted throughout its full range.

## 5.15 Effect of Deadband on Proportional Control

### EXPERIMENT 9

If a controller has a DEADBAND this means that the input signals must be above a certain size before any perceptable change in the controller output occurs.

Using the same set up as for the LIMIT experiment 8, set the controller selector switch to .

Monitor the MEASURED VALUE and note the changes in system response as the DEADBAND control is adjusted throughout its full range. Repeat monitoring DEVIATION and repeat again with reducing disturbance signals.

### SUMMARY

Adjustment of the limits determines the actual MEASURED VALUE that can be achieved.

DEADBAND makes the system insensitive to small input disturbances.

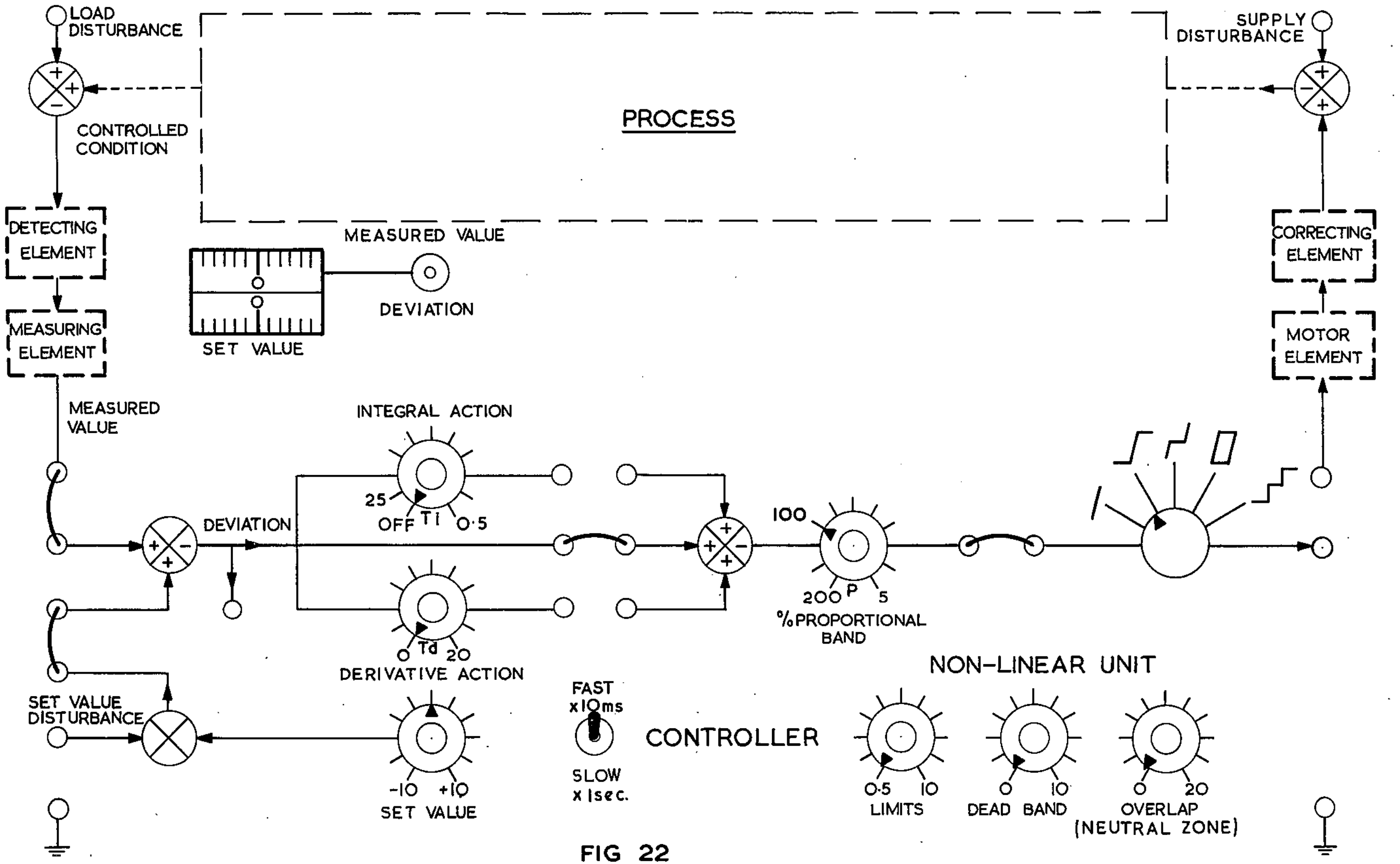

LOAD DISTURBANCE
CONTROLLED CONDITION
PROCESS
SUPPLY DISTURBANCE
DETECTING ELEMENT
MEASURING ELEMENT
MEASURED VALUE
SET VALUE
DEVIATION
CORRECTING ELEMENT
MOTOR ELEMENT
MEASURED VALUE
INTEGRAL ACTION
25
OFF
Ti
0·5
DEVIATION
100
200
P
5
% PROPORTIONAL BAND
0
Td
20
DERIVATIVE ACTION
SET VALUE DISTURBANCE
-10
+10
SET VALUE
FAST x10ms
SLOW x1sec.
CONTROLLER
NON-LINEAR UNIT
0·5
10
LIMITS
0
10
DEAD BAND
0
20
OVERLAP (NEUTRAL ZONE)

FIG 22

## 5.16 Two-Step Control Systems

The systems so far considered have been of the continuous type, i.e. controllers whose outputs are proportional to the DEVIATION signals at their inputs.

Some controllers are of such a design that their outputs can only be particular predetermined values, the simplest being ON and OFF.

