

SHINPADS - Shipboard Integrated Processing and Display System

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1. INTRODUCTION

Modern shipboard data processing systems, however diverse in nature, share one common characteristic; that regardless of system architecture, most data processing has been done in a large computer. Nations have been justly proud of their efforts to develop larger, faster and more capable digital processors. The results of these development efforts has been concentration of processing and control in a single or limited number of digital computers. Virtually every warship has a crucial point which if hit, by even a small shell fragment, would lose overall system capability.

This is due, in part, to the fact that system architectures have been constrained by the very nature of the ships operational environment. For a ship to successfully execute its mission it must sense its environment and respond expeditiously and correctly when faced with multiple decisions. The high price of digital equipment and a desire to compartmentalize subsystem development in the early years of combat systems development led to centralized or federated combat systems. However technology has advanced to the point where the price of digital processing elements is no longer a driving function. Technology as exemplified by development of microprocessors has overcome the cost barrier justification of centralized processing, however the organizational compartmentalization problem remains.

In 1974 a committee was formed within the Canadian Navy to investigate alternate combat system architectures. As a means of avoiding organizational compartmentalization this was later expanded to include the entire ship electronic system architecture. A proposal (1) for a distributed system architecture has become identified as the SHipboard Integrated Processing And Display System (SHINPADS) and is now associated with the deliberation of this committee. This concept is based upon a distributed architecture wherein all system information is made available to all users thereby supporting key system requirements of reconfigurability and redundancy. The SHINPADS architecture is based upon a linear data bus (or highway)

which permits system elements to be interconnected via a common medium, thereby reducing connections between elements to a single easily understood interface (2). If a conventional interconnect system utilizing point-to-point wiring is considered as the communications medium, the idea of distribution quickly becomes entangled in a mass of wiring.

Distributed processing system architectures involving data bus structures have recently been developed for several applications and vary considerably in form and function. Although distributed processing has been applied to research projects and small business systems, rare is the architecture that involves large computer complexes and none to date have addressed the shipboard processing system. The SHINPADS distributed concept was specifically developed based upon a ship's requirements. It goes further. Due to the length of time taken to develop and deploy ship equipments, often conflicting sets of requirements arise. Not only does SHINPADS accommodate future equipments; but it remains compatible with existing hardware. It can do this since SHINPADS design requirements included bus transparency which meant that standard NATO interfaces could be used for connection to the bus, in the same way that they are utilized in present day point-to-point interconnections. Although the SHINPADS concept itself could be considered somewhat revolutionary, to the system designer it can be viewed as evolutionary. Other data bus proposals generally ignore this and force expensive equipment modifications or implement "black boxes" to handle unique handshakes.

THE GLOBAL SHIP

As has been stated the SHINPADS concept is based upon:

- a) a distributed architecture involving geographic distribution, functional distribution, and distribution of control;
- b) standardized components; and
- c) a bus structured "ship's central nervous system".

This data bus is the key element which translates components which have historically been considered subsystem or local resources, into global resources. That is, although subsystems can be functionally identified, individual subsystem components are interconnected via the bus. In this manner, rather than speaking of underwater or surface/air subsystems, the ship can be considered a collection of arrays such as: active sensor array, processor array, display array, etc. (figure 1). For example, as shown in

figure 2, all minicomputers on board the ship are considered to be part of the processor array, and since they are only connected to other components via the data bus each computer is physically identical. As shown in the diagram (as for example in comparing a firecontrol processor and the engine control processor), the only difference between two processors will be the software that they are executing at any instant. The processors can be considered to be replicated and the processing architecture reconfigurable. Similar logic underlies the structure of other component arrays.

Therefore while a particular ship element may only be considered a subsystem component when in a classical system architecture, the SHINPADS architecture permits that device to be utilized as a global device. Such an approach is dependent on a shipwide sharing of resources with each individual component connected directly to the data bus.

