Answers to Common Questions about PALcode for Alpha AXP Systems

PALcode, which stands for privileged architecture library code, has generated considerable interest among customers, partners, and system designers. This booklet provides answers to common questions about PALcode, including:

- What is PALcode and what does it do?
- When and why do you need to customize PALcode for your hardware platform?
- What are the PALcode resources available to you?

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PALcode Description

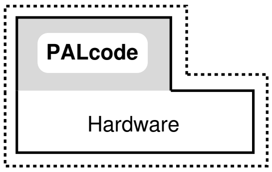
The Alpha AXP architecture has many strengths – one of the most important is that it runs equally well with many different operating systems. This strength comes from PALcode, the privileged architecture library for the Alpha AXP architecture, which provides a mechanism to implement and control low-level chip functions. By changing the PALcode, the system designer can provide customized hardware functions for different operating systems or embedded control programs on any Alpha AXP microprocessor utilizing a variety of platforms.

Because PALcode already exists for Windows NT, OSF/1, and OpenVMS on Alpha AXP platforms, most system designers use the corresponding PALcode without any modifications. However, some system designers require unique low-level chip functions and need to modify the PALcode; these modifications are usually minor. To assist you, PALcode sources, support, and training are available from Digital.

PALcode has evoked considerable interest from system designers. Here are the answers to some of the most common questions asked about PALcode.

What does PALcode do in an Alpha AXP system?

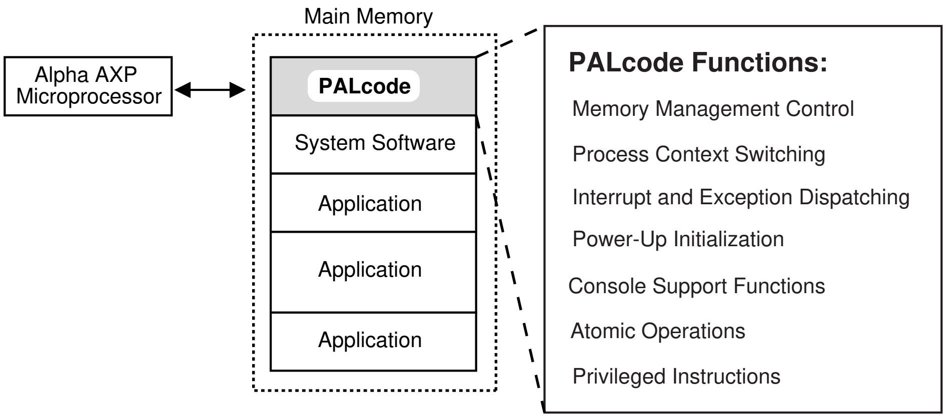
The PALcode and the hardware combine to complete the architecture for an Alpha AXP system. In an Alpha AXP system, PALcode serves as an interface between the hardware and the operating system. The PALcode can be adapted to support many different operating systems, which frees the hardware from being biased towards any particular operating system. The PALcode can also isolate the operating system from functional changes in the hardware to provide a consistent interface for your operating system. By customizing your own PALcode, you determine how the hardware fulfills the unique requirements for your operating system.



The combination of the hardware and the PALcode provides a complete architecture.

What is PALcode and how does it work?

PALcode is software that runs in a non-interruptable privileged hardware mode called PALmode. The PALcode software is written with the standard Alpha AXP instruction set plus some implementation-specific extensions. These implementation-specific extensions provide access to low-level chip functions for changing states, reading and modifying hardware control registers, and performing hardware assists for various functions. Using the instruction set and these extensions, your PALcode performs functions such as hardware initialization procedures, memory management, interrupt handling, and exception dispatching.



PALcode is software that provides access to low-level chip functions.

Why do I need PALcode?