Consider, for example, a domestic hot water system controlled by a thermostat, in this case power is either supplied to the heater or it is switched off.

Assume such a system has a thermostat set so that the switch OFF and ON points are very close together; the controller will give full output until the MEASURED VALUE reaches the level required when it will switch OFF. There will then be some very small time interval as the temperature falls and the controller will switch ON and OFF rapidly and the water temperature will hunt about a value just below the SET VALUE as in fig 23.

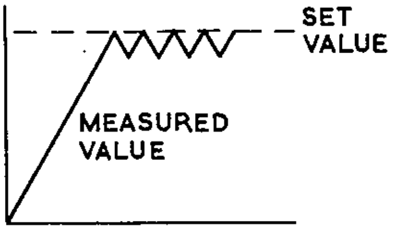


FIG 23

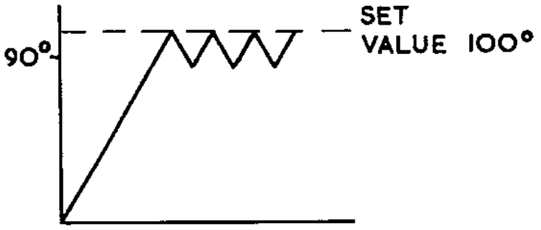


FIG 24

Such a system would cause considerable wear and tear on the controller and it is usual to allow the water temperature to fall a few degrees before the controller is switched ON again.

Fig 24 shows the response of such a system where the difference between switch ON and OFF points is 10°.

The mean value of the temperature is considerably less than in the previous example and the temperature variations larger, but the frequency of controller switching is very much reduced.

The difference between the ON and OFF points in this system is known as OVERLAP.

Fig 24 shows the response of a system giving a mean temperature of 95°, i.e. the DESIRED VALUE is 95°, the SET VALUE is 100°, and the MEASURED VALUE varies between 90° and 100°.

## EXPERIMENT 10

## TWO-STEP CONTROL

To examine the operation of a simulated thermostat-controlled water heating system patch the front panel of the PCS327 as in fig 25.

Set all switches and controls as indicated.

Display the MEASURED VALUE on an oscilloscope.

Adjust the SET VALUE control through its full range and note the changes in response.

Repeat with various settings of OVERLAP and again with various settings of LIMITS.

## SUMMARY

With maximum limit setting and no overlap the system is always oscillatory, but the output mean level can be changed.

Overlap causes a larger amplitude variation but lower frequency oscillation.

## QUESTIONS

Why does adjustment of the limits stop the oscillation?

Why under some conditions of set value does the overlap control stop the oscillations?

