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# SOME DESIGN ASPECTS OF COMPUTER BASED CONTROL SYSTEMS FOR PULSED FUSION EXPERIMENTS

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# SOME DESIGN ASPECTS OF COMPUTER BASED CONTROL SYSTEMS FOR PULSED FUSION EXPERIMENTS

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ABSTRACT

In the design of control systems for pulsed fusion experiments there has been some resistance to the extensive use of integrated electronic circuits because of their low level signalling and susceptibility to damage in the environment of this type of plant.

However, the growing size and complexity of these experiments is forcing consideration of computer-based control systems. It is now recognised that fibre-optic links can be used for the main signalling connections; whereby it is possible to isolate vulnerable electronic units from damaging inputs.

In the design of these systems it is necessary to give careful consideration to the problems of writing appropriate software and to the development of suitable equipment for interfacing between the computer and the plant components.

(Paper presented at 7th Symp. on Engineering Problems in Fusion Research, Knoxville, Tennessee, USA, 25 - 28 October 1977).

January 1978

## Introduction

1. Pulsed fusion experiments usually take the form of a number of capacitor banks coupled to a multi-winding transformer. The energy in the capacitors is used to form, confine and heat the plasma which constitutes the secondary winding and the load of the transformer. The operation of the experiment consists of repeated cycles of events (shots) - dominated by charging the capacitors (generally over about one minute) and discharging them in a precise and predetermined sequence over periods ranging from fractions to a few tens of milli-seconds. Typically, the capacitors are charged to potentials of 10 - 40 kV and discharge currents frequently exceed 1 MA. Thus, in the design of the control and instrumentation schemes for these experiments considerable care must be exercised to ensure the safety of the plant operators and to eliminate problems arising from induction and earth loops in the control system wiring.

2. Traditionally, the designers of these machines have resisted the use of integrated electronic circuits because of their low level signalling and susceptibility to damage in the electrically noisy environment of these experiments. Nevertheless, modern electronics have been introduced to cope with the volume of data arising from plasma diagnostic equipment. There is now a need to introduce computer based control systems to cater for the growing size and complexity of these plants and to integrate machine configuration and performance data with the experimental data.

## Design Concepts

3. The main requirements for the control and instrumentation of a pulsed plasma experiment are shown in Fig 1 - which refers specifically to the proposed Reversed Field Pinch Experiment (RFX) at Culham Laboratory.[1] This diagram illustrates the need for three interleaved circuits subtending from a central control station: viz

(1) The plant control system which is concerned with the functional command of the plant components.

(2) The safety system which is aimed mainly at controlling the access of personnel to dangerous areas of the plant.

(3) The timing circuit which transmits a sequence of labelled timing pulses for the precise timing of events within the plant.[2]

4 The intention, in this paper, is to concentrate upon aspects of the plant control system.

## Electrical Considerations

5. In general there is a need to divide the plant into systems (or areas) and sub-systems so that it is possible to operate sections, independently from others, during commissioning, maintenance and fault finding. This requirement leads to the concept of a hierarchy of control rising from Local, to System (or Area) to Central control as shown in Fig 1. This type of system is commonly accepted practice although it is not always easy to distinguish clearly the various levels because of the large number of interconnections.

6. The present day ability to implement a hierarchical control system using a range of computers of differing capabilities makes it possible to multiplex a large number of signals onto a few interconnectors for passing information between sections of the plant.

7. The economics of signal multiplexing and 'bit serial' transmission of plant data permit the introduction of fibre-optic interconnections; whereby it is possible to isolate vulnerable electronic units from damaging inputs and also to eliminate dangers arising from inadvertent high voltages on signal cables. A further advantage arises from the consequent concentration of system complexities onto printed circuit cards, located at system nodes, which are easy to test and to replace in the event of failure.

## Operational Considerations

8. In operation it is desirable that the experimental physicists and the plant operators are in close proximity to one another so that they can work closely together to achieve the experimental aims. This means that the central control console should fit into a diagnostic area as unobtrusively as possible. This presents a difficult problem because:

(a) It should be possible for an operator, sitting at the console, to operate every section of the plant so as to avoid, as much as possible, the time consuming activities of visiting local control panels for monitoring and/or adjusting functions - particularly if they involve the strict formality of gaining access to some parts of the plant.