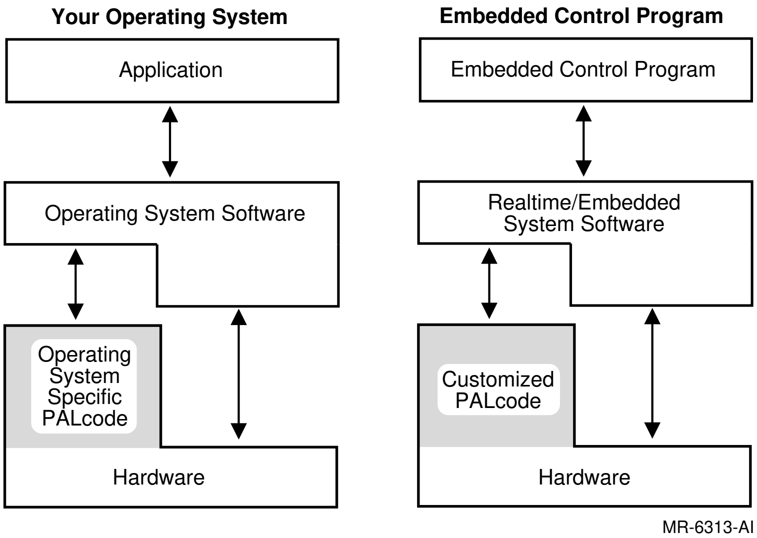
PALcode allows the Alpha AXP microprocessor to adapt easily to different operating systems and hardware platforms. Rather than *hardwiring* some of the functions in hardware or microcode, PALcode provides more flexibility in how these functions are executed. This allows you to create innovative PALcode functions for your system and not be limited to a hardwired architecture.

PALcode can perform the following operations:

- Transition the machine state to and from a PALcode environment called PALmode. While making the transition into PALmode, the Alpha AXP microprocessor stores the PC, disables interrupts, enables implementation-specific hardware functions, and disables instruction stream memory mapping.
- Perform atomic operations (a complex sequence of instructions that appears as a single non-interruptable operation), such as those used for translation buffer fills.
- Access and modify privileged internal processor registers, such as the process status register.

What type of interface does PALcode provide?

PALcode provides you with an interface that can be adapted to the needs of your operating system and hardware, and allows you to determine the structure of important low-level routines for: interrupt delivery and return, exceptions, context switching, memory management, system initialization, and error handling. These routines implement functions that form the privileged architecture library, which have controlled entry points, run with interrupts disabled, and can access hardware (implementation) registers. By modifying the PALcode, the system designer determines the best method for the hardware to fulfill the needs of the operating system, and to define the optimal interface between the PALcode and the operating system.



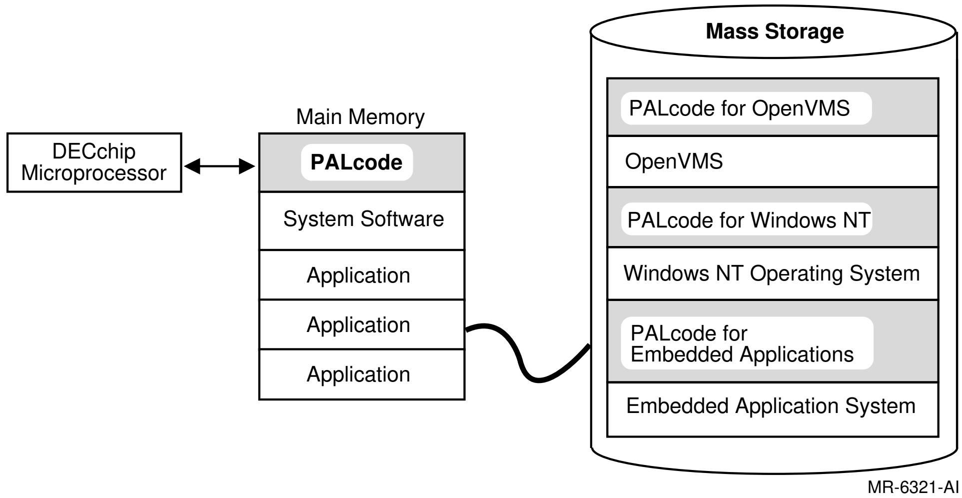
PALcode adapts the hardware to the requirements of the operating system.

How does PALcode define the interface?

PALcode allows you to modify protocols, access privileged registers, and vary the format of shared system data to define the interface between your hardware and operating system. This allows operating systems to change, and implementations of the Alpha AXP architecture to evolve, with PALcode providing a consistent interface for the system software across a variety of Alpha AXP microprocessors.