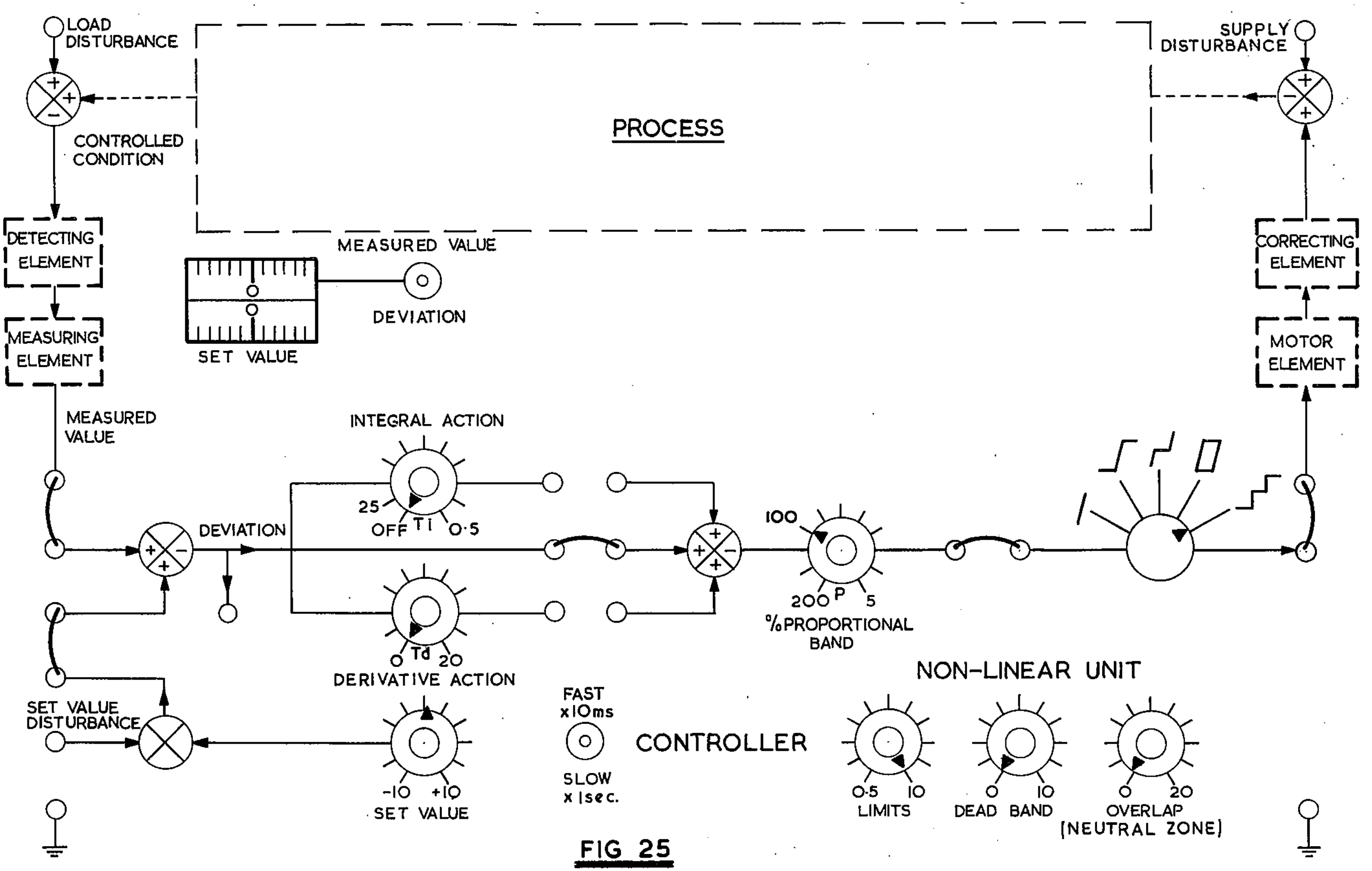

LOAD DISTURBANCE
+
+
−
CONTROLLED CONDITION
PROCESS
SUPPLY DISTURBANCE
+
−
+
DETECTING ELEMENT
MEASURING ELEMENT
MEASURED VALUE
SET VALUE
MEASURED VALUE
DEVIATION
CORRECTING ELEMENT
MOTOR ELEMENT
INTEGRAL ACTION
25
OFF
Ti
0·5
DEVIATION
+
−
+
+
+
−
+
100
200
P
5
%PROPORTIONAL BAND
0
Td
20
DERIVATIVE ACTION
SET VALUE DISTURBANCE
-10
+10
SET VALUE
FAST x10ms
SLOW x1sec.
CONTROLLER
NON-LINEAR UNIT
0·5
10
LIMITS
0
10
DEAD BAND
0
20
OVERLAP (NEUTRAL ZONE)

FIG 25

## 5.17 Three Step Control

Consider a process control system where one of the controlled functions is flow rate through a pipeline. This might well be performed by a motorised valve operated by a controller with three possible outputs ON in one direction, zero, and ON in reverse.

If a demand for a particular valve position was made by the SET VALUE control the motor would drive to reduce the DEVIATION, i.e difference between SET VALUE and MEASURED VALUE, to zero.

When the DEVIATION reached zero the controller would switch OFF and the motor come to rest. In such a system the motor is certain to overshoot the desired position, the DEVIATION would reverse, and the motor valve would oscillate.

Such a condition would be unacceptable but this problem could be overcome by introducing DEADBAND into the system.

This means making the controller insensitive to DEVIATIONS below a particular size.

In these conditions the motor will run to set the valve in position and when the DEVIATION falls below the level set by the DEADBAND, will switch off. The motor will coast to rest and even though the DEVIATION may change sign, the controller will not respond to it. The accuracy of control is reduced as the final settling position of the valve is an arbitrary point within the DEADBAND, but the system is stable.

It is frequently the case that the motor is operated by relays which have an inherent overlap, i.e the relay drops out at a different operating current level than that required to pull it in. This has the effect of reducing the deadband and can cause a system to go unstable.

### EXPERIMENT 11 THREE-STEP CONTROL SYSTEM

Patch the front panel of the PCS327 as in fig 26.

Set all switches and controls as indicated.

Display as oscilloscope MEASURED VALUE which should be oscillatory.

Adjust the DEADBAND until oscillations cease.

Move the SET VALUE control though its complete range and note the MEASURED VALUE response.

Note the effect upon MEASURED VALUE of increase in OVERLAP setting.

### SUMMARY

Introduction of DEADBAND will stabilize the system and it will remain stable for any SET VALUE.

If OVERLAP is also present this can have the effect of reducing the effective DEADBAND to a value that causes instability.

