DIGITAL CONTROL AND SURVEILLANCE SYSTEM DESIGN AND APPLICATION

BY

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This article is based on a paper presented by the author at the Eighth Ship Control Systems Symposium in The Hague in October 1987.

ABSTRACT

The digital control systems of the Type 2400, Type 23 and Single Role Mine Hunter are described. After comparison of their scope and an account of the architecture of each, the design phases and testing are discussed. Commonality of equipment allows standard diagnosis techniques and training. It is suggested that in the future total integration will only be limited by the ability of fewer operators to take on greater responsibility.

Introduction

The new generation of Royal Naval vessels currently in build all utilize microprocessor-based control and/or surveillance equipment for their machinery fits. The transition from what were conventional analogue techniques was fairly rapid, but still resulted in a range of architectures which were set according to their particular applications.

The introduction of digital technology brought with it the introduction of software which, although familiar within weapons projects for many years, had not yet been applied to the quite different demands of marine engineering, making it necessary carefully to specify requirements to the software engineer during the development and test phases.

This article describes the digital systems now being introduced for the Type 2400 UPHOLDER Class submarine, the Type 23 frigate and the Single Role Mine Hunter. Although the applications are diverse, the hardware utilized in each case is largely common, enabling many aspects of diagnosis, repair and logistics to be shared across vessel classes.

Background

Following the appearance of the microprocessor in 1972–1973, the Royal Navy began examining the feasibility of using them in warship machinery control applications in the mid 1970s. Early studies not only indicated the practicality of the devices for their primary tasks but also for additional routines such as health/trend monitoring and equipment self-diagnosis.

Although weapon systems have used computers for several years, the long-term continuous demands placed upon machinery control equipment have dictated a far greater emphasis upon reliability and maintainability. The relatively continuous usage of platform (ship) equipment places a different meaning upon availability, which can be likened to continous testing of most weapons equipments.

Papers given at the previous Ship Control Symposium[1,2,3,4] have charted the progress of designs to the point where installation is now commencing. It is thus appropriate at this stage to examine the experience that has been gained to date in three important systems designed for new Royal Navy vessels.

Following closely behind the Type 2400 submarine development was the Type 23 frigate. The Single Role Mine Hunter (SRMH) was the last of the three designs to commence, and differs significantly in its requirement for whole vessel control in addition to plant control.

The Systems' Scope

Before describing the overall architectures of the three systems, it is necessary briefly to compare the three different applications.

Type 2400 Surveillance System

This surveillance system has been designed to collect information from more than 300 parameters scattered throughout the machinery spaces. Every parameter must be updated at least once per second, constantly compared with set alarm and warning points, displayed upon a Visual Display Unit (VDU) and provided as hard copy where necessary. Examination of data at the local surveillance units is not intended operationally but is possible for fault diagnosis using a portable handset.

Type 23 Frigate

By far the largest of the three equipments, this system is responsible for the control and monitoring of gas turbines, gearboxes, electric motors, diesel generators, chilled water plant and other auxiliary machinery. This extensive requirement has resulted in no less than 17 independent computers performing either as individual local control units or as centralized racks within the Ship Control Centre (SCC). Although overall operation is co-ordinated from the SCC, each local control unit is designed to operate its associated plant independently for 'start-up' purposes or as a fall-back mode.

The Single Role Mine Hunter

This equipment differs from the others by having its machinery and vessel control functions separated. Although the relatively simple machinery configuration has not placed any great demands upon its control system, the position and track keeping requirements of the vessel are demanding. The technique of position-keeping by manoeuvring[5] requires constant reference to a dynamic model of the ship. The model is incorporated in a Kalman filter which is continually updated directly from the vessel's sensors or indirectly via the Action Information Organization (AIO).

System Architectures

The *Type 2400* system is shown in FIG. 1. The individual local surveillance units are situated in the principle machinery spaces of the boat. The serial data linking is relatively simple and utilizes several 'point-to-point' high speed data links (HDLC). Printer and VDU connections employ RS232 and RS422 connections respectively.

