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OpenVMS Backup Products: ABS/MDMS and Data Protector Compared

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Overview

HP offers two backup applications for the OpenVMS operating system at this time: the Archive Backup System/Media and Device Management Services (ABS/MDMS) application and the Data Protector application. This article will point out the similarities and differences between the two, in order to help in the selection process between the products. There are also other backup applications from third-party vendors but this article will not cover them.

ABS/MDMS has been the go-forward application of choice for OpenVMS for a number of years. Development of ABS/MDMS has included new functionality as well as support for the latest devices and operating system releases. HP has also been developing the Data Protector product for many years as well. Formerly known as Omniback, this product is not OpenVMS-centric. It was developed for the large enterprise where multiple operating systems are deployed along with a Storage Area Network (SAN), direct accessible, or network tape devices.

Similarities

ABS/MDMS and Data Protector have the same basic purpose: to provide an automated method of managing backups, volumes, and devices in a user-friendly manner. Some of the areas where the two applications parallel each other are outlined below.

Automatic Backups:

Both products are software that automates backups in an unattended, lights-out environment saving staffing costs particularly in the non-primetime schedules. These products also allow for backups to take place 24 x 7 x 365 and with the flexibility to schedule around holidays and other special days where backups are not required. The products can also run on a predetermined schedule so that different interval backups are performed including weekly, monthly, and yearly.

Data Protection:

Both ABS/MDMS and Data Protector provide data protection by backing up critical data and system files on a regular and predetermined basis. The applications also provide a method of rebuilding a system from the ground up in case of catastrophic outage. Each product has built-in flexibility and methods for saving data. For example, ABS/MDMS can provide image and incremental frequency of backups to ensure the most complete protection with the least amount of recovery time required.

Data Management

Each application manages the data that it backs up via a system of catalogs so that data is easy to find. Once the requested data is located within a catalog, a restore can easily be initiated. These restores can be scheduled for unattended processing as well. ABS/MDMS and Data Protector both use a system of catalog databases that can be created as needed on each system. These files not only allow for easy lookup but also provide a method for retaining data for a predetermined length of time.

Media Management

Both Data Protector and ABS/MDMS manage the media that are used for backup operations. This assures that only the volumes that you require are used, stored, and recycled at their proper times. In the case of Data Protector, it also manages volumes used from different platforms.

Scalability

Both products are considered scalable in that backups can be accomplished from small servers to large clusters of systems. Also, disks connected via SCSI to large disk arrays and data farms can be protected. Disks out on the network, disks located on a SAN, or any other device that can be seen from OpenVMS DCL can be backed up using these products. Both products will manage when and how each of the available devices will be used.

High-performance Backups

As well as using different types of interconnects for access to drives and libraries, these products are able to implement backups to the latest high-performance drives. This allows for the smallest backup window possible. They can also execute backups to drives simultaneously so that peak performance can be achieved using all resources within a large library.

Tape Library Support

These applications provide support for high-performance tape devices as well as a large number of tape libraries, most of which are the latest shipping products available. Qualification is done on both products as soon as a new device is released to ensure that the product keeps running successfully when equipment is upgraded or replaced. Libraries also provide a method for developing a lights-out facility.

Central Administration

ABS/MDMS and Data Protector provide systems manager the ability to manage backup operations from a single point. At its server level, Data Protector provides a cell manager and a cell client. This strategy allows for the grouping of servers and portions of the environment for backups. At the enterprise level, Data Protector provides access via the OpenView Operation Console or through a distributed GUI. ABS/MDMS provides the DCL interface to manage its policies and objects along with a GUI that can be viewed from an OpenVMS system or a Windows-based workstation. ABS/MDMS groups its environment by domain allowing for security boundaries and backup granularity throughout the datacenter.

Disk Staging

For faster backups, both Data Protector and ABS/MDMS can stage their backups to disk. Once the data is on disk, normal production can resume and the staged data backup then sent to tape. Writing to disk is always faster then sending off to tape and this method of backup reduces the typical bottleneck caused by IOs to tape.

Disaster Recovery (DR) Support

Both products are designed to recover a data center in case of catastrophic outage regardless of cause. Documentation and suggestions for setting up a DR strategy are included and the ability to test a recovery is also possible. The key to any DR is the amount of time it takes to recover. Which product is faster is dependent on the current environment and the availability of backup equipment.

Flexibility

These products have some flexibility. But that flexibility is limited to prevent users from getting themselves into trouble by over-customizing their environments. The ability to shutdown and startup applications prior to backup is available as well as the ability to execute some DCL programming via pre- and post-processing command procedures. This functionality typically gives users the flexibility to accomplish backups according to their company policy.

File Attributes

When a file backup takes place on both Data Protector and ABS/MDMS, the following information is backed up:

- File and directory attributes
- Access Control Lists (ACL)

Both products can also back up from any mounted FILES-11, ODS-2, or ODS-5 disk volumes.

Locked Files

Data Protector has a –lock option that can allow the backup of files that have been opened and locked for write. This coincides with the OpenVMS backup qualifier /ignore=interlock, which allows as much of the open files to be backed up as possible.

Include and Exclude File Specifications

Data Protector uses the –skip and –only options to parallel the OpenVMS backup syntax of /include and /exclude. These qualifiers allow for selecting or omitting certain files from the dataset. Both products can use "*" and "$" for wildcarding within files specifications.

Intel® Itanium® Support

Both backup applications are fully supported on the Intel® Itanium® platform. Data Protector's latest OpenVMS client has been ported to Itanium® as well as the latest versions of ABS/MDMS. This is important to consider as some of the older backup application such as SLS are not being moved to Itanium®.

Oracle Database Backup

ABS/MDMS and Data Protector both have the ability to perform hot backups of Oracle 9i and 10i databases with 11i now being qualified. Backups can be written to tape or disk and information about the backup tracked in catalogs for easy restore.

Differences

When it comes to concepts of a backup and archiving application, ABS/MDMS and Data Protector have many similarities. However the functionality and process of how the backup is achieved is different. This section attempts to show many of these differences and how they may affect the backups of a particular environment.

Server versus Agent

The first difference seen between the two products is how each one is viewed on the OpenVMS system. Data Protector views OpenVMS systems within cells as an agent. Agent software needs to be loaded on any OpenVMS system to be backed up. From the Data Protector Cell manager these nodes show up as OpenVMS agents and backups can be initiated from this point. There is also a CLI available on the OpenVMS agent. Note that an additional software kit is required to be loaded for CLI access. Information about backups performed on the OpenVMS system is kept on the Data Protector Server. Data Protector runs its server software on HP-UX, Windows, or Linux operating systems. One of these servers will need to be available in a datacenter in order to use Data Protector to back up OpenVMS nodes.

The advantage for Data Protector is evident in environments where there are numerous operating systems that require backup. Data Protector can manage many different operating system agents from one location including HP-UX, Windows, and Linux. It can also back up numerous application agents including Informix, SQL, Exchange, and Oracle. Note that at this time the Oracle agent is not available for the OpenVMS operating system.

ABS/MDMS uses the OpenVMS system as a server and performs all its management from a selected OpenVMS node. All ABS/MDMS databases are stored on the server. The ABS/MDMS GUI runs on the OpenVMS machine or a Windows server and accesses these databases. Only one node is required to be a server at one time. However, ABS/MDMS has the ability to have standby nodes making failover possible and preventing downtime should the primary server become unavailable.