SHINPADS DATA BUS

The data bus is therefore a crucial item. Yet as was the case for several other crucial elements an examination of worldwide developments in this area only served to confirm early indications that no suitable data bus existed. The decision was therefore taken to develop a data bus with the qualities required to support the SHINPADS concept. Following a competitive examination of the SHINPADS concept, Sperry Univac was contracted to specify the data bus. Conflicting requirements immediately arose; it was desirable that a proven serial data transmission technology be utilized, and interfacing had to be via an existing or near term interface standard. At the same time state-of-the-art features had to be incorporated if the bus could be expected to provide long term services. The data bus had to be able to accommodate up to 256 users and consideration of various ship types dictated that it should be able to operate with bus lengths of up to 300 metres. An analysis of typical frigate data rate requirements (3) indicated that somewhat less than three million bits per second (MBPS) of data would be required to be passed but an examination of delays, latency, and queue lengths demonstrated a real throughput of at least twice this figure would be desirable.

Several possible bus structures were considered with the ring structure similar to that used in the University of California's Distributed Computer System (4) receiving detailed attention. However, it was felt that the nature of the combat environment was such that active bus taps could not

be tolerated. The series reliability problem used by active taps was avoided by the development of transformer coupled passive taps and a linear tree structure was chosen over the ring structure.

Proven technology was utilized in adopting demonstrated transmission methods based on the use of a low level 10 MHz Manchester-coded serial signal transmitted on triaxial cables. Yet an eye was kept on the future of ensuring that the structure was directly compatible with emerging fibre optic technologies (5). The design of SHINPADS thus permits future performance upgrading through replacement of the triaxial cables with fibre optic transmission cables. State-of-the-art microprocessor technology is being incorporated in the SHINPADS node design to provide a general purpose interconnect system suitable for a variety of military and naval applications.

The performance of the data bus system can be tailored to satisfy requirements for a variety of applications. The real data throughput is dependent upon the complex interaction of such factors as the number of users, the message time distributions, bus spatial dimensions, and the length of messages. A peak data throughput of approximately 8 MBPS can be provided however in a frigate application of a SHINPADS system an effective data rate of 6 MBPS is expected.

Since the SHINPADS concept involves unbundling existing subsystems such that their dedicated local resources now become global resources, instances will be encountered in which the data bus interconnect must support time critical tasks. To cater to this eventuality, bus access time for users of the system can be controlled by assigning a priority structure so the time-critical users can gain access to the bus more frequently than other users. In this manner up to 16 users may have priority access while others would utilize the bus less frequently. Past performance indicates that fire control equipment must be updated approximately every 50 milliseconds. Average access for a user in SHINPADS is less than 100 microseconds. Thus access time requirements for time critical functions such as fire control, antennae stabilization, ship monitoring, etc., can be met.

A naval vessel by design is intended to go in harms way. Any interconnect system or data bus must possess a high level of fault tolerance. SHINPADS utilized distributed or non-dedicated bus control and passive bus taps so

that the interconnect does not exhibit a single point of failure. Duplication, let alone replication, of all systems interconnecting wiring found in a classical system architecture is out of the question. In fact, ship designers find a great deal of difficulty in fitting a single ever-expanding set of data processing cables into a ship's configuration. However, if all this wiring is replaced by a two strand SHINPADS bus, replication is easily accomplished. Not only does the bus displace tons of present day wiring but several routes can be replicated; say one down the port side, one down starboard, with another on the keel. Thus the data bus system may have several levels of replication to greatly improve survivability. In this manner a SHINPADS data bus can offer reliability, redundancy and survivability that cannot be achieved with present ship system architectures.

COMMUNICATION MODES

Two general modes of communications are provided by the SHINPADS data bus. Applications may utilize either or a combination of data transmission modes. The point-to-point mode is required if the bus is to provide a transparent replacement for present point-to-point wiring. At any instant a diverse subset of the ships global resources will be acting to carry out the functions of a classical dedicated subsystem application and will require point-to-point communication. In this mode the data bus uses physical addressing to direct a message to a specific user connected to the data bus.