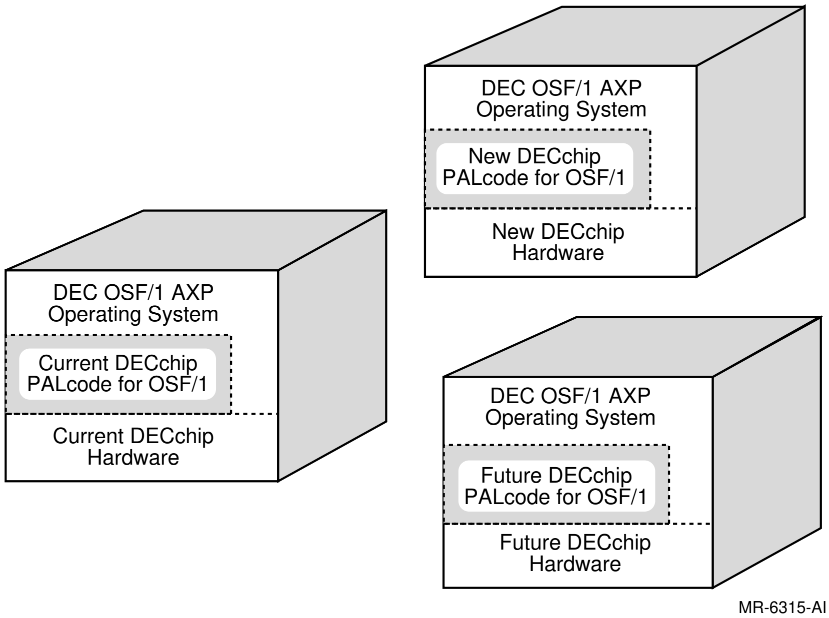
By defining the interface, PALcode allows the system designer to create:

- A variety of operating systems or embedded applications to run on a hardware system, where each operating system or embedded application has a corresponding PALcode image.



One hardware platform runs many different operating systems.

- An operating system or embedded application to run on a variety of hardware systems, where each hardware system has its own PALcode that provides a consistent interface.



One operating system runs on many different hardware platforms.

Where does the PALcode reside?

The PALcode software resides in a protected area of memory, similar to the system's kernel. The loss of memory, however, is negligible to the system because PALcode occupies such a small amount of memory – usually less than 32K. The exact size of your PALcode will depend upon how many functions you implement, and how elaborate you make each function.

What determines the size of my PALcode?

The size of your PALcode is determined by the unique requirements of your hardware platform and operating system. The more elaborate PALcode functions you require, the larger your PALcode will be. However, most system designers are able to use the existing PALcode with little or no changes.

How do I determine my PALcode requirements?

Your PALcode is determined by the following three requirements:

1. **PALcode needs to correspond to the low-level functions of the particular Alpha AXP microprocessor.** A variety of Alpha AXP microprocessors are becoming available, each with unique low-level features that require a matching PALcode implementation.

2. **PALcode needs to correspond to the functions of your platform.** Every hardware platform has unique attributes that provide input/output, external storage, backup cache, reset, interrupts, machine checks, and so on. Each of the attributes on your platform requires a matching PALcode implementation.

3. **PALcode needs to correspond to the structure of the operating system or embedded application.** Every operating system or embedded application has a unique structure and set of protocols, and may require privileged access to specific microprocessor registers or the use of atomic functions. Your PALcode matches how the interface is defined between the operating system or embedded application and the hardware.

   Note: All of the PALcode requirements have already been determined and created for the Windows NT, OSF/1, and OpenVMS operating systems on all of the existing Alpha AXP systems. (Please see the *Alpha Architecture Reference Manual* for more information about PALcode requirements for operating systems.)

How does PALcode respond to my hardware needs?

PALcode responds to your hardware needs with a series of routines, with each routine responding to a particular hardware-activated event. Using PALcode, you determine precisely how the routine responds to the following hardware-activated events:

- Reset
- System hardware exceptions, such as a machine check or arithmetic exception
- Memory management exceptions
- Interrupts

How is PALcode accessed?

All PALcode routines are dispatched either by a hardware-activated event or from the architected software interface (a CALL_PAL instruction). In the Alpha AXP system, hardware-activated events such as exceptions, interrupts, and memory management faults dispatch PALcode routines that are not accessible by users.