The advantage for ABS/MDMS comes in environments where OpenVMS is the predominate operating system. This is particularly helpful at sites where user skills are primarily OpenVMS. It also makes it easier to back up data domains where the only operating system is OpenVMS. No other platform is required to complete the backup.

Backup Formats

Data Protector uses its own proprietary backup format to save data to tape. This data stream includes catalog information about the tape for quick access and retrieval. By using this format, Data Protector can also provide functionality such as multi-streaming of data to single or multiple tapes simultaneously. This format also provides data redundancy on the tape volume for medium verification using CRC.

ABS/MDMS uses the native OpenVMS backup image to write to tapes. It can take advantage of all backup functions and qualifiers available to the image. ABS/MDMS directly uses the BACKUP.EXE image found with the SYS$SYSTEM directory. When ECOs are applied to the systems that affect this image, ABS/MDMS will immediately take advantage of their application. No updates to the application or reboots to the system need to be done. And because the data on tape is in saveset format, native OpenVMS backup can be used to restore without the ABS/MDMS application being available. This is particularly important in disaster recovery situations.

Media Management

Data Protector has the ability to manage devices and media within a heterogeneous network environment with servers of different operating systems that need to use the same library and sets of

tapes. Data Protector can manage this scenario by keeping track of what is written on each tape and by what operating system. The advantage is that an entire datacenter can be seen as one entity and there is no concern over the type of data being written to certain tapes. It makes best use of the Storage Area Network (SAN) tapes and libraries that are available.

ABS/MDMS provides for homogeneous backups within the OpenVMS environment. Its media manager can coordinate traffic coming to SAN libraries from OpenVMS nodes. It does not, however, interact with other operating systems that may be connected to the SAN. Libraries will need to be dedicated to OpenVMS use only so sites that primarily have data stored on storage connected to OpenVMS systems will be a good fit for this configuration. This is particularly true where the operating system expertise exists for OpenVMS only. ABS/MDMS can provide backups for Windows and Tru64 UNIX platforms via agent software. Functionality to back up these platforms is minimal and is most useful when a small amount of data needs to be backed up,

Disaster Recovery

The ability to recover from a disaster is most critical for any backup application. Also key is the amount of time that it takes to make the recovery. An event that requires a bare metal restore of a system can prevent production from taking place and cause high economic impact to a company.

ABS/MDMS has the ability to capture image backups of any disk. This is important for the system disk and will allow the restore to create a "bootable" disk. Image restores of a data disk provide the ability to defrag the disk and increase performance. ABS/MDMS has the advantage in that backups created through the application can easily be used and restored using the native backup image. In the case of a complete system disk rebuild, only the location of the tape needs to be found to be restored. ABS/MDMS does not have to be running to begin the restore.

Data Protector does not have the ability to run an image backup. Because of this limitation, a full system disk restore will not be bootable until a writeboot to place the boot block back out onto the disk is performed. However, the OpenVMS system will need to be booted from some location to run the writeboot image. This requires strategic planning to ensure this is possible.

Network and Direct Backups

ABS has the ability to back up remote nodes located on the network using the Remote Device Facility (RDF). RDF causes tape devices to look local to the remote node. In order to perform these backups, ABS/MDMS needs to be installed and licensed on the remote nodes and appear as a client to the ABS/MDMS server.

To Data Protector, all OpenVMS nodes appear as agents. All server software is located on an HP-UX, Windows, or Linux operating system. To back up a remote OpenVMS node, the client software needs to be installed and configured there. Once completed, the management GUI will be able to view that node.

Data Protector also has the ability to back up network-attached storage using network data management protocol (NDMP). It can also perform a "direct backup" using SNIA x-copy, where data is sent directly to the storage device and not through the server. ABS/MDMS does not have this functionality.

Oracle Backups

ABS/MDMS provides the ability to back up RDB style backups using the RMU facility. These backups are managed within the ABS/MDMS catalogs for easy restore.
Data Protector does not have this ability although an Oracle RDB agent for OpenVMS is currently in the plans for a future release.

File Specifications

ABS/MDMS uses the standard OpenVMS syntax when entering file specifications in either the command line or the GUI. For example, backing up a users login.com file from a disk might look like:

```
$1$DGA100:[USERS.DOE]login.com;1
```

ABS will expect to see the file specification in this format.
Data Protector uses a UNIX style file specification for OpenVMS backups. In the case of the above file specification, Data Protector requires the following format:

```
/$1$DGA100/Users/Doe/login.Com.1
```

Unlike the OpenVMS standard, Data Protector has no explicit version number. A version number always has to be defined or no file will be backed up.

Installation and Directory Structure

The Data Protector OpenVMS Agent software is installed using the PCSI facility. Its files are kept in a directory structure within the system software directory structure:

```
SYS$SYSDEVICE:[VMS$COMMON.OMNI]
```

ABS/MDMS is installed using the SYS$UPDATE:VMSINSTAL.COM procedure. By default its directory tree is created at:

```
SYS$SYSDEVICE:[SYS0.SYSCOMMON.MDMS.] and
SYS$SYSDEVICE:[SYS0.SYSCOMMON.ABS.]
```

ABS/MDMS does allow for the changing of this directory structure to a new device at installation time.

Startup and Shutdown Files

To handle startup and shutdown of Data Protector the following files are provided:

- `SYS$STARTUP:OMNI$STARTUP.COM` – This command procedure starts the Data Protector service.
- `SYS$STARTUP:OMNI$SYSTARTUP.COM` – This command procedure defines the OMNI$ROOT logical name. Any other logical names required by this client may be added to this command procedure.
- `SYS$STARTUP:OMNI$SHUTDOWN.COM` – This command procedure shuts down the Data Protector service.
- `OMNI$ROOT:[BIN]OMNI$STARTUP_INET.COM` – This command procedure is used to startup a new TCP/IP INET process, which then executes the commands sent by the Cell Manager.
- `OMNI$ROOT:[BIN]OMNI$CLI_SETUP.COM` – This command procedure defines the symbols needed to invoke the Data Protector command line commands. Execute this from the login.com procedures for all users who will be using the CLI interface. This file will only exist on the system if you chose the CLI interface option. Several logical names are defined in this procedure, a procedure that is necessary to execute the CLI commands correctly.

ABS/MDMS has the following files available for startup and shutdown:

- SYS$STARTUP:ABS$STARTUP.COM – This command procedure is used to startup the ABS backup engine software. Note that this will startup MDMS as well.
- SYS$MANAGER:ABS$SYSTARTUP.COM – This command procedure is used to put site-specific information for ABS. This command procedure is called during the run of ABS$STARTUP.COM.
- SYS$STARTUP:MDMS$STARTUP.COM – This command procedure can be used to start MDMS alone.
- SYS$MANAGER:MDMS$SYSTARTUP.COM – This command procedure is used to set site-specific information about the MDMS application.

Application UAF Accounts

Data Protector creates a UAF account called OMNIADMIN to handle its OpenVMS administration work during the run of backups. OMNI services (processes) on the OpenVMS system also run under this account. It has a login directory of OMNI$ROOT:[LOG]. Log files for the startup of INET are placed in this directory along with any debug files.

ABS/MDMS creates two accounts from which it runs its processes and backups; ABS and MDMS$SERVER. Their login directories are ABS$ROOT:[000000] and MDMS$ROOT:[SYSTEM].

