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A MODULAR APPROACH TO OCEANOGRAPHIC INSTRUMENTATION.

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SUMMARY.

Packaging of Electronics systems for unfriendly environments, in particular an underwater environment requires a different approach for logic, linear and power systems for optimum results. A modular approach showing the variation required by these system types is described for use in oceanographic instrumentation.

DESIGN REQUIREMENTS.

Most underwater systems require special attention to be paid to one or usually more of the following criteria.

Weight
Space
Power consumption
Cost
Reliability
Repairability.

The relative importance of these items will of course vary with specific system requirements. As well as these items there is implicit in the design of underwater systems a hazardous environment with a fairly high risk of exposure of the components to sea water.

With the exception of repairability micro-electronics can give immediate advantages on all other design requirements, However, no matter which system of interconnecting multileaded devices is used, repairability is a major problem. For this reason a throw away principle has been adopted where a higher level module which can be handled forms the throw-away unit.

The basic building brick around which the modular system has been developed is the silicon integrated circuit thus meeting the other design requirements. It is the performance of these devices that dictate the form of the module design.

To supplement the improved reliability one hopes to achieve by the use of integrated circuits it was decided to use a controlled jointing technique and as space was a major consideration in the development of our modular system it was decided that a welded construction offered both the control required and occupied a minimum of space. This construction finally encapsulated fulfills the remaining requirements of environmental ruggedness.

To complete the system the sub-system modules are welded or wire-wrapped onto a multilayer interconnect which is manufactured using similar techniques.

LINEAR SYSTEMS.

Linear integrated circuits require the addition of conventional components to achieve a working system. Until recently, in addition to gain setting components considerable frequency compensation was required. This has meant that two or three capacitors and four or five resistors are required to realise a functional unit in addition to the integrated amplifier itself.

To accomodate these components a modified type of Cordwood construction is used. The basis of this "wrap round module" is a flexible nickel printed circuit.

This flexible circuit comprises nickel track on a polyester (mylar) base in which the significant feature is that the dielectric has an etched pattern of holes with exposed tabs of nickel overhanging the etched holes. The integrated amplifiers are assembled onto the unformed mylar film using the etched holes as access for the weld electrodes. The film is then formed and the remaining nickel tabs bent through 90° to facilitate welding of the conventional components. Figure 1 shows the module build up.

After testing the module is placed in a plastic box which has a plated metal screen on it and the box finally filled with an encapsulant, this being either a filled epoxy or a foam.

Typically modules contain two linear integrated circuits plus their associated conventional components. In special cases where a completely discrete component circuit is required the system is flexible enough to cope, but of course with a decrease in the complexity/space ratio.

It is the interconnection of these modules that presents a major problem. Presenting so many outputs in so small an area requires a multilayer interconnect to distribute the signals. This is further complicated when distribution of low level signals is required. The general approach is to run low level signals on a seperate layer with inter-track screening. This layer is in turn sandwiched between two screens which can double as power distribution layers.

Assembly if these interconnecting layers utilises the same techniques as used in the module construction i.e. welding. Again the flexible Nickel-Mylar circuit forms the basis of the assembly. A baseboard of epoxy glassfibre is preassembled with output and module mounting pins. The layers are loaded singly and welded with inspection taking place after each layer. After assembly of all layers there is a continuity check, the unit is then encapsulated and there is then a final continuity check.

These interconnects can become very complex, the maximum number of layers used in a sonar application to date being 12. A computer utilising similar interconnects has more than 20 layers and there is no forseable limit to the number of layers.

The disadvantages of such a system are largely cost orientated. The module is encapsulated and hence unrepairable, there is therefore a throw away cost limitation to be considered for each module. A target limit of £50 is applied and usually modules fall well below this. The exceptions to this being where space is a premium large quantities of small modules cannot be accommodated and a large complex and therefore costly module results.

Also, there is implicit in this design a relatively expensive manufacturing technique. i.e. welding. The 'trade off' for this is the better control obtained during manufacture and consequently a better long term reliability.

These techniques have been used to produce a electronic beam forming system. The system produces beams by summing phase components from a multi transducer array. Three basic modules are used:

a) A preamplifier comprising 2 linear I.C. giving 25 dB gain.

b) Thin film summing resistor modules.

c) Summing amplifier comprising 2 linear I.C. giving 25 dB gain.

The total system occupies a cylinder ten inches diameter by 0.6 inches thick giving eight discrete beams with an overall gain of 50 dB.

DIGITAL SYSTEMS.

It is within digital systems that the integrated circuit has had the most impact. The integrated logic element has been available for much longer than its linear counterpart, it was therefore used in the early stages in systems that had conventional linear circuit peripheries.

There are two approaches in adopting digital I.Cs:

1) If space is not a premium and the reason for adoption is based solely on cost and reliability then the dual in line encapsulation offers a solution which utilises conventional manufacturing techniques. There is still a problem of repair with this approach but the packages are more use orientated than flat packs or T.O.5 and this problem can be overcome using soldering irons fitted with suction attachments for removing faulty devices.

2) Where space and weight is a premium the flat pack will be used posing a more severe interconnection problem usually overcome by reflow soldering to a printed circuit or by welding.

In our modular system approach we decided to use a welding assembly method and gaining an improved packing density by using multilayer interconnects. To decide on the optimum module size the following points were considered.

1. Where are the convenient sub system breaks.
2. How many I.C's in a sub system.
3. How many input/output connections to the sub system.
4. Total space available for the system.
5. Cost.

