FAULT INSERTION IMPROVES MAINTENANCE TRAINING

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SUMMARY

An effective electronic maintenance training program is dependent on the ability to insert faults into training equipment so that students may have hands-on experience in troubleshooting "failed hardware". The faults, and method of presentation to the student, must reinforce the training objectives while at the same time demonstrate the classic failure mode of the training equipment. Ideally, the method of fault insertion will be: transparent to the student, low cost, easily maintained, require a minimum of support documentation, be remotely and rapidly controllable, limit wear and tear on training equipment, and pose no safety hazard to personnel or equipment.

The increased complexity and size of operational systems coupled with higher costs for personnel and training dictate the need for a more realistic, effective, and efficient fault insertion technique as opposed to those in common use today. This paper will examine the concept of a microprocessor based fault insertion device (FID); a technique which has been successfully utilized in several major training systems. Comparisons will be made between a FID and other common methods of fault insertion.

Introduction

In order to teach corrective maintenance skills in the realm of fault location and repair (troubleshooting) it is necessary to have a means of causing the training equipment to operate improperly. The method employed must have predictable results, be reproduceable in nature, and have no lasting effect on the training equipment. Selection of the problem area must be determined by the training objectives and cannot be dependent on individual instructor skills. The time required to implement the fault should be nominal as this time represents lost training time and has direct relation to the overall efficiency of the training course.

History

Traditionally, fault insertion has been accomplished by taping over connector pins and lifting or grounding equipment wires. These methods, however, present personnel safety hazards and cause very high rates of actual equipment failure because of instructor-induced problems. The real long term costs associated with this method are high and include not only repair of equipment, but also lost lab time for repair and for routine insertion and removal of training faults. With the increased complexity and sophistication of operational equipment, the application becomes more difficult and costly in terms of induced casualties and increased wear on the training equipment.

A second method of inserting faults, is the Pre-Faulted Module (PFM). With this method, actual printed circuit cards or modules from the equipment in question are caused to operate improperly. This method requires the purchase of a separate PFM for each fault in the training course. There are two major drawbacks to pre-faulted modules: 1) the cost, and 2) lost lab time due to time required for fault insertion. In calculating the cost of PFM it is necessary to look at not only the initial cost of the module itself, but also the supporting life cycle costs. Each PFM requires separate nomenclature, drawings, test procedures, and parts support to ensure that depot repair personnel repair only genuine faults and not the desired pre-fault when an actual problem occurs. Insertion of a PFM into the training system typically requires that the equipment be powered down and the students removed from the immediate area. The PFM is installed and the equipment is powered up, after which the instructor checks out the fault for proper operation and recalls the students. This process normally takes 15-20 minutes per fault and will cause the loss of 60-90 minutes of training time for each day spent in the lab.

A common problem associated with the use of both PFM's and instructor inserted faults is the inability to demonstrate faults in the face of state of the art On Line Diagnostics and Built In Test (BIT). In many cases the installation of a PFM will cause the BIT or diagnostic to disable the power-on sequence so that the student never actually "sees" the symptoms that would appear if the equipment failed during normal operation.

Solution

An alternative which meets all requirements for fault insertion and has been successfully employed in several complex training systems, is the Fault Insertion Device (FID). This microprocessor based method of fault simulation provides a more flexible approach than either PFM's or instructor inserted faults. The FID simulates equipment casualties by selectively activating predetermined faults within the training equipment. These faults can be either analog or digital and the instructor is given the capability of selecting the faults singularly or simultaneously.

Description of Technique

The FID acts as a dual position switch for the selected signal (Fig. 1). In the OFF position, the signal passes through the normally closed contacts of the switch and the FID appears transparent to the training equipment. When the switch is activated, the signal to be faulted is routed through the normally open contacts of the switch. The actual faulting is accomplished by bussing the signal to a predetermined logic level or inserting a known resistive, capacitive, or inductive load into the signal path.

Hardware Description

All instructor interaction with the FID takes place at the Display Terminal (Fig. 2) which consists of a video display, keyboard and internal power supplies. Data for display is received from the Control Station via an RS-232 interface and presented to the instructor in menu format. Instructor commands/selections are returned to the Control Station over the same RS-232 interface.

The Control Station contains an MC68000 microprocessor, two power supplies and I/O circuitry to interface with the Fault Cards. Software for the microprocessor is contained in Externally Programmed Read Only Memory (EPROM). The Control Station provides information for display on the Terminal and in return

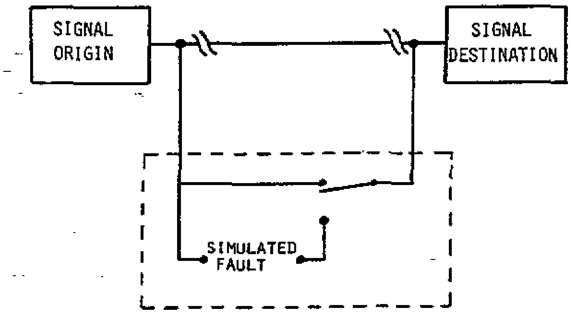

figure 1. Theory

receives fault selection commands from the keyboard. The commands are coded for fault address and sent to the Fault Cards via an RS-422 port. The Control Station power supplies provide power to both the Control Station and the Fault Cards.