Device Support

The MDMS portion of ABS/MDMS manages tape devices and volumes. It is included as part of the install of the application and no additional software is needed to ensure that connectivity is available to OpenVMS tape devices. ABS/MDMS documentation explains how to set up the drives to be used for backups.

Data Protector is based on a non-OpenVMS operating system. In order to use devices locally attached to the OpenVMS system, an additional software package, the Data Protector Media Agent, must be installed. Data Protector README.TXT files have more information on installing this software.

Both products follow the OpenVMS device support matrix to ensure that any recently purchased libraries or tape drives are usable. Check the OpenVMS software product description (SPD), Release Notes, or online support pages for the latest supported devices.

Summary

Which software to use in a particular environment will be dependent on a number of factors:

- What operating system is predominant in the environment? Environments that have mostly OpenVMS servers may find ABS/MDMS more feasible for them.
- Are your libraries and devices used by more than one operating system? Data Protector will be the application that can manage multiple systems to a library or device. ABS/MDMS will require that a library be dedicated to an OpenVMS system.
- On which operating system does most of the data reside? If it is mostly on OpenVMS, ABS/MDMS may prove most efficient. However, if there are large SQL, Exchange, or other applications or databases on other operating systems, Data Protector can back those up along with your OpenVMS system.
- What type of operating skills does your staff have? If your staff is OpenVMS centric, then ABS/MDMS may prove to be the best choice. You should do an analysis of how much it will cost to hire new skills such as those required for HP-UX.

- How fast must a disaster recovery take place? If OpenVMS is the primary operating system in the datacenter and quick, flexible restores are required, ABS/MDMS may be the best choice. If there are other operating systems, however, their restore time and criticality need to be considered.
- Is there particular OpenVMS backup functionality that is needed or required? Data Protector will be somewhat of a cultural change for users and the list of qualifiers that backup owns is not available. You should carefully consider what types of backups and their associated functionality are required before deciding on an application.

Another deciding factor is the cost of the application. Your choice of one product or the other depends on your environment, current applications running, and future growth considerations.

For more information

You may contact the author at

OpenVMS Technical Journal V9

Alignment Faults – What Are they and Why Should I Care?

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Overview

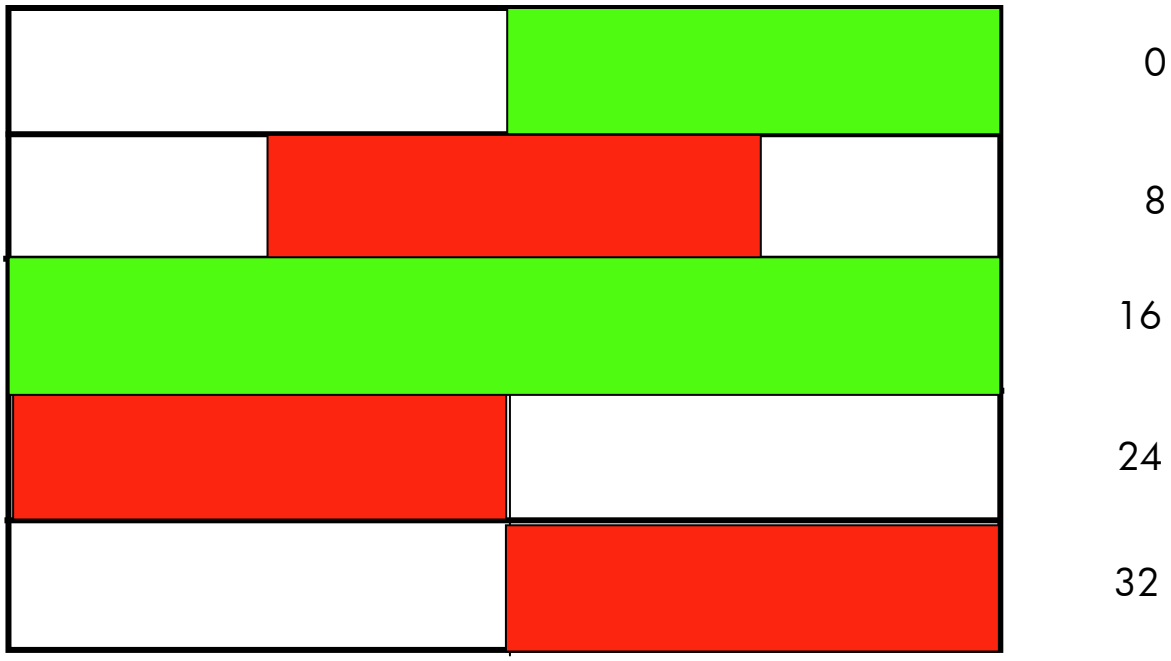
The article explains what alignment faults are, describes how alignment faults impact application performance, presents ways to detect alignment faults on a running system, and provides a few ideas on fixing alignment faults.

What is an Alignment Fault?

AlphaServer and Intel® Itanium® 2 processors provide fast access to naturally aligned data. To be naturally aligned, a word datum must be on a word boundary, a longword datum must be on a longword boundary, and a quadword datum must be on a quadword boundary.

When an attempt is made to load or store a quadword, longword, or word to or from a memory location that does not have a naturally aligned address, the processor transfers control to a special routine (PALcode on AlphaServer systems and an operating system routine on Intel® Itanium® 2 systems) to execute a series of instructions to perform the unaligned access. The step of executing a special set of routines to access unaligned data is referred to as alignment fault.

The following diagram illustrates the difference between aligned and unaligned memory access:



In the first row, we access a longword starting with address 0 that is naturally aligned so all is well. In the second row we attempt to access a longword starting at address 10. This address is not naturally aligned (10 divided by 4 does not yield a remainder of 0). Alignment fault will occur in this case. In the third row, we attempt to read a quadword starting at address 16 that is naturally aligned (16 divided by 8 yields a remainder of 0) so all is well. In the fourth row, we attempt to access a quadword starting at address 28. Address 28 is not quadword aligned so an alignment fault will occur.

Okay…I understand Alignment faults but why should I care?

When the compiler can detect misaligned data, what would normally take three instructions on an AlphaServer system will take fifteen. As not all of these instructions access memory, the aggregate degradation in performance is an instruction stream that is three times slower. When the compiler cannot correct the problem, a run time alignment fault is incurred. The alignment handler is about ten to twenty times slower than accessing naturally aligned data.

The behavior of an Intel® Itanium® 2 system is similar to the AlphaServer, except that alignment faults are hundreds to thousands of times slower than accessing naturally aligned data, as alignment faults are handled by the operating system itself instead of PAL code (firmware). There is also a system-wide impact for resolving alignment faults. This impact is due to the requirement for spinlock (MMG) and associated MP synchronization time.