However, users can dispatch CALL_PAL routines in software with a CALL_PAL instruction. Unlike hardware-activated routines, all CALL_PAL routines are classified as either *privileged* or *unprivileged.* As the following table shows, privileged CALL_PAL functions can be called only by programs that execute in kernel mode, while unprivileged CALL_PAL functions can be called by any program.

This type of function...	Is dispatched from...
Hardware-activated routines	Interrupts, exceptions, or memory management faults
Privileged CALL_PAL routines	Programs that run only in kernel mode
Unprivileged CALL_PAL routines	Any program

How can Digital help me write PALcode?

Digital provides you with functional sample PALcode source files, standard assemblers, documentation, and the hardware tools necessary to write PALcode. Digital also offers training, and has an experienced support staff to assist you. Some designers start by modifying the sample PALcode kit for their particular hardware platform or operating system, while some use the sample PALcode kit only as a model.

Ordering PALcode Products

Digital offers documentation, training courses, software, and hardware to assist you with your PALcode needs. This section describes all of the services that Digital offers, and explains how to order the PALcode products.

What are Digital's PALcode products?

Digital provides an evaluation module and a functional sample PALcode source file in two products. The following table describes Digital's PALcode products.

Name of Product	Order Number	Description	Purpose
DECchip 21064 Evaluation Board Kit 150 MHz (Supports OSF/1 and Windows NT.)	21A01-03	Includes an evaluation module plus all of the related software and documentation listed for order number 21A01-13.	Use the evaluation board to perform hardware tests and to debug your system. Included in the evaluation board kit is the sample PALcode product, software, and documentation.
DECchip 21064 Evaluation Board Design Package and Software Tools	21A01-13	Includes a functional sample Alpha AXP PALcode for OSF/1, plus standard assemblers, linkers, checkers, and documentation.	Use the sample PALcode product for the OSF/1 operating system, or use it as an example to model your PALcode.

How do these PALcode products help me?

These products allow you to port, test, debug, and evaluate how well your software operates with your PALcode before your hardware platform is designed. Use the evaluation board for a hardware platform to perform hardware tests and to debug your system. Use Digital's sample PALcode product for porting to an OSF/1 environment, or as an example for modeling your PALcode. The following table provides more information about how the PALcode products help you.

<table>
<tr><th>Type of Product</th><th>Order Number</th><th>Operating System</th><th>How this Product Helps You</th></tr>
<tr><td>Evaluation board</td><td>Part of 21A01-03</td><td>Any operating system</td><td>Use the evaluation board to perform hardware tests and as a debug tool for your system.</td></tr>
<tr><td rowspan="2">Sample PALcode</td><td rowspan="2">Part of 21A01-13</td><td>OSF/1</td><td>Use the functional sample PALcode product for the OSF/1 operating system.</td></tr>
<tr><td>Any operating system</td><td>Use the sample PALcode product as an example for modeling your PALcode, or as a starting point for modifications to meet your needs.</td></tr>
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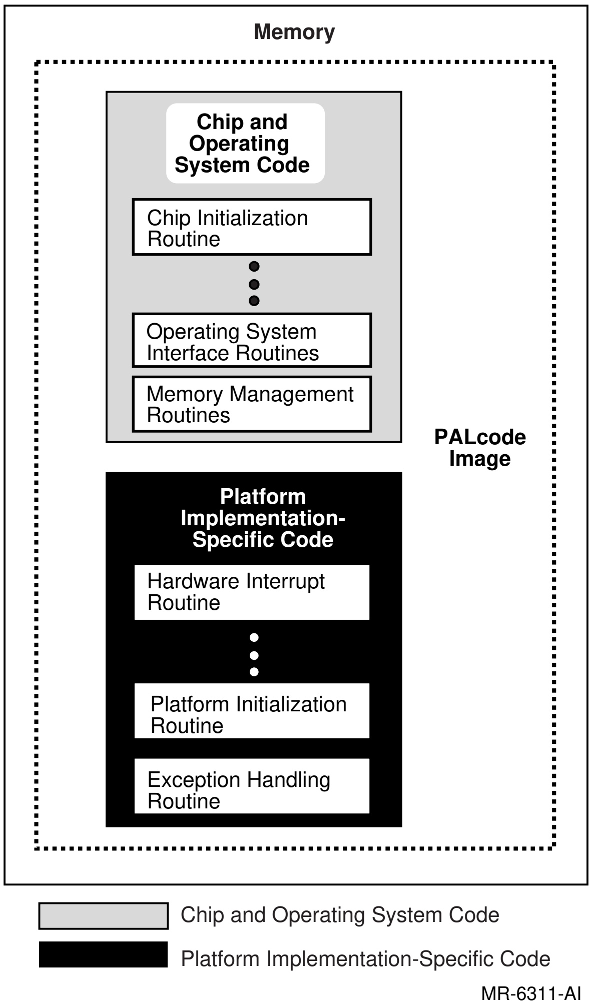
How is the sample PALcode product structured?