The internal architectures of the Central and Local Collection Units (FIG. 2) are fundamentally the same except for the absence of transducer boards in the Central Units and of RS232/422 boards in the Local Surveillance Units. Each unit has been engineered as a 19 inch rack arrangement with double Eurocard boards in the same fashion as the majority of weapons equipments are configured.

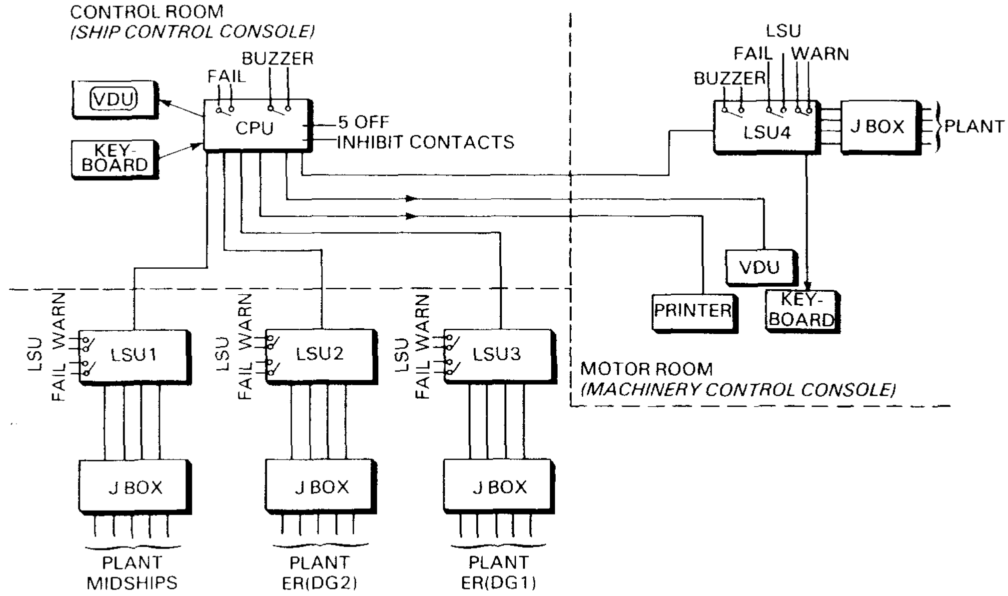

FIG. 1—TYPE 2400 CONTROL SYSTEM

CPU: central processing unit
ER(DG1): engine room (diesel generator 1)
J box: junction box
LSU: local surveillance unit
VDU: visual display unit