However, in a distributed system architecture such as espoused by the SHINPADS concept many messages will be directed from a single source in a multitude of receivers or sinks. The broadcast mode permits a message sender to transmit his data to multiple sinks through logical addressing in which the sink recognizes the importance of the data by its type. This eliminates the need to retransmit messages destined for more than one user and permits parallel processing. Although much of a ship system's traffic will be sent via this mode, several recently developed but systems cannot support broadcast addressing.

The SHINPADS has a block transfer capability that is an asset especially during system loading, system reconfiguration or transfer to mass storage. A block transfer transmits messages which are longer than the normal message length. Either transmission mode (point-to-point or broadcast) may utilize the block transfer by sending a series of message packets.

TOPOLOGY

As shown in figure 3 the data bus system consists of a linear data bus and the components required to provide for user connections. The data bus is tapped at various locations by a bus access module (BAM). A node is connected to the BAM by stub cables and acts as the user's interface to the data bus. In turn the data bus user is connected to the node by a standard interface.

In this manner up to 256 users may be accommodated within the maximum bus cable length of 300 metres. The data bus consists of a minimum of two serial data cables. One cable is utilized for data transmissions while the other cable carries control information. Each cable operates at a 10 MHz clock rate using Manchester biphasic signals compatible with NATO low level serial transmission standards (STANAG 4153). (6) Two triaxial cables (TRF-8) make up this operating or primary bus and handle all control/data transmissions. However, from one to four additional cables, following alternate routings through the ship, may be utilized to provide redundancy through replication. Any two cables may then be selected by logical assignment so as to provide an operating or primary bus.

The BAM contains the signal transceiver logic for the data bus system and acts as a fanout for node input/output ports. The BAM contains a transformer coupled passive connection to the bus cable and is designed to isolate the data bus from any BAM, node, or user failure. The node in turn provides the user's interface to the data bus system. Figure 4 indicates the functional construction of the device. The node is micro-processor based and uses random access memory (RAM) for data buffers and parameter storage. It contains all the intelligence in the bus system. The user wishing to pass information via the bus communicates through a standard interface to the node. The node handles all bus protocol so as to direct the data to the appropriate receiver node. The sink node in turn extracts the data from the bus and passes it on to the sink user via the same standard interface. Thus the two users can consider the bus to be transparent with the sender and receiving user both communicating via a standard interface just as they would if they were wired directly together.

The present SHINPADS data bus has incorporated NATO type B (STANAG

4146 type B/ML-STD-1397 type B) parallel interfaces, and NATO serial (STANAG 4153) interfaces. The node design provides for modular implementation of other interfaces as a data bus system options and it is planned to implement further NATO parallel (type A) and NATO serial (STANAG 4156) interfaces at a later date.

DATA BUS OPERATION

Communications within the data bus system are implemented by assigning control of the bus to one of the nodes, which then controls transmission of messages on the data cable. Since control can be exercised by any node in the case of the controlling node being hit or otherwise failing another node can assume control. For this reason the control is said to be distributed.

Contention between bus users is resolved by selectively polling the users and then granting bus access to the highest priority user. Users with time-critical communications requirements will be polled more frequently than other non-priority users. The priority algorithm is implemented through software so that the priority structure can be modified to adapt to the mission. When a node is polled, a response is transmitted to the controlling node indicating the needs of the polled node and its current status.

Polling is carried out via poll commands and node responses on the control cable of the bus. The data cable is utilized to pass information messages and infrequent control messages. Traffic on both cables is asynchronous, enabling polling and queuing of users while the current information message is being transmitted on the data cable.

