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Multiple Processors vs. A Single Processor In Attribute Measurement Systems

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SUMMARY
Competing design proposals for data acquisition and analysis components in an attribute measurement system (AMS) differ in the processor (CPU) specifications, and in the distribution and tasking of the processors. Primary design considerations include the number of CPU's, their locations within the system, and their processing assignments. Because the processor system must communicate with multiple measurement collection units, viable design options include the use of one multitasking CPU or multiple single-tasking CPU's.

After a comprehensive comparison, the authors advocate the use of multiple, single-tasking CPU's rather than a single, multitasking unit (Tables 1.a and 1.b). This comparison is made on the basis of anticipated attributes for generic systems. Detailed comparisons in each of the categories require formal system descriptions, which are beyond the current scope of this effort.

The multiple processor design provides distinct advantages for AMS hardware and software simplicity, certification, authentication, repair times and failure modes, processing capabilities, and information security. The single processor design has advantages for apparent hardware simplicity (i.e., the visual perception of simplicity), integration, system size, and communication network security. Ties are recorded for physical security, the cost of processor acquisition, and processing system reliability.

Table 1.a. A Categorical Comparison of Processor Design Solutions.

Category	Advantage To		
	Multiple Processor	*Single Processor*	*Tie*
Hardware/Software Functional Simplicity	•		
Hardware Apparent Simplicity		•	
Hardware Integration		•	
Physical Size of the Processing System		•	
Processor Certification	•		
Processor Authentication	•		
Duration of Processor System Unavailability and Repair Time	•		

Table 1.b. A Categorical Comparison of Processor Design Solutions (Continued).

Category	Advantage To		
	Multiple Processor	*Single Processor*	*Tie*
Restriction of Processor Failure Modes and Criteria	•		
Processing Mode Capabilities	•		
On-Processor Information Security	•		
On-Network Information Security		•	
Physical Security			•
Reduced Cost of Acquisition			•
Processor System Reliability			•

INTRODUCTION

An AMS allows qualitative assessments to confirm declarations for nuclear material properties without divulging classified information. Differences among competing design proposals for an attribute measurement system include the specifications for computer processor (CPU) control of the measurement subsystems, and for the distribution and task-devotion of the processors. Primary design considerations include the number of CPU's in the system, and their processing assignments among many possible system control distribution plans.

A proposed design solution uses several small microprocessors in the data gathering system to implement different functions. An alternative proposal is to use only one processor to perform all the functions in multitasking operations. In this paper, we present advantages and disadvantages of each approach. Because advantages for the multiple processor implementation are disadvantages for the single processor configuration and visa-versa, both advantages and disadvantages are presented in the context of the multiple processor implementation. The disadvantages of the multiple processor implementation are understood to be advantages of the single processor configuration.

ADVANTAGES OF A MULTIPLE PROCESSOR DESIGN

The use of a multiple processor design for the attribute measurement system confers advantages in the categories of simplicity of function, certifiability, authenticatability, modularity, length of system recovery and repair time, system development time, failure criteria and modes, processing modes, and information security. There is no significant advantage for either solution in the category of physical security of communication and power lines.

Simplification

Simplicity is a desirable system design characteristic that may enhance system reliability. Simplicity additionally accelerates maintenance and repair operations, and eases certification and authentication activities. A multiple processor solution is preferable for achieving a high degree of system simplicity.

A multiple CPU design employs a basic single-tasking operating system and limited instruction set on each processor. A simple processor running a basic operating system is easier to inspect than a single processor running a more complex multitasking operating system. This observation is consistent with the findings of a working group formed to review information barrier system concepts, which has recommended that extraneous code and complex operating systems be avoided.[1] A simple design facilitates visual inspection of the physical layout of the CPU's, cables, interconnections and interfaces to other hardware. An advantage of a multiple processor solution is that the physical architecture better mimics the functional architecture. It is therefore easier to visually inspect a multiple processor design with a smaller number of traces and connections at each of the dedicated CPU's, and a limited distribution of interfaces among CPU's, because the required function of each CPU is simpler than for the single processor design. Additionally, the multiple CPU solution better facilitates the removal and replacement of individual processors because fewer interconnections exist at each processing node and because simple single-tasking software requires only a limited suite of diagnostic checks following installation. Finally, the hierarchical software structure that is inherent to the multiple CPU solution better compliments the hierarchical physical architecture.[2]