Let's take a look at a small example. The following program allocates 1 GB of virtual memory in P2 space and randomly increments 50,000,000 quadwords.

```
$ ty aligned.c
#include <far_pointers>
#include <gen64def>
#include <ints>
#include <starlet>
#include <stdio>
#include <stdlib>
#include <lib$routines.h>
#include <unistd.h>
```

```
#include <stsdef>

#define random_key(upper_bound) (abs (random () % upper_bound))

void main()
{
int             NumberOfBytes    =      1000000000;     // 1GB using marketing bytes
int             status;
VOID_PQ         MappedVA;
INT64_PQ        RandomVA;


        lib$init_timer();               // initialize timer

        //
        // Allocate 1GB from P2 space
        //
        status = lib$get_vm_64 (&NumberOfBytes, &MappedVA);

        if (!$VMS_STATUS_SUCCESS(status))
        {
                lib$signal (status);
                return;
        }

        RandomVA = MappedVA;

        for (int i=0; i<50000000; i++)
        {

                // Increment a random Quadword
                RandomVA [random_key((100000000/8) -1)] ++ ;

        }

        //
        // Free VM
        //
        status = lib$free_vm_64 (&NumberOfBytes, &MappedVA);

        if (!$VMS_STATUS_SUCCESS(status))
        {
                lib$signal (status);
                return;
        }

        lib$show_timer();
}

$! Run the program – rx2600 1.3 GHZ
$ cc/pointer=long aligned
$ link aligned
$ r aligned
```

```
 ELAPSED:    0 00:00:18.97  CPU: 0:00:18.97  BUFIO: 0  DIRIO: 0  FAULTS: 713808
$
```

Incrementing 50,000,000 random quadwords on a 1.3 GHz Integrity rx2600 Server took 18.97 seconds.

Now, let's force the above program to increment 50,000,000 quadwords using unaligned pointers:

```
$ ty not_aligned.c
#include <far_pointers>
#include <gen64def>
#include <ints>
#include <starlet>
#include <stdio>
#include <stdlib>
#include <lib$routines.h>
#include <unistd.h>
#include <stsdef>

#define random_key(upper_bound) (abs (random () % upper_bound))

void main()
{
int             NumberOfBytes    =      1000000000;     // 1GB using marketing bytes
int             status;
VOID_PQ         MappedVA;
INT64_PQ        RandomVA;


        lib$init_timer();               // initialize timer

        //
        // Allocate 1GB from P2 space
        //
        status = lib$get_vm_64 (&NumberOfBytes, &MappedVA);

        if (!$VMS_STATUS_SUCCESS(status))
        {
                lib$signal (status);
                return;
        }

        //
        // Force the pointer to become unaligned
        //
        RandomVA = (INT64_PQ)((char *) MappedVA + 1);


        for (int i=0; i<50000000; i++)
        {
```

```
                // Increment a random Quadword
                RandomVA [random_key((100000000/8) -1)] ++ ;

        }

        //
        // Free VM
        //
        status = lib$free_vm_64 (&NumberOfBytes, &MappedVA);

        if (!$VMS_STATUS_SUCCESS(status))
        {
                lib$signal (status);
                return;
        }

        lib$show_timer();
}

$ cc/pointer=long not_aligned.c
$ link not_aligned
$ r not_aligned
 ELAPSED:    0 00:03:45.62  CPU: 0:03:45.53  BUFIO: 0  DIRIO: 0  FAULTS: 200027
$
```

The same 1.3 GHz Integrity rx2600 Server increments 50,000,000 unaligned quadwords in 3 minutes and 45 seconds.

For our small test program, performance degrades by more than *12 times* when accessing unaligned data.

Detecting Alignment Faults

Now that you are all convinced that alignment faults are bad for performance, let's take a look at various tools provided by OpenVMS for detecting alignment faults:

- MONITOR ALIGN (V8.3)
- FLT extension in SDA
- Symbolic Debugger

MONITOR ALIGN

OpenVMS V8.3 introduced a new class for the monitor utility. The align class monitors alignment faults currently occurring throughout the system and breaks out the output per mode.

The following display was generated while running the NOT_ALIGNED program:

```
$ monitor align/int=1

                            OpenVMS Monitor Utility
                          ALIGNMENT FAULT STATISTICS
                                on node IT13
```

```
                        21-NOV-2006 01:50:13.26

                                      CUR        AVE        MIN        MAX


   Kernel Fault Rate                 0.00       0.44       0.00       4.00
   Exec   Fault Rate                 0.00       0.00       0.00       0.00
   Super  Fault Rate                 0.00       0.00       0.00       0.00
   User   Fault Rate            445492.00  220809.67       0.00  445492.00

   Total  Fault Rate            445492.00  220810.12       0.00  445492.00
```

Our test program generates more than 445,000 alignment faults per second, all in user mode.

MONITOR ALIGN provides a high-level overview of alignment faults currently occurring on the system. It helps detect alignment faults and warns that the system is suffering from alignment faults. But MONITOR ALIGN does not provide any information about which process or program generated the alignment faults. MONITOR ALIGN is intended to help and determine if you are suffering from alignment faults. Different tools should be used to determine what is generating the faults. Note that MONITOR ALIGN is currently available on Intel® Itanium® 2 systems only.

FLT Extension in SDA

Once you determine that your system is prone to alignment fault issues, the next step is to determine where the faults are coming from. The FLT extension in SDA is a very powerful tool for detecting and logging alignment faults. For each alignment fault that occurs while logging is enabled, it logs the time the fault occurred, the CPU encountering the fault, the unaligned Virtual Address, access mode, and process id. This information allows the developer to determine the exact location in the application which generated the alignment fault. The FLT extension is available on both AlphaServer and Intel® Itanium® 2 systems.

Here are few examples demonstrating the use of FLT

```
$ ana/sys

OpenVMS system analyzer

Load the SDA extension

SDA> flt load
FLT$DEBUG load status = 00000001

Start tracing …

SDA> flt start trace
Tracing started...

Look at the summary display

SDA> flt show trace/sum
```



```
Fault Trace Information: (at 21-NOV-2006 02:07:21.87, trace time 00:00:00.190015)
-------------------------------------------------------------------------------
Exception PC              Count   Exception PC                          Module
Offset
----------------   ------------   -----------------------------------  ---------------------------------
-
00000000.000103D1          39384   SYS$K_VERSION_16+00391
00000000.000103E1          39383   SYS$K_VERSION_16+003A1
```

Two Program Counters are displayed pointing to PC 103D1 and 103E1, each PC generated more 39834 faults. Let's find our culprit, instead of looking at the summary output we can look at individual entries in the trace buffer for more information:

```
SDA> flt show trace

Unaligned Data Fault Trace Information:
---------------------------------------
Timestamp             CPU  Exception PC                                  Unaligned VA       Access
EPID    Trace Buffer
--------------------- ---  --------------------------------------------  -----------------  ------  ----
----  -----------------
21-NOV 02:08:22.002794  00  00000000.000103E1 SYS$K_VERSION_16+003A1        00000000.840BECF9  User
2160057F  FFFFFFFF.7E4E86C0
21-NOV 02:08:22.002791  00  00000000.000103D1 SYS$K_VERSION_16+00391        00000000.840BECF9  User
2160057F  FFFFFFFF.7E4E8658
21-NOV 02:08:22.002789  00  00000000.000103E1 SYS$K_VERSION_16+003A1        00000000.84617049  User
2160057F  FFFFFFFF.7E4E85F0
21-NOV 02:08:22.002786  00  00000000.000103D1 SYS$K_VERSION_16+00391        00000000.84617049  User
2160057F  FFFFFFFF.7E4E8588
21-NOV 02:08:22.002784  00  00000000.000103E1 SYS$K_VERSION_16+003A1        00000000.8252A0E1  User
2160057F  FFFFFFFF.7E4E8520
21-NOV 02:08:22.002781  00  00000000.000103D1 SYS$K_VERSION_16+00391        00000000.8252A0E1  User
2160057F  FFFFFFFF.7E4E84B8
21-NOV 02:08:22.002779  00  00000000.000103E1 SYS$K_VERSION_16+003A1        00000000.850E3241  User
2160057F  FFFFFFFF.7E4E8450
21-NOV 02:08:22.002776  00  00000000.000103D1 SYS$K_VERSION_16+00391        00000000.850E3241  User
2160057F  FFFFFFFF.7E4E83E8
21-NOV 02:08:22.002774  00  00000000.000103E1 SYS$K_VERSION_16+003A1        00000000.84CD53D1  User
2160057F  FFFFFFFF.7E4E8380
21-NOV 02:08:22.002771  00  00000000.000103D1 SYS$K_VERSION_16+00391        00000000.84CD53D1  User
2160057F  FFFFFFFF.7E4E8318

……
```