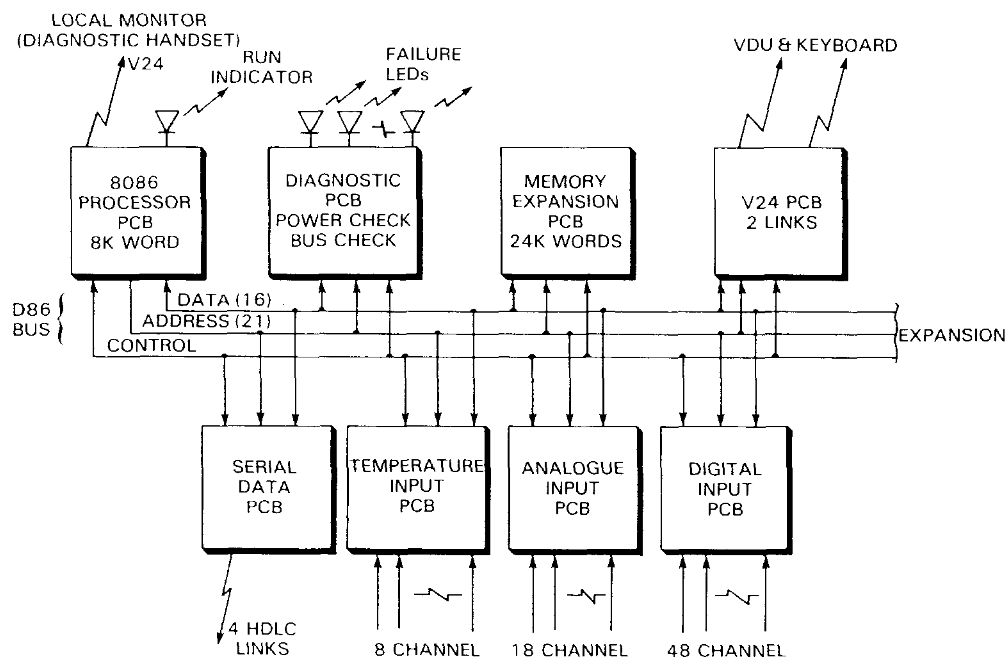

FIG. 2—INTERNAL ARCHITECTURE OF TYPE 2400 CONTROL SYSTEM

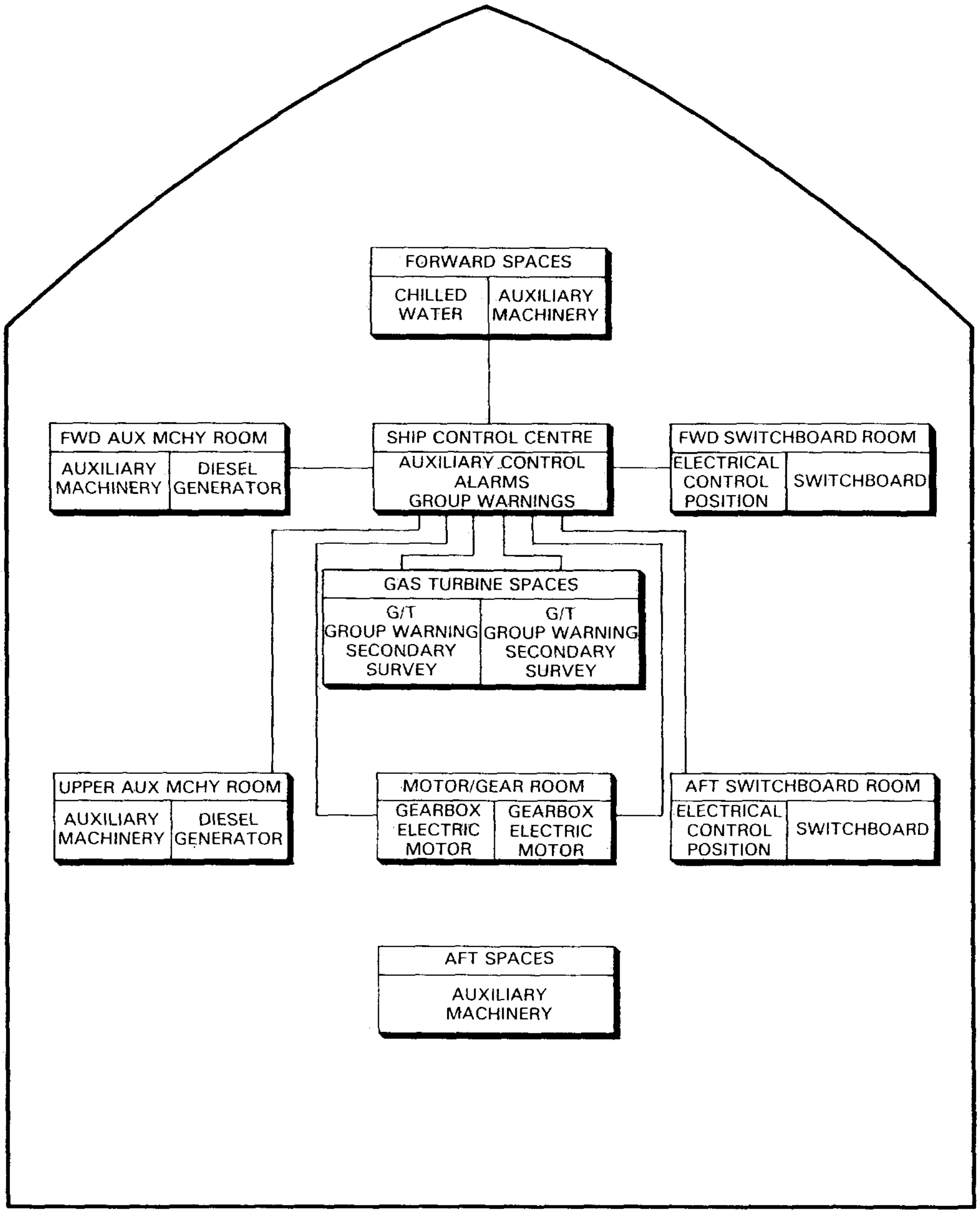

FIG. 3—TYPE 23 CONTROL SYSTEM

The *Type 23* system architecture (FIG. 3) is more complex by virtue of the far greater number of nodes that have to be coupled and the fact that control is now encompassed in the application. Many individual analogue displays also have to be driven and so require extensive digital to analogue coversion. A significant feature of this architecture is the fact that the control and primary surveillance interconnections remain hardwired whilst the secondary surveillance is implemented completely using data links.