The Fault Cards are the actual means of fault insertion within the FID system. Each Fault Card contains its own MC68001 microprocessor, address select switch, and circuits for 30 predetermined faults. A maximum of 127 faults cards may be interfaced with the Control Station on a single RS-422 interface. The address select switch provides a unique numerical identification to each fault card which is used when decoding the Control Station commands. The Fault Cards receive data from the Control Station which determines the fault to be activated and translates that data into a relay action that inserts the fault via the back-plane wiring assembly of the training equipment.

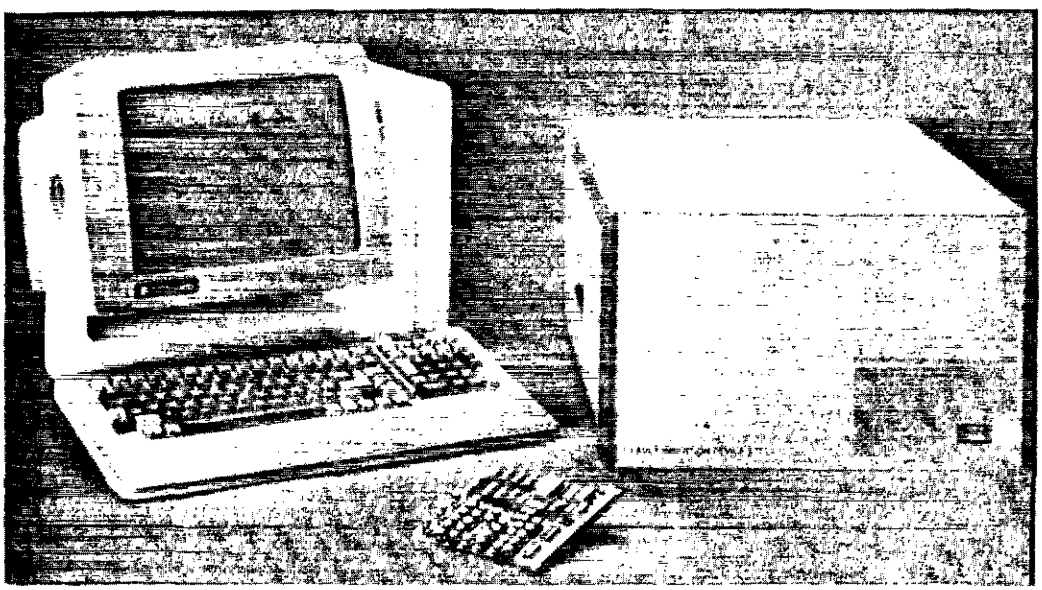

figure 2. Fault Insertion Device

Interface

The Fault Cards are located in the training equipment cabinets to be faulted and are connected by a common digital bus to the Control Station. Interface between the Fault Card and the training equipment is accomplished through the back-plane wiring assembly (fig. 3).

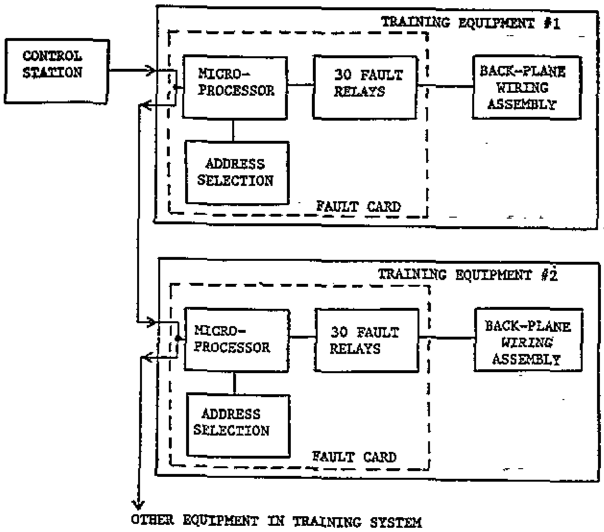

figure 3. Interface

Operation

Activating a fault takes just seconds to accomplish and requires only three keyboard entries. The instructor is first presented with the Primary Menu which contains a listing of all the equipments within the training system. The instructor selects the equipment to be faulted and the program sequences to the Secondary Menu. The display now indicates all the faults available for the selected equipment, any currently active faults are highlighted with reverse video. Now the instructor makes the second required entry to select the individual fault, the computer asks for verification, and upon receiving an affirmative response from the instructor, the fault is activated and the program sequences to the Current Status Menu. The display now shows all active faults within the entire training system. Should the instructor desire to remove a fault from the system, he may do so while in the Current Status Menu. He first selects the fault from the list displayed, then the program will again ask for confirmation. Upon receiving an affirmative response, the fault is removed and the affected circuit is restored to normal operation.