All the entries are pointing to process with ID 2160057F, let's look at the process to find out what image it is executing:

```
SDA> set proc/id=2160057F
SDA> show proc/image

Process index: 017F   Name: Faulty           Extended PID: 2160057F
-------------------------------------------------------------------

                          Process activated images
                          ------------------------

              Image Name                    Type       IMCB          GP
------------------------------------ ------------ -------- -----------------
```

```
NOT_ALIGNED                              MAIN          7FE89290 00000000.00240000
DCL                                      MRGD     SHR 7FE88BD0 00000000.7B0D8000
LIBRTL                                   GLBL     SHR 7FE8BC10 00000000.7B546000
LIBOTS                                   GLBL     SHR 7FE8A690 00000000.7B560000
CMA$TIS_SHR                              GLBL     SHR 7FE88010 00000000.7B73C000
DPML$SHR                                 GLBL     SHR 7FE88270 00000000.7B904000
DECC$SHR                                 GLBL     SHR 7FE883A0 00000000.7BB10000
SYS$PUBLIC_VECTORS                       GLBL         7FE886C0 FFFFFFFF.8CA00400
SYS$BASE_IMAGE                           GLBL         7FE88920 FFFFFFFF.8CA24E00

Total images = 9                         Pages allocated = 322
SDA> map 0103E1
Image                                          Base               End          Image Offset
NOT_ALIGNED
    Code                                 00000000.00010000 00000000.0001059F 00000000.000103E1
SDA>
```

We found out that all the alignment faults are generated by process "Faulty" executing the NOT_ALIGNED image. Next step would be to look at the listing and determine the offending code in offset 103E1.

Before we look at the listing, the FLT extension can interpret the location of the faulting PC if the image contains traceback information and if it lives in system space. Now, let's install NOT_ALIGNED.EXE as resident image, it will force the image to be copied into system space:

```
SDA> flt stop trace
SDA> spawn instal add/resi SYS$SYSDEVICE:[PELEG]NOT_ALIGNED
SDA> flt start trace
Tracing started...
SDA> flt show trace/summ

Fault Trace Information: (at 21-NOV-2006 02:13:23.77, trace time 00:00:00.190637)
-------------------------------------------------------------------------------
Exception PC              Count   Exception PC                          Module
Offset
----------------   ------------   -----------------------------------   ---------------------------------
-
FFFFF802.11EFE3D1         39384   NOT_ALIGNED+103D1                     NOT_ALIGNED
000103D1
                                  NOT_ALIGNED + 000003D1 / main + 000002D1
FFFFF802.11EFE3E1         39383   NOT_ALIGNED+103E1                     NOT_ALIGNED
000103E1
                                  NOT_ALIGNED + 000003E1 / main + 000002E1
SDA>
```

We start tracing again, now the summary display show the exact location in the image that generated the fault. In our example this is routine main+2D1 and main +2E1 in NOT_ALIGNED.EXE.

Let's look at relevant portion of the listing in NOT_ALIGNED.LIS

```
001000000046     0240          (pr6)  break.m 1048577
00C7080121C0     0241                 setf.sig f7 = r9
```

```
018402242200     0242              cmp4.lt pr8, pr0 = i, r34 ;;            // pr8, pr0 = r33, r34
// 023707
                         }
                         { .mfi
00C708006180     0250              setf.sig f6 = r3                    // 023711
000008000000     0251              nop.f   0
000008000000     0252              nop.i   0 ;;
                         }
                         { .mfi
000008000000     0260              nop.m   0
0000E000E240     0261              fcvt.xf f9 = f7
000008000000     0262              nop.i   0
                         }
                         { .mfi
000008000000     0270              nop.m   0
0000E000C200     0271              fcvt.xf f8 = f6
000008000000     0272              nop.i   0 ;;
                         }
                         { .mfi
000008000000     0280              nop.m   0
000630910280     0281              frcpa.s1 f10, pr6 = f8, f9
000008000000     0282              nop.i   0 ;;
                         }
                         { .mfi
000008000000     0290              nop.m   0
018448A021C6     0291        (pr6) fnma.s1 f7 = f10, f9, f1
000008000000     0292              nop.i   0 ;;
                         }
                         { .mfi
000008000000     02A0              nop.m   0
010438A142C6     02A1        (pr6) fma.s1  f11 = f10, f7, f10
000008000000     02A2              nop.i   0
                         }
                         { .mfi
000008000000     02B0              nop.m   0
010438700186     02B1        (pr6) fma.s1  f6 = f7, f7, f0
000008000000     02B2              nop.i   0 ;;
                         }
                         { .mfi
000008000000     02C0              nop.m   0
0104508001C6     02C1        (pr6) fma.s1  f7 = f8, f10, f0
000008000000     02C2              nop.i   0 ;;
                         }
                         { .mfi
000008000000     02D0              nop.m   0
010430B16286     02D1        (pr6) fma.s1  f10 = f11, f6, f11
000008000000     02D2              nop.i   0 ;;
                         }
                         { .mfi
000008000000     02E0              nop.m   0
0184389102C6     02E1        (pr6) fnma.s1 f11 = f9, f7, f8
000008000000     02E2              nop.i   0
                         }
                         { .mfi
000008000000     02F0              nop.m   0
018448A02186     02F1        (pr6) fnma.s1 f6 = f10, f9, f1
000008000000     02F2              nop.i   0 ;;
                         }
```

```
                        { .mfi

main + 2D1 and main + 2E1 point to line number 23711 in the source:

     1   23707        for (int i=0; i<50000000; i++)
     2   23708        {
     2   23709
     2   23710                // Increment a random Quadword
      2   23711                RandomVA [random_key((100000000/8) -1)] ++ ;
     2   23712
     1   23713        }

The next step logical step would be fixing the program to avoid unaligned memory access.
```

Symbolic Debugger

The symbolic debugger can be used for detecting alignment faults. The SET BREAK/UNALIGN command will cause the debugger to break each time an alignment fault occurs. The faulting Virtual Address, the current PC, and the source line that generated the fault will be displayed:

```
$ run/debug not_aligned

         OpenVMS I64 Debug64 Version V8.3-009

%DEBUG-I-INITIAL, Language: C, Module: NOT_ALIGNED
%DEBUG-I-NOTATMAIN, Type GO to reach MAIN program

DBG> set break/unaligned
DBG>
* SRC: module NOT_ALIGNED -scroll-
source**********************************************************************************
****
 23703:         // Force the pointer to become unaligned
 23704:         //
 23705:         RandomVA = MappedVA + 1;
 23706:
 23707:         for (int i=0; i<50000000; i++)
 23708:         {
 23709:
 23710:                 // Increment a random Quadword
->3711:                 RandomVA [random_key((100000000/8) -1)] ++ ;
 23712:
 23713:         }
 23714:
 23715:         //
 23716:         // Free VM
 23717:         //
 23718:         status = lib$free_vm_64 (&NumberOfBytes, &MappedVA);
 23719:
```



```
* OUT -
output*****************************************************************************************
**
Unaligned data access: virtual address = 0000000081E0E7E1, PC = 00000000000103E2
break on unaligned data trap preceding NOT_ALIGNED\main\%LINE 23711+402
 23711:                RandomVA [random_key((100000000/8) -1)] ++ ;


DBG>

NOTE: SET BREAK/UNALIGNED can not be used while the FLT utility is in use. When FLT is
running, attempting to use the debugger for reporting alignment faults will fail with the
following error:

DBG> set break/unalign
%SYSTEM-E-AFR_ENABLED, alignment fault reporting already enabled
-FOR-W-NOMSG, Message number 00189E80
DBG>
```

Guidelines for Fixing Alignment Faults

The perfect application avoids alignment faults completely; however life is not always perfect. Alignment faults are likely to be encountered when a module that declared unaligned data calls a routine in another module that does not anticipate receiving unaligned data. Remember that alignment faults are bad on AlphaServer systems, but are *really* bad on Intel® Itanium® 2 systems.