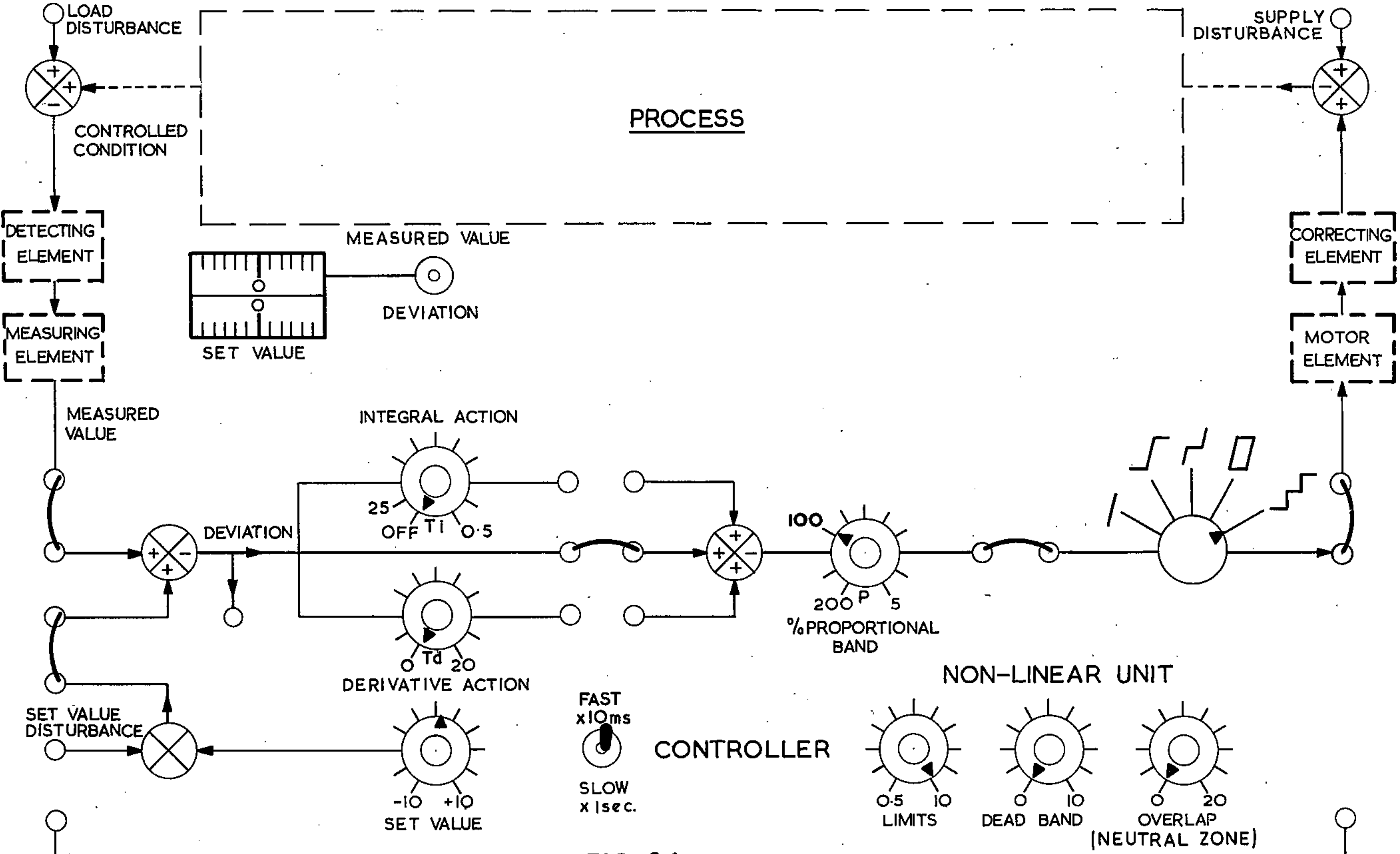

LOAD DISTURBANCE
PROCESS
SUPPLY DISTURBANCE
CONTROLLED CONDITION
DETECTING ELEMENT
MEASURING ELEMENT
CORRECTING ELEMENT
MOTOR ELEMENT
MEASURED VALUE
DEVIATION
SET VALUE
MEASURED VALUE
INTEGRAL ACTION
25
OFF
Ti
0·5
DEVIATION
100
200
P
5
% PROPORTIONAL BAND
O
Td
20
DERIVATIVE ACTION
SET VALUE DISTURBANCE
-10
+10
SET VALUE
FAST x10ms
SLOW x1sec.
CONTROLLER
NON-LINEAR UNIT
0·5
10
LIMITS
0
10
DEAD BAND
0
20
OVERLAP (NEUTRAL ZONE)

FIG 26

# CIRCUIT DESCRIPTION AND MAINTENANCE — SECTION 6

## 6.1 Circuit Description

Amplifier Module Drwg. No. 4-327-5081 Each module contains a pair of identical circuits. The integrated circuit operational amplifier IC1 or 2 is supplied with a zero setting current from preset potentiometer R1 or 2 via resistor R3 or 4. C2 and R5 (C3 and R6) are compensating components as is C4 (C6). The power lines are each decoupled to ground (C1 and C5).

All computing components are mounted externally to the module.

Main Board - Drwg. No. 3-327-5080 The circuit follows almost exactly the front panel layout and the amplifiers are used in conventional computing arrangements. The only points of particular interest concern the integral term amplifier 4 and the distance-velocity lag amplifier 16. Switch S6 is arranged to close when potentiometer R27 is fully counter-clockwise so that the integrator will produce zero output without actually being uncoupled. It also serves the purpose of clearing the integrator capacitor when making open-loop frequency response measurements.

The network associated with amplifier 16 is designed to give a phase shift approximately proportional to frequency over a sufficient range to simulate with reasonable accuracy a distance-velocity lag.

Non-Linear Unit- Drwg. No.3-327-5079 Two main non-linear circuits producing limits and deadband, together with an integrator 10 and inverter 11 are connected in various ways to produce the desired range of non-linearities.

Amplifier 8 acts as a linear inverter of gain -1 until the output voltage is sufficiently positive or negative that diodes D2 or D1 respectively are able to conduct. The bias potentials on these diodes are set by ganged potentiometers R63 and R62 respectively. When the diodes conduct the gain falls to not more than

Amplifier 9 produced deadband; while the input via R66 lies between the potentials set by ganged potentiometers R71 and R72, all four diodes D3, 4, 5 and 6 conduct so that the overall gain is very low. If the input becomes more positive than the potential set by R71, D3 cuts off. Any excess positive current into R66 now flows via D4 and R69, raising the potential of the junction of D4 and D6, causing D6 to cut off.

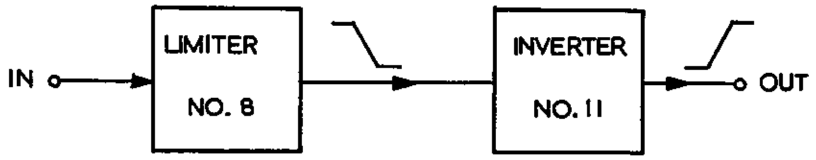
Both diode paths being non-conducting the feedback path is now only via R67 (switched to amplifier output by S6C in position 3) and the gain of the amplifier becomes -1. A similar process occurs for negative inputs.

The various configurations of the four amplifiers are shown in fig 27.