(b) In the design of fusion experiments considerable flexibility must be incorporated to allow the

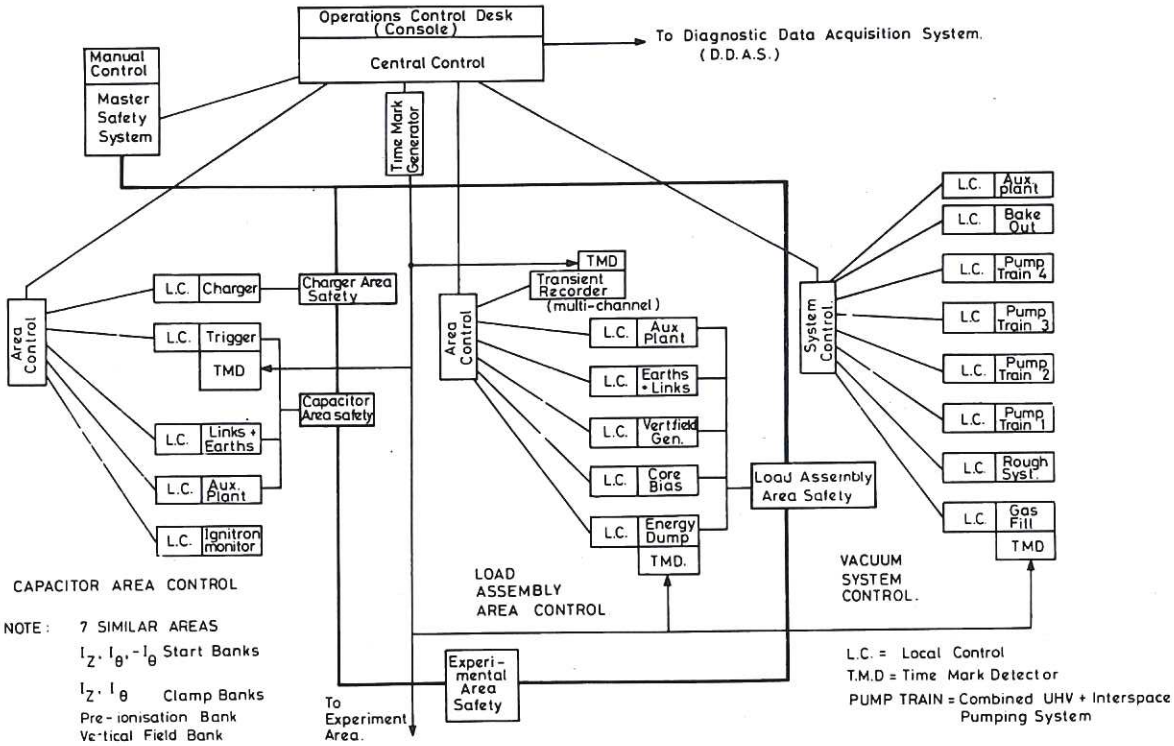


**Fig.1 Outline design of R.F.X. machine control system.**

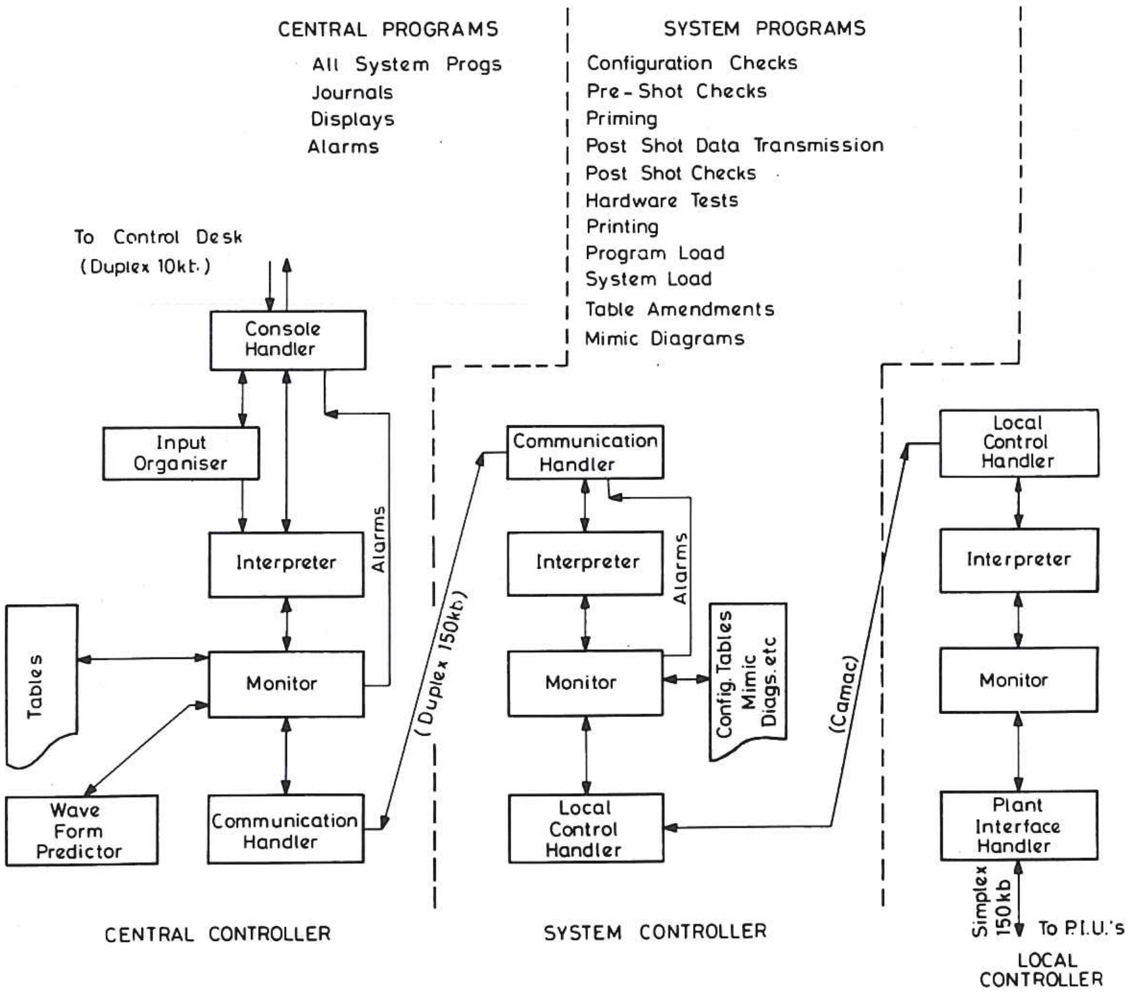


**Fig.2 Organisation of software for R.F.X.**

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configuration of the plant to be altered by the re-allocation of resources to its various sections, so that plasma forming, confining and heating parameters can be varied over significant ranges. Also in the make-up of the plant there is often a large number of components, such as heavy duty switches, which should be monitored both to diagnose incipient failure and to gather statistical data toward future designs. Thus, in these plants there is a large amount of data which is not concerned in the operation of the plant, but which should be available, on demand to the plant operator(s).

9. It is possible to compress the requirements outlined in paras. 8 (a) and 8 (b) into the confines of a reasonable sized console using colour video monitors and an assignable keyboard connected to a standard communications multiplexor in the central control computer. This solution requires the recognition that control information (other than alarms) does not have to be displayed continuously but it must be readily available on request.

10. It has been amply demonstrated in the control of large process plants and high energy accelerators that colour video monitors can present control information such as mimic diagrams, alarms and measured values in a clear and very easily perceived way.[3, 4] It is difficult to conceive of an economic alternative to the low cost and ready availability of highly developed colour video monitors for interfacing between plant operators and computer based control systems.

Software Considerations

11. The implementation of a multi-level computer-based control system is critically dependent upon the design of its software because the advantages of the system can be obtained only with the aid of effectively written programmes.

12. The conceptual organisation of the controllers for RFX is shown in Fig 2. This diagram illustrates the three aspects which must exist at each control level viz

(a) The handlers of the communications network

(b) The autonomous monitoring functions

(c) The instruction interpreters

In addition there is the need to organise the interactions with the control console and to provide facilities for additional functions such as predicting the machine performance (e.g. waveforms) based upon the current plant configuration.

13. The existence of the Communications Handlers, Monitors and Interpreters at each level is dictated by the need to provide 'stand-alone' capability for commissioning, maintenance and fault finding. Thus it should be possible to substitute a simple mobile controller for any communications link and operate the associated plant in isolation.

14. Clearly, the communications network will need to be very reliable, but the techniques need not be discussed here because the topic is covered extensively in the literature.