Some alignment faults are easy to fix, some are very hard, and some are close to impossible. Here are the most popular ways of fixing alignment faults:

- Align the data.
- Hint to the compiler that the data about to be accessed is (or may be) unaligned.
- Copy the data to an aligned buffer.

Align the Data

Aligning the data is the best solution for avoiding alignment faults.

Today's compilers are smart enough to detect alignment faults problems most of the time and add code to access the data through multiple loads, shifts, and masks.
Sometimes it is not possible or not practical to align the data. Such examples would be when transferring data between systems or when reading/write from/to fixed record layout in a file.

Make sure fields within data structures are naturally aligned. Some compilers like C and C++ do this by default. In MACRO, use .align [quad|long]. In SDL, use basealign [quad|long]

Hints to the Compiler

Programming languages may support declaration modifiers that will cause predicated code to be generated that will test for unaligned data and operate on it in such a way as to preclude alignment faults.
Language support includes:

Alignment faults…what are they and why should I care? – Guy Peleg

- __unaligned (C)
- .set_registers unaligned=<Rx> (Macro)
- align(x) (Bliss32/Bliss64)
- aligned(x) (Pascal)

Using the options will eliminate the alignment faults. However, code accessing aligned data will be slower than normal.

Remember – the extra code generated when giving hints to the compiler that data maybe unaligned will *perform much better than hitting an alignment fault*.

Let's modify the NOT_ALIGNED program to declare that the pointer for the random data is unaligned:

```
$ ty not_aligned.c
#include <far_pointers>
#include <gen64def>
#include <ints>
#include <starlet>
#include <stdio>
#include <stdlib>
#include <lib$routines.h>
#include <unistd.h>
#include <stsdef>

#define random_key(upper_bound) (abs (random () % upper_bound))

void main()
{
int             NumberOfBytes    =      1000000000;     // 1GB using marketing bytes
int             status;
VOID_PQ         MappedVA;
INT64_PQ        RandomVA;


        lib$init_timer();               // initialize timer

        //
        // Allocate 1GB from P2 space
        //
        status = lib$get_vm_64 (&NumberOfBytes, &MappedVA);

        if (!$VMS_STATUS_SUCCESS(status))
        {
                lib$signal (status);
                return;
        }

        //
        // Force the pointer to become unaligned
        //
```

```
        RandomVA = (INT64_PQ)((char *) MappedVA + 1);

        for (int i=0; i<50000000; i++)
        {

                // Increment a random Quadword – pointer now declared unaligned
                __int64 __unaligned *MyData = &RandomVA [random_key((100000000/8) -1)];
                *MyData = *MyData + 1;

        }

        //
        // Free VM
        //
        status = lib$free_vm_64 (&NumberOfBytes, &MappedVA);

        if (!$VMS_STATUS_SUCCESS(status))
        {
                lib$signal (status);
                return;
        }

        lib$show_timer();
}
$ cc/pointer=long not_aligned.c
$ link not_aligned
$ r not_aligned
 ELAPSED:    0 00:00:20.74  CPU: 0:00:20.67  BUFIO: 0  DIRIO: 0  FAULTS: 703741
$
```

Now our program completed in 20.74 seconds…this is a big improvement comparing to 3 minutes and 45 seconds when the compiler was not expecting unaligned data.

Copying the Data

The last option for fixing alignment faults is to copy the data to an aligned buffer. This approach is useful when the data itself is aligned but the buffer containing the data is not.

If the amount of data that needs to be moved is small and many references are made to it, then copying the data is a good idea. However, if the quantity of data to be moved is large and only a small number of references are made to it, then it is better to take a few alignment faults and leave the data alone.

Summary

From a performance standpoint, Alignment faults are expensive on AlphaServer systems but are VERY expensive on Intel® Itanium® 2 systems. For achieving good performance on the latter, alignment faults need to be resolved. OpenVMS allows monitoring alignment faults using the MONITOR ALIGN command, the FLT extension in SDA, and the debugger.

To avoid alignment faults, naturally align the data, declare pointers to be unaligned, or copy the data to an aligned buffer where it makes sense.

For more information

To get to the latest issue of the OpenVMS Technical Journal, go to:
http://www.hp.com/go/openvms/journal

Author Bio

Guy Peleg joined BRUDEN-OSSG last September, he is a Senior Member of the Technical Staff and Directorof EMEA Operations. Prior to joining BRUDEN-OSSG, he was a software engineer in the OpenVMS Engineering group working on the various utilities. He was part of the team ported OpenVMS to Integrity Server Platforms (IPF), he lead the LMF port to IA64, the EDCL project and various virtualization projects on IPF. Before joining Engineering, Guy provided customer support and consulting with Compaq/DEC in their field offices. He is known worldwide for his commitment to the OpenVMS customer. He has given numerous technical presentations and has been published in the OpenVMS Systems Technical Journal. His presentations are entertaining and highly informative.

OpenVMS Technical Journal V9

Methodologies for Fixing Alignment Faults

Ajo Jose Panoor, OpenVMS DECnet Engineering

Overview

The OpenVMS operating system is one of HP's key operating systems and has been successfully ported to the Intel® Itanium® 2 architecture. As a strategy, one of the foremost initiatives is to provide performance improvements for the operating system including other layered components on the Intel® Itanium® 2 architecture. The "alignment faults" on OpenVMS were expensive and led to performance degradation Fixing this became a focus area for us.

Most of the layered products on OpenVMS were found to have alignment faults that had to be addressed. This paper describes the methods followed to fix the alignment faults in OpenVMS DECnet Itanium. DECnet-Plus being a networking protocol, any performance degradation arising from the protocol stack has major implications on overall system performance and utilization. Hence, it was mandatory to address the alignment faults. These methods can be adopted for use on any OpenVMS product on the Intel® Itanium® 2 architecture. Fixing alignment faults can significantly boost performance, not just of the application, but of the overall system as well.

This article describes the methods followed to fix the alignment faults in DECnet. DECnet-Plus V8.3 on the Intel® Itanium® 2 architecture is the most recent version and includes the fixes for alignment faults.

Memory Alignments and Alignment Faults

Based on the architecture, a processor requires its data/variables to reside at particular offsets in the system's memory. For example, a 32-bit processor requires a 4-byte integer to reside at a memory address that is evenly divisible by 4. This requirement is called "memory alignment." Thus, a 4-byte integer can be located at memory address 0x2000 or 0x2004, but not at 0x2001. Alignment is thus the aspect of a data item that refers to its placement in memory.