The *Single Role Mine Hunter* realizes a true bussing structure with the implementation of the Mil-Std 1553B bus (FIG. 4). Interconnection between the AIO and several other key equipments, including the Ship Positioning System, results in a fairly extensive bus for a relatively small ship.

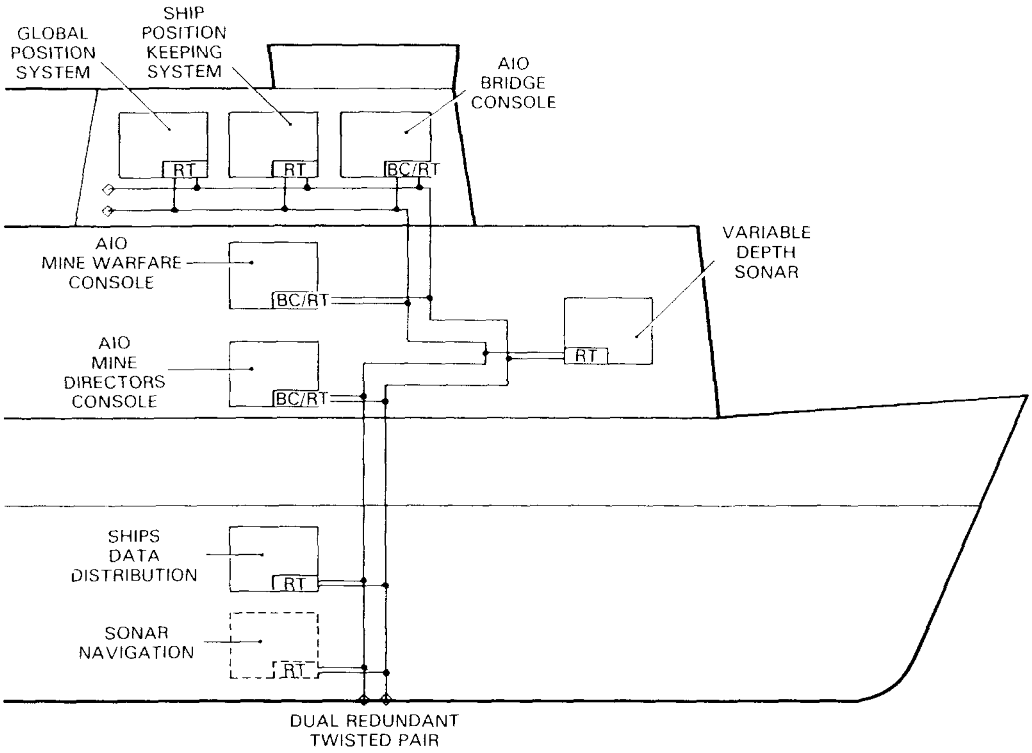

FIG. 4—SRMH CONTROL SYSTEM WITH MIL-STD 1553B BUS
BC: bus controller
RT: remote terminal

Simulation

The degree of simulation found necessary for each of the applications has varied considerably, both in quantity and type.