15. The main Monitor functions can be listed as follows:

(a) To scan all of the plant functions under its control

(b) To operate, to send alarms to higher levels or to take corrective action as specified by the logic in its configuration tables

(c) To supply, on request, a copy of the current mimic diagram for its associated plant

(d) To validate requests for changes in the state of the system under its control - thereby acting as a first line of defence against spurious control signals or inappropriate commands

(e) To supply, on request, information about the system under its control - e.g meter readings etc.

16. The interpreters will be based upon one of the interpretive computer languages such as BASIC[5], FOCAL[6] and therefore could be very similar to NODAL.[7] In deciding to use interpreters the main objective was the provision of a capability for the easy implementation of new (or changing) operational procedures. However in normal circumstances, the intention is to hide the interpreter from the plant operator by using a control desk organiser. This organiser will interact with the input/output devices in the control console and will therefore set the ergonomics and the operator's view of the control scheme.

Implementation

17. The general concepts of a multi-level computer based control system are illustrated in Fig 3. The main items of equipment required for this scheme are readily available from reputable suppliers - viz

(a) Central control computer (16 bit mini-computer)

(b) System control computer (16 bit micro-computer)

(c) Camac interfaces for (a) and (b)

(d) Control console facilities - video monitors and key pads.

The three control modules (Communications, Local and Ignitron Monitor) are identical and derive from a Camac Peripheral Controller (Culham Type 8307) which incorporates a micro-processor (Intel 8080).

18. An important divergence from commercially available equipment occurs in the interface between the computer system and the plant components. The most readily available interface equipment is too sophisticated for our purposes - being concerned with servo-systems for controlling temperature, pressure and flow in large process plant. At the other extreme there exists a range of simple logic controllers which are so basic that they do not allow the building of control hierarchies or (in most cases) permit the input/output of analogue signals. We are not aware of any equipment in between these extremes or indeed of any using fibre-optic interconnections.

19. The functional requirements of the plant interfacing equipment can be listed as follows:

(a) Digital Inputs
i.e. plant status information

(b) Analogue Inputs
i.e. Measure values

} Computer 'READ' functions

(c) Digital Outputs
i.e. plant commands

(d) Analogue Outputs
i.e. pre-set values

} Computer 'WRITE' functions

20. In practice, it is necessary to consider the overall interfacing scheme because connections must be made to a large number of widely distributed plant components. The cost of each individual connection is then an important aspect in the economics of the design. For this reason, the means for fanning-out the signals from the controllers to the plant and then interfacing to the components must be simple, inexpensive and reliable.

21. The scheme shown in Fig 3 permits continuous scanning of the plant and transmission of control commands through strings of Branch Multiplexor Units (BMU's) to the Plant Interface Units (PIU's). The outline design of the BMU is shown in Fig 4 and for the PIU in Fig 5. The main features are:

(a) These units are designed around well established integrated circuits.

(b) The basic design is simple and therefore easy and cheap to replicate in suitable quantities.

(c) It is possible to incorporate test facilities within the units - e.g.

(1) the ability to fold outputs onto inputs so that it is possible to write data to the unit and read back the results

(2) the provision in the BMU for the transmission of reduced level signals for the occasional checking of marginal operation of the various signal paths.

(d) The units are small and therefore they can be screened effectively.

(e) The design is adaptable and can be extended to meet specific control problems - e.g. the extension of the PIU for Ignitron Fault Detection (Fig 6).

(f) Only a single fibre-optic link is required for the transmission of data.

[Also note that there is only one electro-optical element; which doubles as a transmitter and a receiver.]

(g) The units can be packaged conveniently for easy connection to plant cabling.

## Conclusions

22. From the foregoing we conclude

(a) The growing size and complexity of Fusion Experiments is forcing consideration of computer-based control systems.

(b) The adoption of computer based control systems permits multiplexing of control signals onto a small number of interconnections between sections of the plant. The resulting economy allows the use of fibre-optic interconnections; whereby it is possible to electrically isolate vulnerable electronic units from damaging inputs.

(c) It is recognised that the gains in hardware terms can be bought only at the expense of carefully reasoned and effectively written software.

(d) In general the main items of equipment - i.e. computers, monitors, system interfaces etc - are available from reputable suppliers as well developed, reliable and relatively inexpensive items. It is also possible to outline a scheme for interfacing between the computer system and plant components where suitable equipment is not available from commercial sources.


## Acknowledgements

We gratefully acknowledge the contributions of our colleagues in the development of the scheme outlined in this paper. In particular we thank Messrs. A J Vickers, C A Steed, D L Trotman.