Certification

Certification and attestation of the AMS are performed by the party hosting the measurements (i.e., usually the steward of the nuclear materials). Certification and attestation ensure that the AMS adequately protects sensitive information while operating in a secure acquisition mode. It is more efficient for the hosts to certify a simple processor running a basic operating system than a single processor solution running a more complex multitasking operating system. From the certification standpoint, a network of simple processors, each running a basic operating system and instruction set, can be evaluated on a node-by-node basis to ensure operational integrity. Compared to a single processor design, the multiple CPU design is better distinguishable in terms of component functionality and dedication of purpose. The functional dedication facilitates systematic inspection processes consisting of a series of simple checks that are specific to a given processing node. Because individual CPU tasks are dedicated, and reduced compared to the single multi-tasking CPU design, it is easier to identify execution errors, aberrant and unauthorized operations at a given node. Smaller CPU stacks and layers of boards can be used for each processor, thereby reducing the likelihood that undetected programmable logic or persistent memory is present, or that extraneous functionality exists. With simpler instruction sets, smaller sizes for executable single-tasking programs on each CPU, and dedicated function, the multiple CPU design allows minimization or elimination of unused sections of memory so that they are not exploited for covert data storage or code execution. Memory optimization for the intended processing operation also provides impediments to the execution of self-modifying code. Similarly, with the functional dedication and reduced number of interconnections at a single processor in the multiple CPU solution, the certification of inputs and output connections at processing nodes is simpler than for the single CPU option.

Authentication

Authentication is performed by the party monitoring the measurements. Authentication activities provide assurance that the AMS implementation provides genuine and accurate output. Accurate output is demonstrated by the evaluation of reference materials in an open (non-secure) measurement mode. The benefits of a multiple CPU design to the authentication procedures are analogous to those for certification procedures. The multiple CPU design facilitates the authentication process in three major categories: abilities to conduct (1) detailed examination of equipment, (2) functional and (3) system performance testing.

Multiple processor implementations may include standardized hardware components to allow for module exchange. For a modular CPU design, a single processor is considered to be an interchangeable module. Replacements for the CPU hardware components of multiple subsystems can be stored in a reduced (compared to a single CPU solution involving multiple expansions) spare parts inventory that consists of a single type and model of processor board, perhaps with the exception of the software PROM. The use of standard modular hardware allows random component selection from a larger pool of replacement parts. Because the same part may be used for components in multiple subsystems in a modular, interchangeable component design, it is less likely that a defect or engineered vulnerability in the replacement can be successfully exploited for installations in all eligible subsystems. The use of a random hardware selection procedure in situations where the host supplies the hardware, therefore, provides authentication process advantages that are amplified where modular CPU designs are employed. Moreover, these modules are inexpensive. Additionally, if all of the modules (processor systems) are identical with the exception of the software PROM, replacement of a failed module is faster. Two existing attribute measurement system designs with specifications for multiple processors use single board computers conforming to a PC-104 architecture to achieve a degree of modularity.[1,3]

Recovery and Repair Times

For identical types of CPU failure, the time to system repair and the duration of system unavailability can be reduced with a multiple processor design, relative to a single processor design. System state-of-health software can identify a failure in a single module, and notify the operator of the problematic module. Prior attribute measurement system designs conduct operator notification by use of an unclassified output error signal that crosses the data barrier.[4] More detailed error messages would probably require operator access to diagnostic messages that reside within the information barrier security enclosure, and may need to be preceded by an active purge of sensitive information. The distribution of control and processing tasks among dedicated CPU's makes problem isolation and identification simpler; the characteristic of the failed function indicates the problematic node and operation in a multiple processor design. Finally, the replacement of the failed processor requires installation and manipulation of a limited number of connections for the multiple processor design (e.g., see Reference 4, p. 10, Fig. 8). Processor replacement would be a standard and rapid operation where modular components are concerned.

The scope of diagnostic and operational integrity checks for a replacement module in a multiple processor design can be limited to tests for the proper operation of the affected subsystem. The

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