Apart from performing a 'resource analysis' it was not considered necessary to undertake any other form of simulation for the *Type 2400* surveillance application. Collection points, update rates, number of signals, their types and resolution were all definable and, apart from the interaction of certain display activities, were all clearly known with a high degree of confidence at an early stage.

The interactions both within the propulsion plant and the control electronics of the *Type 23* made it necessary to reduce design risk at several levels by the use of simulation[6]:

(*a*) Operationally, the characteristics of the vessel and its likely responses to a large range of manoeuvres were examined because of the novel nature of the new propulsion configurations.

(*b*) Electrically, the common factors connecting the distribution and propulsion systems made it necessary to examine carefully any interactions that could occur between the two. Concern over the likely effects upon power supply quality resulted in what was a successful shore trials evaluation.

Simulation for the *Single Role Mine Hunter* took a fundamentally different role with initial examination of the feasibility of position-keeping manoeuvres and the ability of both the operator and the potential control algorithms to support the task. Simulation will also be used to test the final control algorithms.

Design Phases

The design phases for each of the systems followed conventional lines in many respects. The 'cardinal points' for hardware definition were considered to be:

(*a*) Number of transducer lines.
(*b*) Form of signal (analogue/digital).
(*c*) Resolution.
(*d*) Update rate/response time.
(*e*) Expansion capability.
(*f*) Storage capability.
(*g*) Failure/fall-back modes.

In all cases the software definition was based upon a structured analysis of the required tasks expressed in terms of level. Software integration and test followed the procedure:

(*a*) Software development on a host machine to the point where further testing required the use of target equipment.
(*b*) Emulation* with representative equipment.
(*c*) Software 'build' and insertion into programmable memory.
(*d*) Insertion into a full configuration of the target hardware.
(*e*) Testing against a full 'operational' test schedule.
(*f*) Subsequent design modification against a recorded issue state if considered necessary at sea.

Test and Integration

In keeping with the testing of similar electronic equipment, the hardware portions of all the systems described have been subjected to extensive measurements at board level using Automatic Test Equipment. All circuit boards that depend upon software for their operation are subjected to further tests by the addition of 'test software' to ensure that all individual hardware activities are carried out satisfactorily. Following initial integration of the application software in its target hardware, functional testing commences at individual rack level before total integration takes place. According to the complexity of the application, each equipment has had additional tests or trials applied to it.

In addition to extensive integration trials at the factory, the Type 23 equipment was used at a combined shore test facility during trials of part of the propulsion plant.[7] In addition an independent trial of a duplicated equipment will take place against simulation.

The Single Role Mine Hunter equipment is also to be subjected to independent assessment in order to validate its effectiveness in advance of the ship trials, and will be subjected to additional position-keeping assessment during sea acceptance trials.

Diagnosis

All the equipments described in this paper utilize common hardware within a 'family' of circuit boards based upon the INTEL 8086 D86 family of microprocessors.

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*Emulation is defined as the operation of developed but unproven software in its final hardware under the controlled conditions of a development computer.

This compatibility of hardware has made it practicable not only to standardize upon a common range of boards across several classes of vessel but also to standardize the diagnosis techniques and subsequent training. The fault-finding philosphy is shown overall in FIG. 5. and can be described as forming two distinct levels:

(*a*) system level

(*b*) equipment level.