The sample PALcode product is partitioned into two major sections, with each section being a composite of many individual files. Every file has accompanying documentation that identifies the function of each file. The two sections are:

- **Chip and operating system**. This section contains files that pertain to a particular DECchip microprocessor and a particular operating system. Examples of these files include chip-specific initialization routines, the operating system interface, and memory management.
- **Platform implementation-specific**. This section contains files that pertain to a particular platform. Examples of these files include hardware interrupts, platform-specific initialization and reset procedures, and exception handling.



The PALcode image is a composite of many files partitioned into two sections.

How does PALcode share information with the system software?

The sample PALcode product and the system software share data through data structures called the PALcode parameter block and the hardware restart parameter block. The following table describes the system software data and where they are shared.

System software data	Description	PALcode and the system software share this data in...
Address of the hardware restart parameter block	A pointer to a data structure that is common between the firmware, PALcode and the operating system.	The PALcode parameter block
Initial state information	This includes the kernel stack pointer and the page table base register.	The hardware restart parameter block and the PALcode reset routine
Address of the impure area	A pointer to a scratch area for logging machine checks.	The PALcode parameter block
System software entry point	The transfer address of the system software.	The PALcode parameter block

What products do I need to write, assemble, and debug PALcode?

You will need an Alpha AXP system running the OSF/1 operating system and the related software development tools listed in the product *DECchip 21064 Evaluation Board Design Package and Software Tools* (order number 21A01-13). Digital can also provide you with product briefs, data sheets, reference manuals, user guides, and other detailed documentation.

What are the tools required to write PALcode for OSF/1?

The following table briefly describes some of the tools required to write PALcode for OSF/1.

Tool	Type of Tool	Purpose of Tool
GAS	GNU assembler	Produces PALcode object files
GLD	GNU Loader	Links GAS object files
PVC	PALcode Verification Checker	Checks for PALcode timing and coding violations

What documentation and training exists for PALcode?

Digital offers a complete line of documentation and training for all of its Alpha AXP products. This includes the:

- *DECchip 21064 PALcode System Design Guide* (Order Number EC-N0543-72)
- *Modifying and Building PALcode* course (Course Number EY-Q152E-S0)

What are the licensing requirements for PALcode?

There are no licensing requirements associated with the sample PALcode product. This includes the modification, reselling, and distribution of the sample PALcode product.

How do I obtain PALcode support?

Digital is committed to making you successful by offering a full range of support. This includes training, documentation, and an experienced support staff. The following table describes how to obtain PALcode support.

If you need...	In the U.S.A. or Canada, call...	Outside the U.S.A. and Canada, call...
Training	1-800-DIGITAL	Your local Digital sales office.
Evaluation Board Documentation	1-800-DIGITAL	Your local Digital sales office.
Alpha Architecture Reference Manual (EY-L520E-DP-YCH)	1-800-DIGITAL	Your local Digital office or technical or reference bookstore where Digital Press books are distributed by Prentice Hall
Technical support and information about DECchip microprocessors	1-800-DEC-2717	1-508-568-6868
A TTY phone number for technical support and information about DECchip microprocessors	1-800-DEC-2515 (Only in the U.S.A.)	–

How do I order the PALcode kit?

Contact DECdirect or your local Digital sales office. To order the PALcode kit:

- In the United States and Canada, call 1-800-DIGITAL.
- Outside the United States and Canada, contact your local Digital sales office.