Capabilities

Although the FID is capable of controlling up to 127 fault cards (3810 faults total) a more practical limitation is the size of the training system and the effective span of control for the instructor. Typically a single Control Station will have the capability to insert 350-500 faults. These faults will be dispersed throughout 15-20 separate equipment cabinets. The FID has the ability to provide multiple, simultaneous faults and therefore, can support a separate lab group on each equipment. Another option to the instructor is "system level" training where all equipments within the system are interfaced to produce a shipboard system. While in this mode, the training equipment can provide either system level maintenance or operator training. The FID supports either training mission by allowing the instructor to insert both equipment and interface oriented faults. The "real time" association (the equipment is faulted during normal operation) of the faults allows the student to make maximum use of the on-line diagnostics for fault location.

Growth Potential

One area which has major potential for increasing both the effectiveness and efficiency of the training, is increased utilization of the microprocessor. Adding an off-line storage device such as a 10M byte hard disk and modifying the program to include the capability for instructor authoring would provide a wide variety of instructional aids. Now the system could provide such things as troubleshooting hints, technical manual reference, schematics, flow diagrams, student history, etc. The addition of a printer could provide instanteous hard copy of these aids for use during the exercise. Additional software modification could provide for such things as student performance monitoring, testing and remediation.

Maintainability

The Fault Insertion Device is repairable at the organizational level. The degree of repair (LRU or piece part) depends upon the capability of the technician affecting the repair. The device is built to commercial standards utilizing off-the-shelf parts which are available through local electronics supply dealers. Supporting documentation in the form of parts lists, schematics, wiring diagrams, and troubleshooting hints are provided in a commercial quality technical manual.

Summary and Conclusion

The information presented in Table 1 provides comparison of the FID and common methods of fault insertion. In general, the FID provides the instructor with a much needed capability for dynamic fault simulation that is not available with other common methods. Because the fault insertion time is minimal with a FID, the training efficiency (hands-on-time divided by course time), is increased 25-40% as compared to other methods. In general terms this translates to more lab time per student while keeping course length constant which equates to better training at lower cost.

Utilization of a microprocessor based Fault Insertion Device has proven to be the best approach to fault insertion available. The additional lab time gained due to time saved in fault insertion alone has had an effect on student achievement and training effectiveness. The ability to insert and remove faults quickly has significant training importance in the area of reinforcement. If a student becomes confused during a lab session, to the point he cannot remember how the equipment reacts when operating normally, the instructor simply removes the fault, demonstrates proper operation, and then reinserts the fault. While the application to operator training has yet to be fully explored, it is readily apparent that "realtime" fault insertion can be directly related to demonstrating "degraded mode operations". For the system level technician the FID represents the only method to fully stimulate all the built in troubleshooting aids, such as BIT and On-Line-Diagnostics, available.

Based on the information presented in this paper, it is evident that the microprocessor based fault insertion technique is a more training effective and efficient method of providing controlled fault insertion than either the static PFM or instructor inserted approach. The benefits of the FID will be realized both during initial training program development and across the life cycle of the curriculum, including anticipated system and equipment updates and changes.

TABLE 1. COMPARISON OF FID/PFM/INSTRUCTOR FAULTING TECHNIQUES AND TRAINING EFFECTIVENESS

CRITERIA	FID	PFM	INSTRUCTOR
1. Standardized Faults/Symptoms	1. Completely standardized upon installation	1. Standardized with formal issue; can become non-standard over time	1. Varies instructor to instructor
2. Time needed to activate (lab time lost)	2. 10-20 seconds per fault	2. 20-30 minutes over PFM group (equipment shut-down needed)	2. 30-40 minutes per fault - includes equipment restoration
3. Transparent to Student	3. Yes	3. Generally Yes	3. Depends on instructor
4. Realism of fault conditions	4. High fidelity realism	4. High fidelity realism of fault types supported	4. Dependent on selection
5. Effect on training hardware	5. No wear-and-tear after installation; any FID equipment failure can be circumvented by Jumper Cards to avoid impacting prime hardware	5. Possible degradation over time. Also subject to insertion-created problems	5. Definite cause of equipment degradation
6. Ease of changing or adding faults	6. Given basic FID hardware suite, a simple field installation and wire list update can accommodate changes in a short time (estimate - 4 hrs)	6. Very rapid addition, with non-formal PFM's; full PFM development and procurement needed for controlled PFM's (estimate = 24 mos)	6. 30-40 minutes
7. Duplication of String of Training Equipment	7. Very low cost Only cost of additional h/w and installation. Can be performed immediately	7. Much higher cost Also schedule impact due to procurement cycle for PFM	7. Low initial cost but much higher maintenance costs

BIOGRAPHY

Mr. Lance Young is a systems engineer with the trainer research and development department of Hughes Aircraft Company's Ground Systems Group. Mr. Young brings thirteen years experience in training systems development including ten years with fault insertion methodology to his position as project engineer for fault insertion systems.

His previous twenty years service in the Navy, the last six as training program coordinator with the Chief of Naval Technical Training, provides insight to the specialized needs of military training.