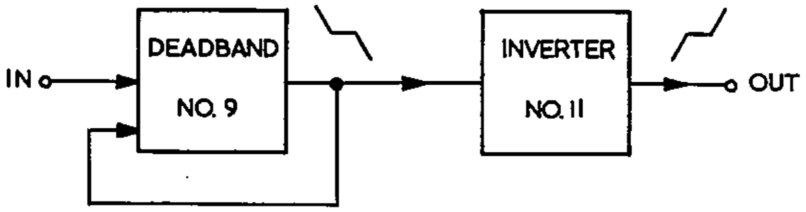
Position 1 gives a straight-through connection.

Position 2 inverts the limiter output to produce the characteristic in correct sense.

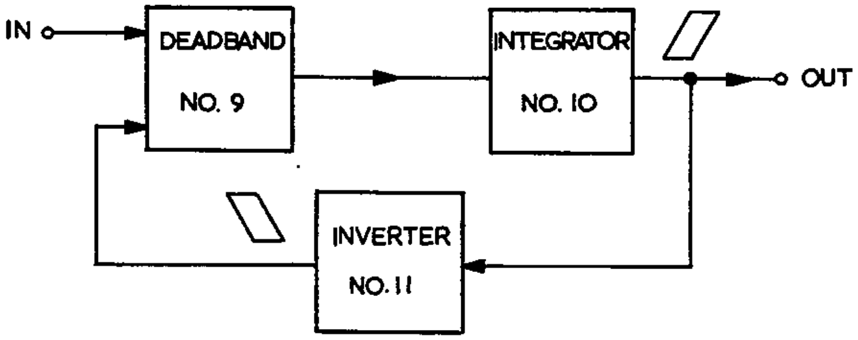
1 LIMITS – POSITION 2



2 DEADBAND – POSITION 3



3 BACKLASH – POSITION 4



4 RELAY – POSITION 5

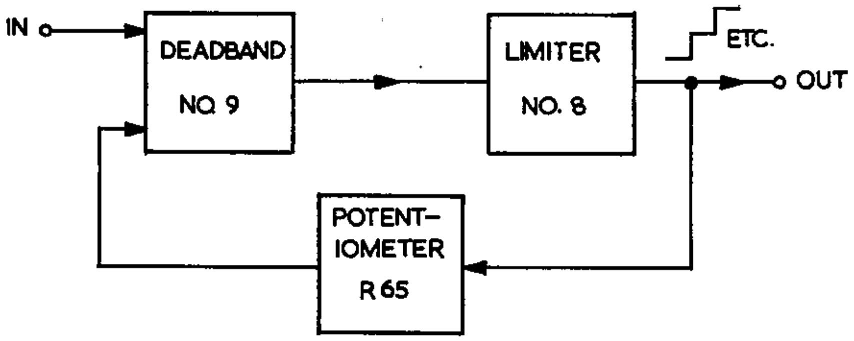


FIG 27 NON-LINEAR UNIT CONFIGURATIONS

Position 3 inverts the deadband characteristic to produce the correct sense; the output of the deadband amplifier feeds back to the second input (R67) as explained above.

In Position 4 the second input to the deadband unit is the integral of its output (via the inverter to achieve the correct sense of negative feedback). Once the input reaches the deadband threshold any further increase causes a small output, which is integrated and fed back negatively so as to maintain the amplifier output just above the threshold. When the input reverses the deadband output becomes zero and the integrator output holds, providing a steady offset at the second input to the deadband unit. When the input has gone sufficiently in the reverse direction to overcome this offset the integrator starts to integrate in the opposite sense and so on. The frequency range of the circuit is limited at high frequencies by the reduced integrator gain and at low by its holding characteristics.

In Position 5 the second input to the deadband unit is positive feedback via a potentiometer R65; assume the limiter is set to ±10 and the deadband to zero. When the input goes slightly positive the limiter output goes positive also - its output, fed back to the second input, accentuates the change and a cumulative switch occurs to +10 output. When the input goes negative again no change will occur until it is equal and opposite to the positive voltage at the second input, an amount which is set by the overlap control R65. An exactly similar process occurs in the reverse direction.

If the limits are reduced this has an effect similar to that of reducing the overlap setting so that the limit and overlap controls are to this extent interacting. The deadband control, however, is independent.

Power Supply Drwg. No. 4-327- 5082 Two identical circuits generate ±15V at 100mA. For the positive line TR1 and TR2 are the series current controllers fed from amplifier TR3. The reference is provided by zener diode D9. No voltage adjustment is provided.

## 6.2 Maintenance

Routine maintenance will involve only replacement of mains fuse or indicator lamp and periodic adjustment of amplifier zeros.

Access to all preset controls and to the mains fuse etc is obtained by removal of the front panel complete with its printed circuit board.

Certain connections and settings on the front panel are necessary in some cases to provide the correct conditions for zero setting. The meter used should be centre-zero of about 1V fsd and resistance not less than 10k ohm; it is connected from the output pin of the amplifier to ground.