Data bus system users communicate by transferring variable length messages. A set of commands and interrupts are utilized for intercommunications between the users and the data bus system. External Function (EF) commands originate with the user and External Interrupts (EI) are generated by the bus system. Figure 5 indicates the type of traffic that is transmitted via the user interface.

Messages in the data bus system consist of command and response, and information messages sent on the data cable of the active bus. The messages are variable in length and may contain up to 254 16-bit words, although the block transfer mode allows messages of larger lengths to be

sent. Figure 6 indicates the External Function command and message format.

CONCLUSION

Advantages of SHINPADS concept and bus system approach have been pointed out. Although space does not permit discussion of all the advantages foreseen some self evident benefits can be enumerated. Standardized interfacing with a predefined interconnect system decouples current platform/payload interference by removing custom interconnections, thereby permitting parallel platform and payload development. Shore integration of equipments, ship fitting, and system set-to-work are also all simplified. Ship updating during overhaul and refit will also be made possible where the problems of rewiring would have prevented such actions in classical systems. New systems may be "plugged in" and devices removed by simply "unplugging". In addition substantial savings are predicted in initial ship wiring costs.

Even if the above advantages were not characteristic of this concept there is an overriding reason for considering such an approach. It is suggested that the redundancy and replication provided by the SHINPADS concept cannot be provided in any other way. Certainly combat capability today depends on survivability. SHINPADS cannot guarantee that a ship will survive, but compared to any classical system architecture, it insures that a ship's system will remain operational longer and in a more sophisticated manner.

It is suggested that the SHINPADS concept offers life cycle cost savings, redundancy, and reliability that cannot otherwise be realized. The data bus described in this paper is a cornerstone of this concept.

REFERENCES

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- (6) NATO Naval Armaments Group, Draft STANAG 4153, "A Standard Specification for a Serial Point-to-Point Input/Output Interface for NATO Naval Systems".

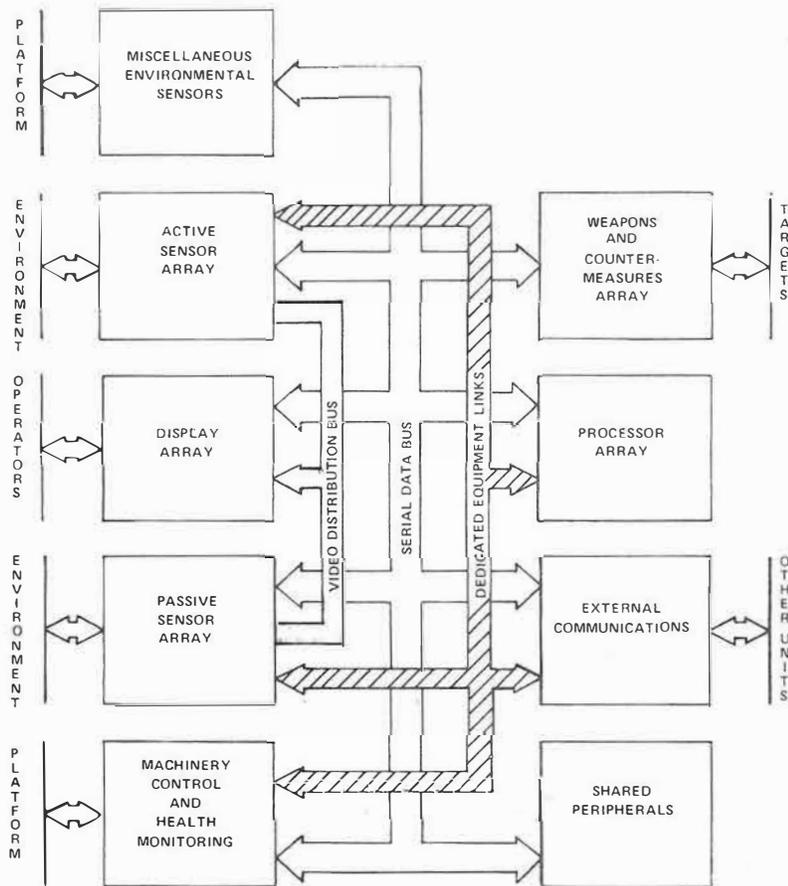


Figure 1. SHINPADS Top Level Diagram

- RECONFIGURABLE MINICOMPUTERS
- DEDICATED BUT REDUNDANT MINICOMPUTERS

NOTE: ALL MINICOMPUTERS ARE AN/YUK-20(V), ONLY SOFTWARE DETERMINES A GIVEN COMPUTER'S TASK.