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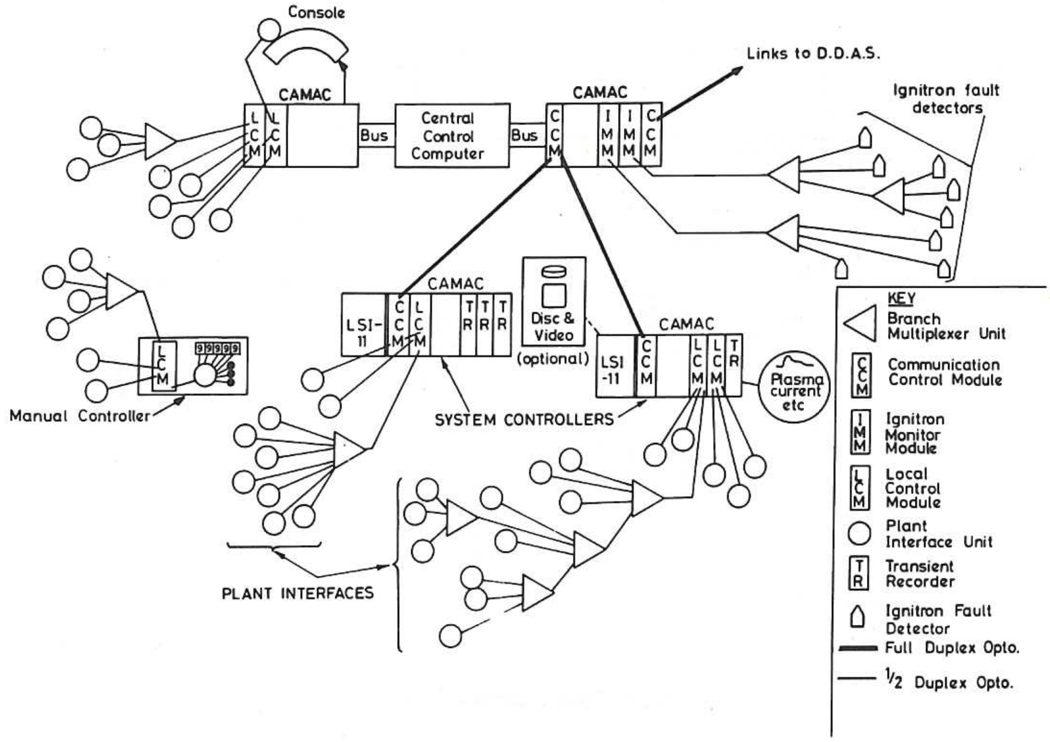