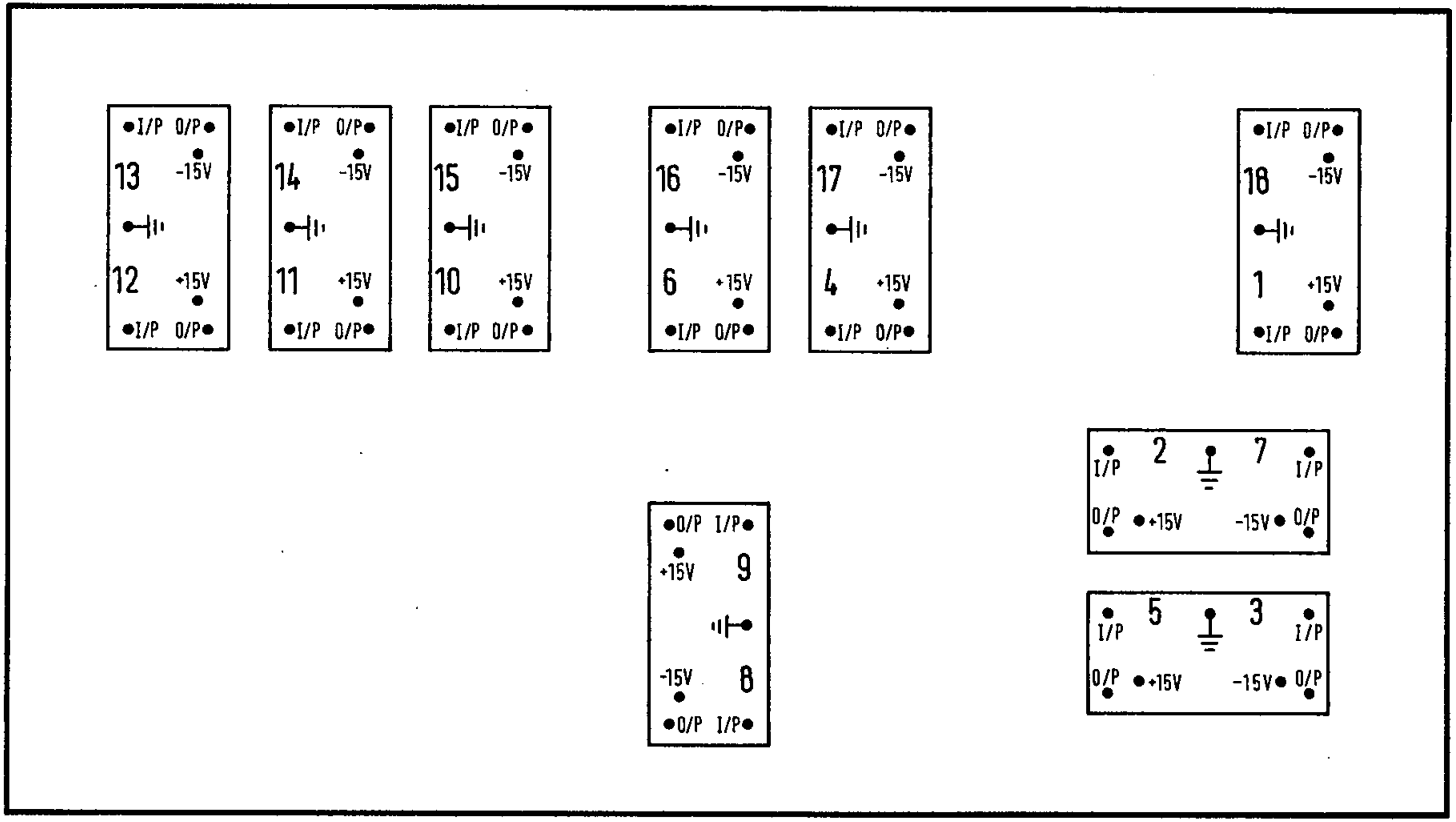
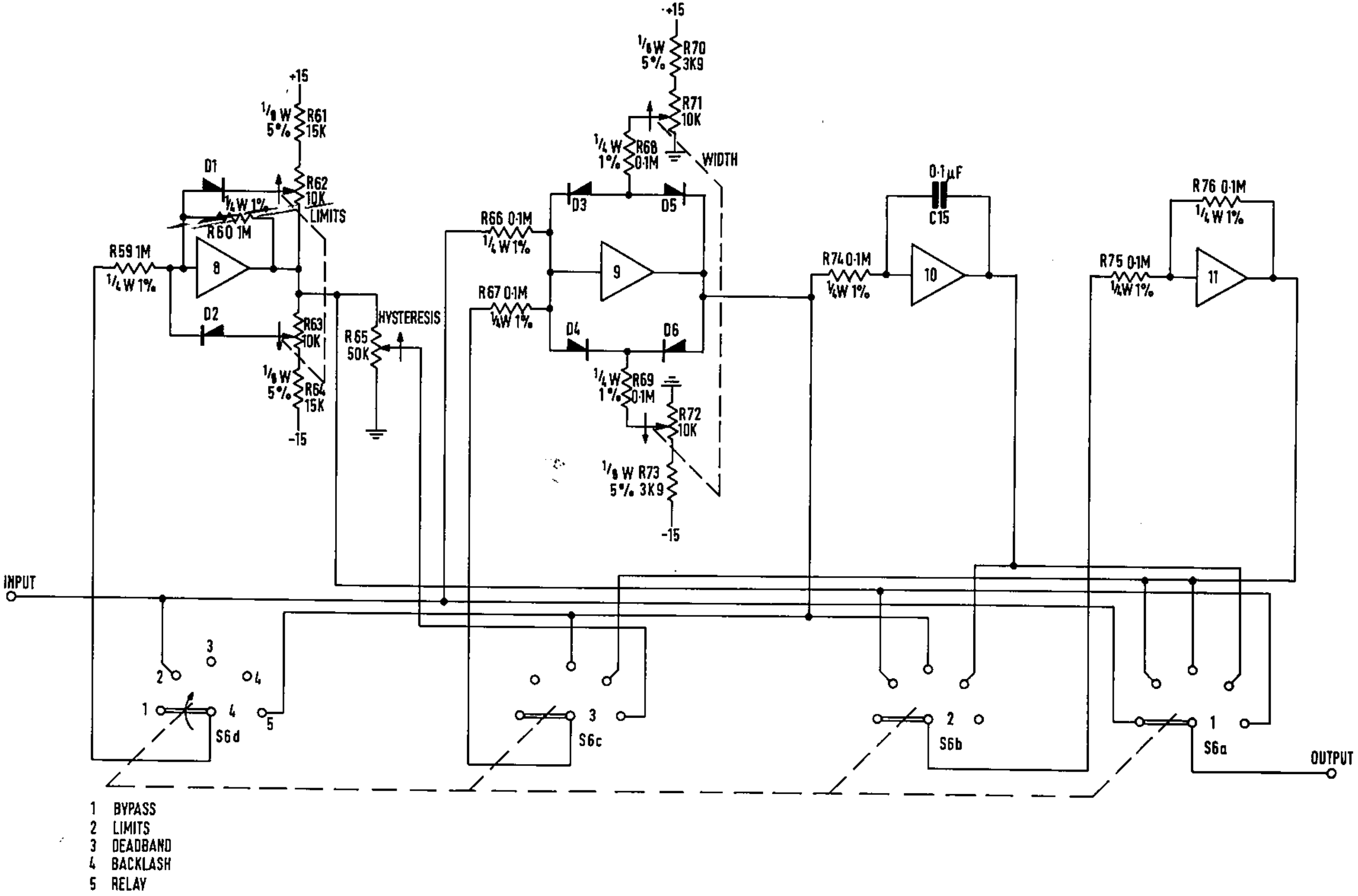