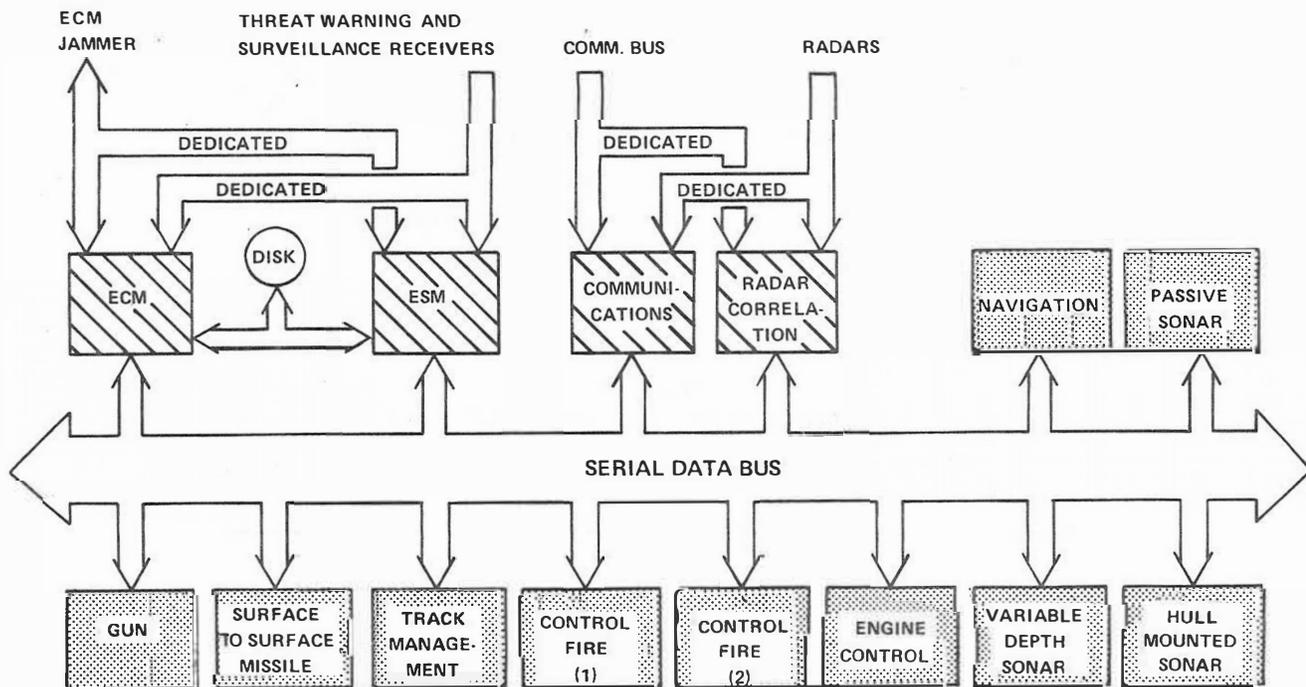
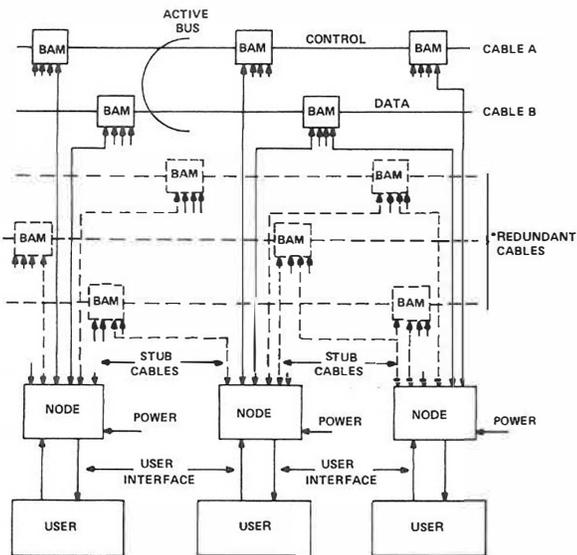