**Fig.3 General concepts of computer based control system.**

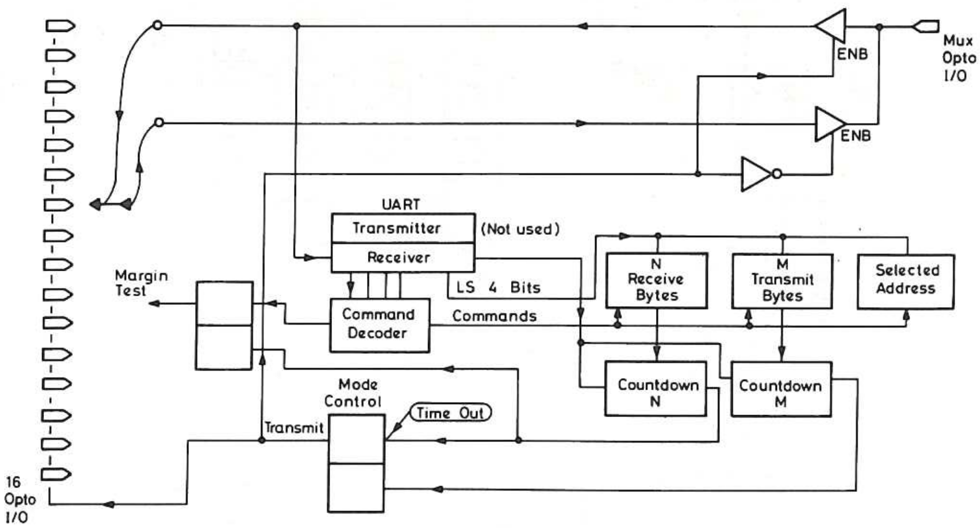


**Fig.4 Branch Multiplexer Unit.**

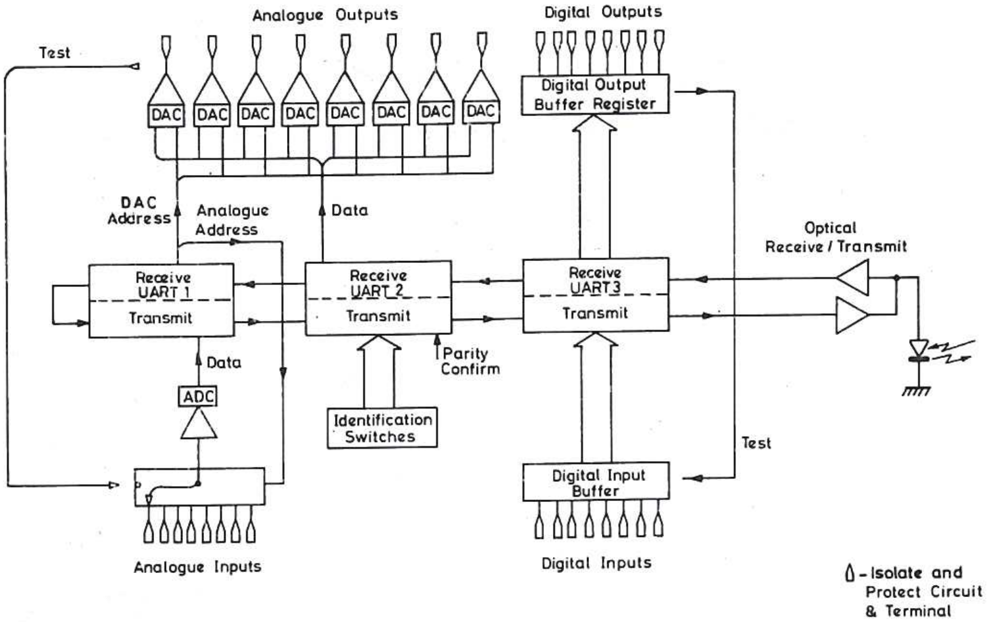


**Fig.5 Plant Interface Units.**

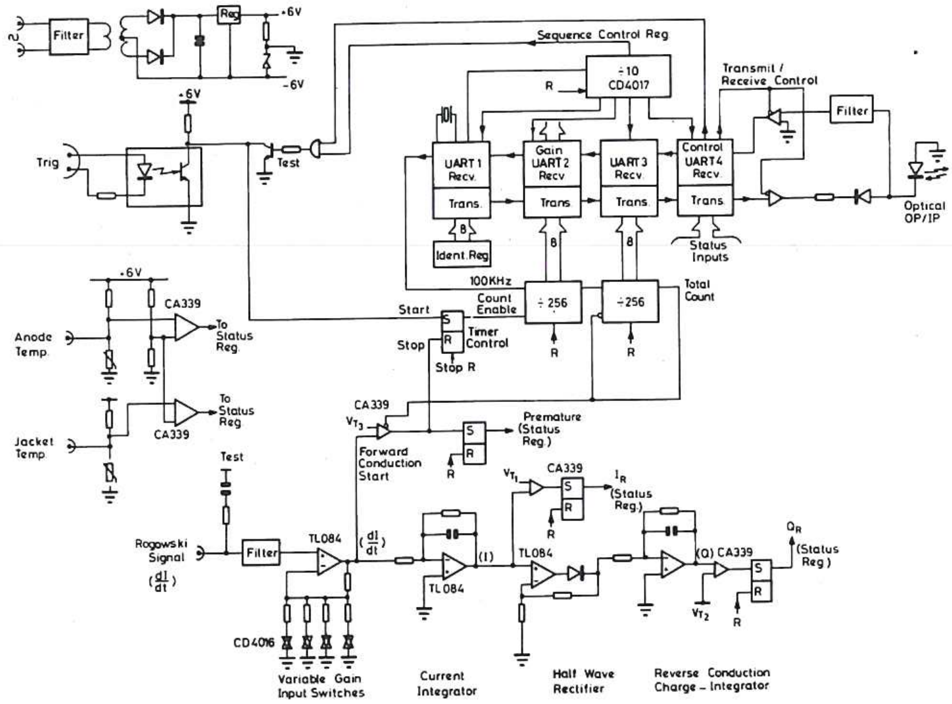


**Fig.6 Ignitron Fault Detector.**