FIGURE 28

Fig28 shows the positions of the various amplifiers and their output pins when looking at the back of the front panel, and the table shows the settings etc required for each amplifier. Zeroing is achieved by a small screwdriver. Commence by removing all patch leads from the panel and set the zeros in the order shown, with both process and controller switches at slow.

| AMPLIFIER NO. | CONTROL SETTINGS, IF ANY |
|---|---|
| 1 | ----- |
| 4 | 'Integral action' to 25 - set for zero drift |
| 2 | 'Integral action' OFF |
| 3 | 'Derivative action' to zero |
| 5 | ----- |
| 6 | 'Proportional band' fully clockwise |
| 7 | 'Set value' to mid-scale (zero) |
| 12 | ----- |
| 13, 14 | Select 'lag' on lag integrate switch |
| 15, 16, 17, 18 | ----- |
| 8 | Select 'limits' and set 'limit' control fully clockwise |
| 9 | Select 'deadband' and set deadband control fully counter-clockwise |
| 10 | Select 'deadband' and adjust for zero drift rate. |
| 11 | Select 'relay' or 'linear' |



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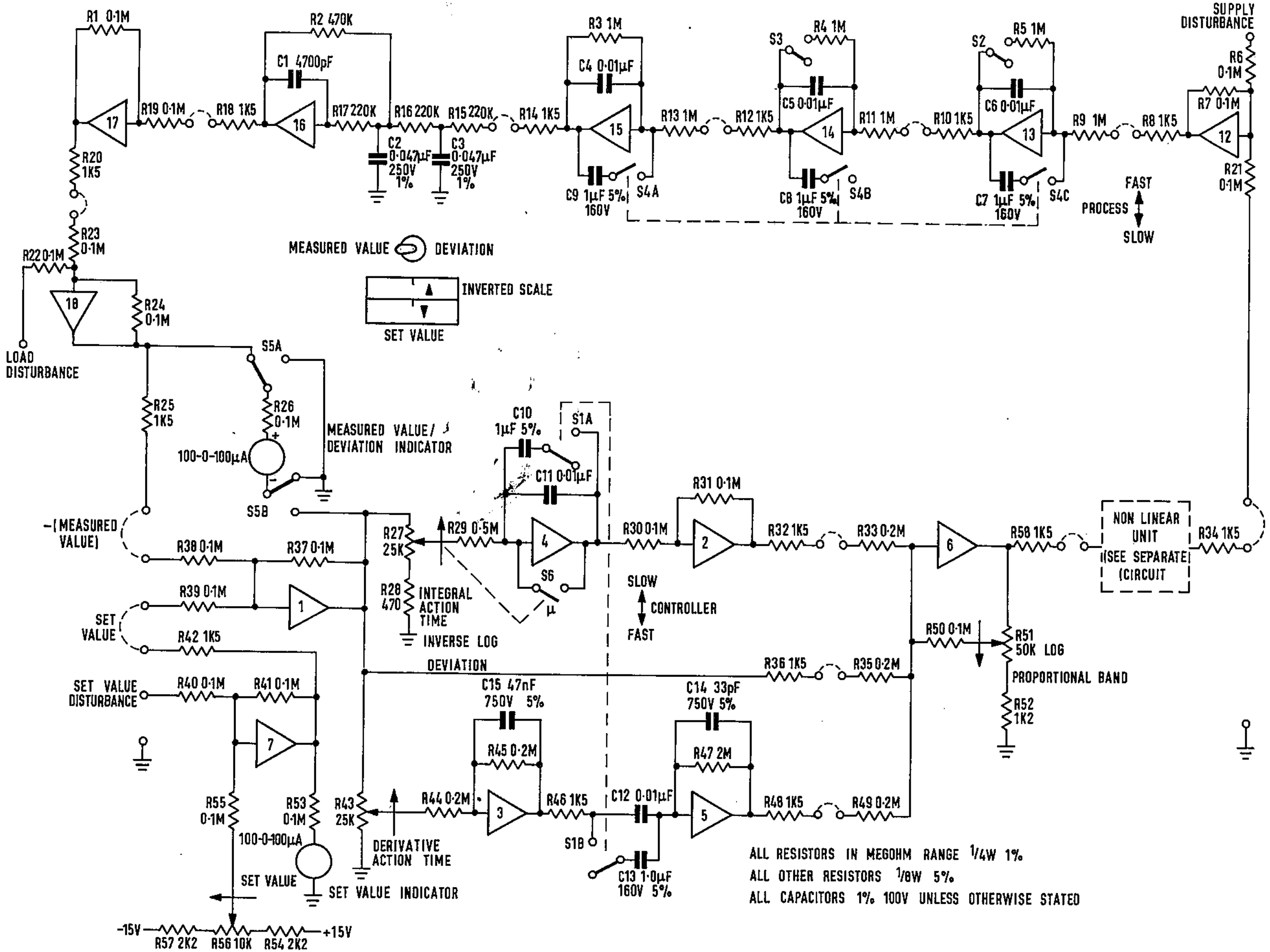
PCS327 NON-LINEAR UNIT - CIRCUIT DIAGRAM