The results obtained on a number of evaluation using D.T.L. show subsystems of about 25-30 packages and 30 to 50 connections. To interconnect these packages together we decided a multilayer system was required to give better packing density and screening. As the cost of such a system is directly related to the number of layers one has to balance the number of layers against the space available. The standard array finally chosen provides 30 I.C. 62 outputs and usually five layers including seperate power and outputs and usually five layers including seperate power and earth planes are sufficient to interconnect the subsystem.

There is flexibility, in that the array is based on a standard matrix and its' size can be reduced or increased by stepping a single position pattern a number of times. The standard matrix also makes the use of computer aided design an attractive possibility.

The basic printed circuit layer of the system relies on the etched nickelmylar approach as used in the linear system modules. When the system first evolved the cost of integrated circuits was such that we required the facility to replace individual circuits on such a large array. The assembly of the packages did not therefore take place until the multilayer interconnect had been welded and encapsulated. The I.C's were then mounted to the projecting posts using opposed electrodes fig.2.

With costs of I.C's at their present level we can begin to consider an assembly of this size as throw-away item, mount the packages direct to the nickel interconnecting layers and encapsulate the whole. This approach gives an obvious manufacturing saving and increase in reliability due to the reduction in total number of joints.

The impact of integrated circuits can be seen by the reduction in size achieved on the timing logic of a remote acoustic transmitter over a number of years. The first attempt using silicon transistors and conventional components occupied two fifteen inch diameter semicircular boards.

The second attempt two years later used multichip digital integrated circuits in T.O.5 cans, this resulted in an array of about 100 T.O.5 cans packaged into half of a 10 inch diameter board.

The third attempt using the technique described previously gave an array of 40 flat packs mounted on a six layer interconnect three and a half inches by four and a half inches.

The progression of this system not only gave size and weight reduction but an increase in reliability and in the final instance a 20% increase in complexity.

POWER AMPLIFIER AND POWER SUPPLIER

By far the main impact on power circuitry has been the development of high voltage, high current transistors and not micro-electronics.

The effect of micro-electronics is limited to the low level circuitry where in our modular approach the linear system type of design is adopted.

A module system is adopted, however, for the higher power stages for completeness should be mentioned.

In many cases the nickel mylar flexible circuitry is too resistive to handle the currents required and two alternative techniques are adopted.

1. A Cordwood module in which the end films are made using a matrix of solid nickel wires.

2. A flexible interconnect film comprising copper tracks on an epoxy fibreglass base. As in the nickel-mylar circuit tabs are etched to lie over etched holes in the dielectric. To aid welding the copper is plated with about 100 micro inches of gold.

The choice of technique depends on the component types used, stud diodes, for example, would use discrete wires and T.O.5 transistors the flexible film interconnect.

Finished modules are encapsulated in loaded resins but the encapsulents have to be better controlled than those used in other parts of the system.

Experience has showed that if the mixes are not controlled excess hardener forms a surface film which is hygroscopic giving possible high voltage breakdown.

THE FUTURE.

The experience gained so far on complete systems gives confidence in the system breaks adopted. It would therefore be reasonable to carry this concept forward into new systems.

In the future the sub-system modules can be further reduced in size and weight by the further application of micro-electronics. Rather than an increase in integrated circuit complexity the change is likely to be brought about by the use of hybrid circuitry.

The linear system, because of the tolerance and matching of resistors, would comprise an evaporated thin film substrate with active devices and chip capacitors mounted on it.

Where interconnection of devices only is required as in the logic modules a multilayer thick film, i.e. screened inks, system would be used. This film technique would also be used for low level power modules where tolerance of resistors is not critical. It is also possible that power transistor chips could be mounted directly on the substrate together with this low level driver circuitry.

These techniques do not offer any advantage for the sub-system interconnects and these interconnects would take their existing welded form.

Adopting this approach a further reduction in space and weight of about three could be achieved.

CONCLUSION.

1. The modular approach adopted meets the design requirements of an underwater system.

2. With few exceptions the throw away cost of modules is less than £50.

3. In future systems the same system break philosophy would be adopted.

FIG. 1. MODULE ASSEMBLY.

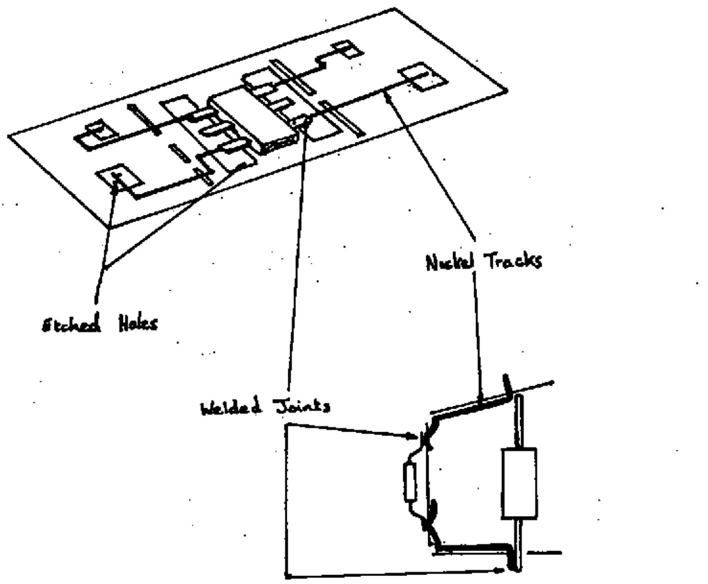

FIG. 2. DIGITAL I.C. MOUNTING.