The mixing of byte, word, longword, and quadword data types can lead to data that is not aligned on natural boundaries. When accessing these unaligned data we end up generating a fault. (A fault normally occurs when the instruction cannot complete and the Program Counter is left pointing at the instruction, and we have to rectify this fault to resume execution.) Normally, for each of the alignment faults, a fault handler is called for retrieving the data from the unaligned address, thereby using more CPU cycles. Thus, an alignment fault is a concern for performance, not for program correctness.

On AlphaServer systems, we had the LDx_U and STx_U instructions that allowed an unaligned access to be handled efficiently with a few instructions. The PAL (Privileged Architecture Library) code manages the alignment issues with applications on the VAX and Alpha architectures. However the Intel® Itanium® 2 hardware does not support PAL and any memory access to unaligned data results in an alignment fault.

Alignment faults on the Intel® Itanium® 2 architecture introduce additional software overhead as access to memory is serialized with spin locks. This results in performance degradation. More software overhead and spin lock contention results in draining valuable CPU cycles. The challenge is to eliminate the generation of alignment faults for performance improvement.

Types of Alignment Faults

An alignment fault is normally generated while a read or write of 'N' bytes occurs on an address that is not an integral multiple of the size of the data in bytes. The occurrence can be generalized as follows:

- Reading/writing a word that is not on a word boundary.
- Reading/writing a longword that is not on a longword boundary.
- Reading/writing a quadword that is not on a quadword boundary.

Ideally there should not be any alignment faults. But, while porting some legacy code, we may have unaligned data structures.

Standard Techniques for Resolving Alignment Faults

Following are some of the standard techniques used for resolving alignment faults:

- The best solution is to align the data itself.
- The next option is to teach the compiler that the data is unaligned so that it may generate more instructions to avoid alignment faults.
- The final option is to copy the data to an aligned buffer and use it.

Techniques adopted to resolve DECnet Alignment faults

The following are the causes for alignment faults in DECnet:

- An unaligned structure.
- Comparison of unaligned data.
- Bit field access from unaligned address.
- DECnet fork blocks placed in unaligned addresses.

In most alignment fault hits, the faulty addresses generated are caused by complex calculations or from some runtime values. In such cases, we need to find the exact location where the unaligned address is generated and fix the problem appropriately. We made use of the TR_PRINT macro to find the exact location of alignment faults. Each case was treated separately and analyzed before adopting the appropriate technique.

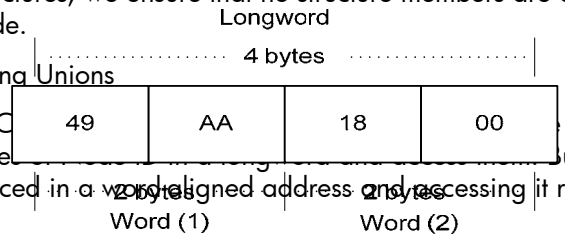
Note: Because DECnet is a networking protocol, we had to take care not to modify the structures (or Protocol Data Units (PDUs)) that are sent through the wire. Moreover, the structure offsets which are accessed through symbols or constants in code (some bit fields offsets in BLISS sources) are also not modified in consideration of code stability.

Following are the methodologies used to resolve the alignment faults:

Structure Rearrangement

We had several structures that were unaligned. In one such case most of the members were a combination of "length" (2 bytes or word) and "address" (4 bytes or longword) and the arrangement was leading to subsequent address fields placed in unaligned addresses. Hence the fields are rearranged such that the address fields are aligned on longword boundaries. In such cases "fillers" can also be added to make proper alignment (Structure Padding). In locations where we modify the

structures, we ensure that no structure members are accessed through hard-coded definitions in source code.



Using Unions

DEC called IDNodeType. We store the low-order 4 byte ut, in some runtime allocations, the node ID is placed in a word-aligned address and accessing it results in alignment faults.

Figure 1 -- Union with one longword and two words

So a new union is introduced through which the Node ID can be accessed as a longword as well as two separate words as shown in figure 1. The longword access causing the fault is then replaced with two word accesses, thereby avoiding the alignment fault.

```
IDLow_u  UNION;
      IDLow      LONGWORD UNSIGNED;
      Low_s     STRUCTURE;
                   IDLow_1     WORD UNSIGNED;
                   IDLow_2     WORD UNSIGNED;
      END IDLow_s;
END IDLow_u;
```

Bit Field Access to get the Structure Fields

While extracting the network service access point (NSAP) length from the routing PDUs we always ended up in an alignment fault due to the following:

```
source_nsap = pdu [pdu$b_iso_address_part];
source_nsap_length =..source_nsap; ! - Alignment fault
```

In the second line for fetching a single byte we were making the compiler fetch 4 bytes (ld4 instruction) from an unaligned address and then used just one byte from it resulting in an alignment fault. Hence, using bit-field access, the fault is avoided. Here, the complier generates an ld1 instruction for fetching a single byte. (This method relies on the way instructions are generated by the complier, so behavior may vary based on the BLISS compilers)

```
source_nsap_length =.source_nsap[0,0,8,0];
```

Comparison of Unaligned Data

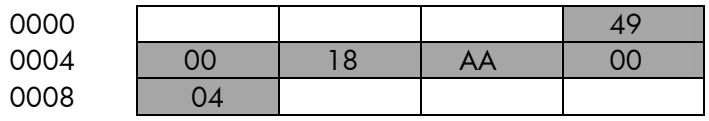


Figure 2 – Unaligned data

Comparison of the System ID which is 6 bytes is usually done as a 4-byte and 2-byte comparison. In cases where the memory is allocated from the pool and used at runtime, there is a chance of data storage as shown in the Figure 23, i.e., the allocation starts from an unaligned offset. So the first 4-byte comparison and the second 2-byte comparison also cause an alignment fault. In order to avoid the alignment fault, we can make a byte-by-byte comparison to avoid the alignment fault. Similarly, in

cases where a word alignment is found to be consistent, we adopted a word-by-word comparison to resolve the problem.

DECnet Fork Blocks placed in Unaligned Addresses

DECnet commands had a large number of alignment fault hits in the NET$FORK routine. (NET$FORK is a DECnet wrapper over the VMS Fork routine, EXE$FORK). The faulting address is found to be inside the VCRP structure allocated from the non-paged pool. (VCRP is a data structure used by network protocol stack to communicate between different layers). On formatting the address we found that the hitting address lies inside the fork block (FKB), which was placed from the start of the VCRP scratch area.

By default, VMS-FORK BLOCKS expects itself to be in a quadword-aligned address. But, the start of the VCRP Scratch area is not a quadword-aligned address and usage of the scratch area as a FORK BLOCK from that address caused the alignment fault. So, in order to make the fork block aligned, we moved the fork block to the nearest quadword-aligned offset from the beginning of the VCRP scratch area. Because VCRP is a common data structure used by other VMS networking products, we took extra care not to modify the existing structures but to move the fork block to the nearest quadword-aligned address without overflowing the scratch area. As a code fix, we generated a new symbol that has as its value the nearest quadword-aligned offset from the VCRP scratch address. The symbol VCRP$T_SCRATCH was the initial offset where the fork block was copied, and it has as its value 468 dec/1D4 hex which is not a quad word aligned offset. So a new structure is introduced for generating the symbol with its value as 472 dec/1D8 hex that is quadword aligned.