3-327-5079 ISS. 1



ALL RESISTORS IN MEGOHM RANGE 1/4W 1%
ALL OTHER RESISTORS 1/8W 5%
ALL CAPACITORS 1% 100V UNLESS OTHERWISE STATED

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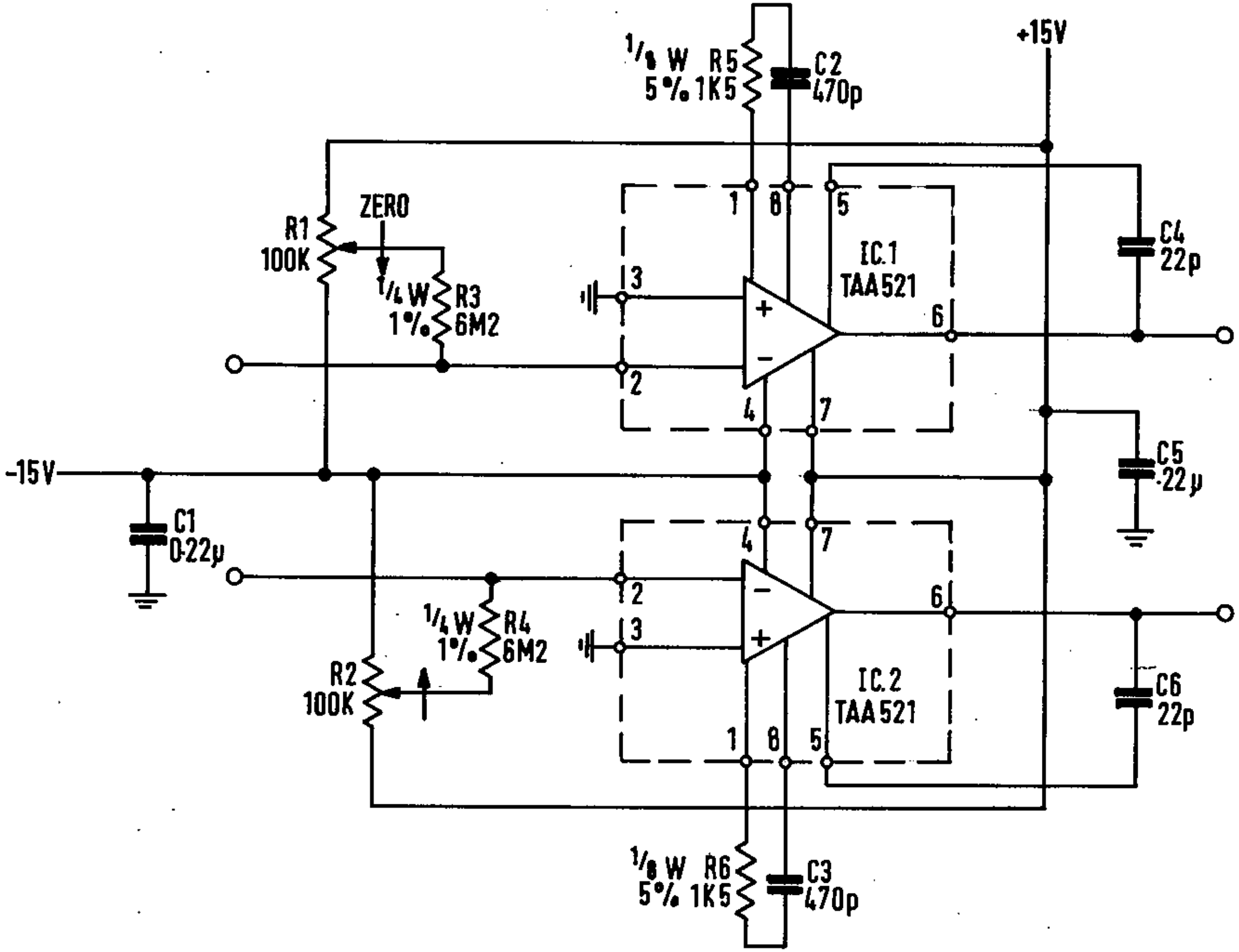
# PCS327 CIRCUIT DIAGRAM

3-327-5060 ISS. 3



FEEDBACK LTD. PT326 & PCS 327 OPERATIONAL AMPLIFIER PAIR-CIRCUIT DIAGRAM 4-326/327-5081 ISS.1