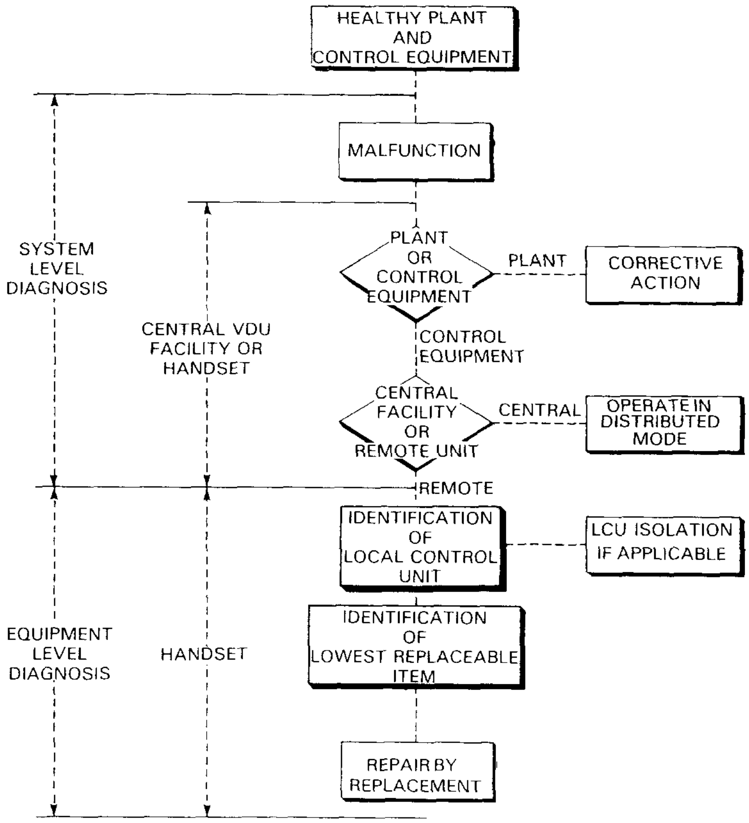

FIG. 5—D86 DIAGNOSIS

System Level

Diagnosis at system level will vary according to the architecture of the equipment, but it forms the first important steps in the sequence following a suspected malfunction.

After establishing the symptoms it will be necessary for the maintainer to decide whether the fault exists within the plant or the control equipment. If initial evidence does not naturally point to a particular 'node' of equipment, the central VDU or diagnostic handset will enable the activity of signalling between each rack to be examined. As signals can be examined in engineering units, the maintainer is more able to identify incorrect or unreasonable values at a glance.

Following location of a specific node or unit of equipment, and the decision as to what section(s) of the plant may require closing down, the specific rack of boards may be examined to isolate the fault.

Equipment Level

Diagnostic activities exist within the equipment as standard facilities and procedures which are independent of the particular application. They split into a further sub-division, which is:

(*a*) active routines

(*b*) maintainer rountines.

The active routines are built in to the equipment and continuously monitor the health of memory, processor bus, input/output timeouts and power supply continuity. Alarm conditions occur if malfunction is detected.

Maintainer routines are performed using a diagnostic handset, which enables the user to examine signals entering and leaving specific boards. The ability to examine signals in this fashion is important as, by their nature, intermittent faults entering a board can lead the maintainer to believe that the board itself is at fault.

A clear division between the common 'equipment' level diagnosis and 'system' level diagnosis makes it possible to apply the former to the general career training of maintainers and the latter to their application training.

The Future

The microprocessor and its attendant software are now firmly established as the way ahead for marine control and surveillance. The technology, formerly reserved for weapon system equipments, now provides the ability to increasingly integrate platform and payload to the point where central co-ordination of all facilities is possible. Such a trend poses the question of whether a single data bus will become the transporter of all ship information and control or whether each major platform system will retain its own identifiable data bus and pass on only essential information via a 'gateway' activity. The true 'whole ship' bus must either dictate exact interfaces to all users or provide the degree of 'transparency' currently afforded by hardwiring. The latter path can result in a more complex bus but certainly provides for greater flexibility in the integration process.

The trend towards complete integration can now only be limited by the ability of fewer operators to take on greater overall responsibility for the total control of the vessel.

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