Figure 2. SHINPADS Processing System Architecture



* UP TO 6 DATA BUS CABLES MAY BE IMPLEMENTED.

Figure 3. Data Bus Topology

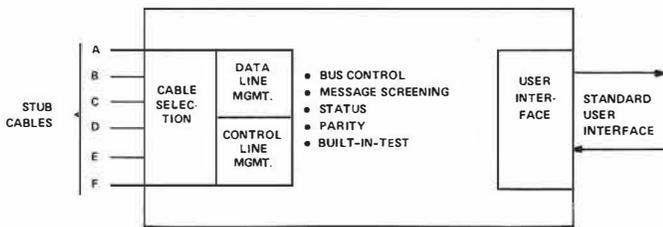


Figure 4. Functional Construction of Node

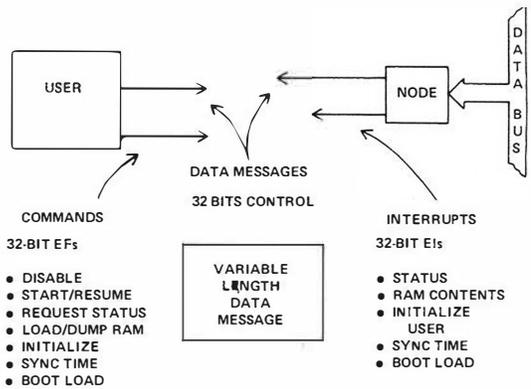


Figure 5. User Communications

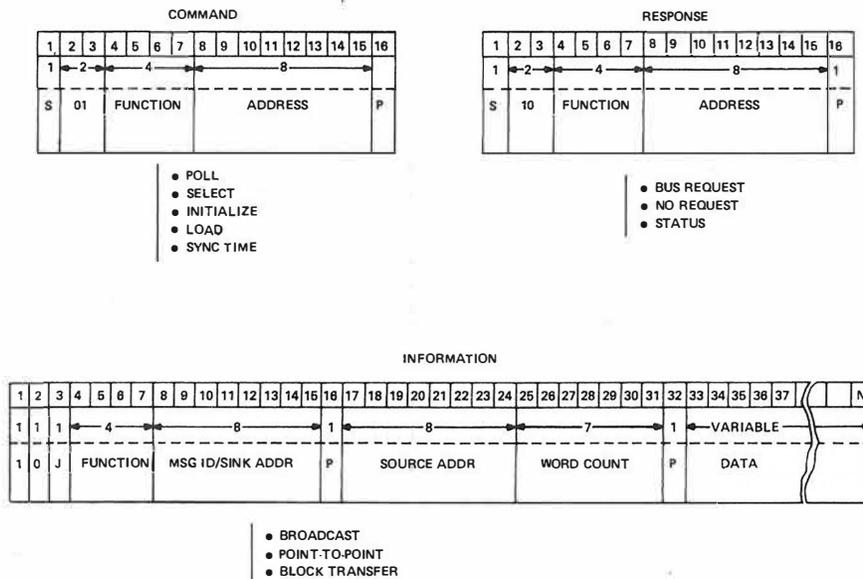


Figure 6. Message Formats