Teaching the Compiler

- Align (n) Qualifier for BLISS
  Align Qualifier tells the compiler that the data in the specified location is unaligned so that it generates extra code to handle this condition. At locations where the rearranging of structures or structure padding is not an option we normally go with teaching the complier to align naturally.

```
local
   tpdu    : REF ALIGN(0) BLOCK[,BYTE];
```

Figure 3 – Align Qualifier for BLISS

  Here the ALIGN (0) qualifier tells the complier to perform a byte access to any of the succeeding references to the tpdu variable. The compiler generates more instructions to meet the byte access, which is one of the main disadvantages of using this method.

- CH$MOVE – BLISS inbuilt for Byte-by-byte copy
  Alignment faults due to bit accesses from unaligned addresses were fixed by using CH$MOVE function. CH$MOVE does a byte-by-byte copy to move the appropriate number of bytes from the unaligned address to a local variable. It then uses that variable for accessing the required bits, thereby avoiding the faults. A drawback is allocating more temporary storage. Adding Align (n) is more appropriate if the number of hits is less.

- BIND "Type Field" with Align (n) qualifier for BLISS
  The operation of associating an address with a name is called binding. Complex references causing the alignment faults can be replaced by bind variables locally and an align (n) qualifier can be added to avoid the alignment fault.

- Set_registers unaligned/ Set_registers aligned Qualifier for Macro32
  "Set_registers unaligned/ Set_registers aligned" are the counterparts for Align qualifier in Macro32. For example,

```
.set_registers unaligned=<R3>
MOVL    R1,(R3)+
.set_registers aligned=<R3>
```

Figure 4 – Alignment Qualifier for Macro32

The content of R3 is an unaligned address and trying to access a longword from it generates an alignment fault. So the ".set_registers unaligned" directive is added to inform the complier that the content of register is unaligned. After accessing R3 the register is marked as an aligned one using the ".set_registers aligned" directive. This has to be reverted to “aligned” so that complier will not treat the register contents as unaligned for the rest of its access.

__unaligned	Directive used in C, indicates to the compiler that the data pointed to is not properly aligned
#pragma	nomember_alignment & member_alignment, for C structure padding
.align	Directive used in Macro32
Basealign	Directive used in SDL files

Figure 5 -- Other Compiler Directives

Tools and Utilities

- FLT SDA Extension

SDA provides a fault trace utility for finding the alignment faults. Loading and starting the FLT trace utility in SDA and running the program will provide the PC value of the instructions that causes an alignment fault.

- Monitor Align

The Monitor Align utility shows a statistical analysis of the alignment faults occurring in the system on different Execution Modes. The following table shows the alignment fault statistics taken over a small period of time after establishing almost one-hundred active DECnet connections.

MONITOR ALIGN	CUR	AVE	MIN	MAX
Kernel Fault Rate	27704.00	29114.74	26756.59	37276.94
Exec Fault Rate	0.00	0.07	0.00	6.80
Super Fault Rate	0.00	0.00	0.00	0.40
User Fault Rate	372.00	350.20	276.60	432.60
Total Fault Rate	28076.00	29465.02	27108.19	37613.87

Figure 6 -- Alignment fault statistics

After installing DECnet V8.3, where the alignment faults were fixed, the alignment fault rate reduced to a large extent for the same period of time.

MONITOR ALIGN	CUR	AVE	MIN	MAX
Kernel Fault Rate	23.00	21.42	12.99	99.00
Exec Fault Rate	0.00	3.70	0.00	164.50
Super Fault Rate	0.00	0.00	0.00	0.00
User Fault Rate	337.00	139.24	124.93	337.00
Total Fault Rate	360.00	164.37	137.93	373.50

Figure 7 – Alignment fault statistics in DECnet V8.3

Performance Analysis

Significant performance improvements were observed after fixing the alignment faults. The following table shows the comparison between the DECnet kit with and without alignment fault fixes after establishing almost one hundred active DECnet connections with minimal disk access. The alignment hit count was reduced significantly and the CPU utilization was reduced by 35%.

For a period of 3 minutes	Unaligned	Aligned
Alignment hit count	78,039	37
CPU Utilization	95%	60%

Figure 8 – DECnet kit with and without alignment fault fixes

References

- Alignment Faults and Performance - by Christian Moser.
- OpenVMS Internals – by Ruth Goldenberg/Lawrence Kenah/Denise Dumas/Saro Saravanan

For more information

Please contact the author with any questions or comments regarding this article at. To get to the latest issue of the OpenVMS Technical Journal, go to: http://www.hp.com/go/openvms/journal.

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Ajo Jose Panoor works for OpenVMS DECnet Engineering and was involved in fixing the alignment faults in DECnet. Ajo holds a bachelor's degree in Computer Science.

OpenVMS Technical Journal V9

OpenVMS Mailboxes: Concepts, Implementation, and Troubleshooting

Bruce Ellis, President, BRUDEN-OSSG

Overview

This article intends to cover mailboxes from the basic concepts through advanced troubleshooting. If you are just starting with mailboxes, you might want to read from the beginning to the basic examples. If you have experience with mailboxes you may want to move ahead to the troubleshooting section. Hopefully, there is something for everybody in this article.

Much of the implementation details, starting at the "Mailbox Creation" section are discussed in more detail in the *HP OpenVMS I/O User's Reference Manual* Chapter 4 and under the $CREMBX section of the *HP OpenVMS System Services Reference Manual.*

Inter-process Synchronization and Communication

OpenVMS processes provide an environment in which programs can be executed. This environment includes software context, hardware context, and virtual address space. The "divide and conquer" approach to problem solving allows different programs, running simultaneously under different processes, to take on parts of a task concurrently. To support this design, the processes need methods to communicate with one another and to synchronize, or coordinate, activities between the processes.

OpenVMS provides several methods for interprocess synchronization and communication. Methods for interprocess communication include shared files, logical names, mailboxes, and global sections (shared virtual memory). Inter-process synchronization methods include common event flags, mailboxes, and lock management services.

Shared files are generally slow methods of communication. Logical names are potentially faster than shared files, but extensive use may fragment paged pool. Global sections are probably the fastest form of interprocess communication. The one major drawback to each of these methods is that there is no built-in signaling mechanism to notify the target process that there is a need to obtain the new

data. In each case, the application could poll for new data, but this wastes CPU time and/or may cause delays in event notification.

For synchronization within a single system, common event flags have limited name space. You can only wait on one common event flag cluster at a time and there are only 32 (single-bit) event flags per cluster. Lock management system services are designed more for coordination of activities than signaling, although signaling mechanisms can be implemented using the lock management services. Mailboxes provide methods that allow processes to communicate with one another and to receive notification that there is data to be processed. In addition, there is an implicit queuing mechanism for multiple messages that have been written to the mailbox. The programming interface to mailboxes is simple to implement and can be written in just about any programming language, including DCL.

Mailbox Concepts

Mailboxes are pseudo-devices, similar to UNIX-style pipes. However, mailboxes allow bi-directional communication, i.e., a single process can read and write the same mailbox. Messages written to a mailbox are queued in first-in-first-out fashion. To implement pipe-oriented communication, channels can be assigned to a mailbox, such that the mailbox channel can only be written, or conversely, can only be read.

A mailbox can have multiple writers and multiple readers, although multiple reader designs are probably rarer than multiple writers. It is usually easier to implement a single reader of a mailbox (Figure 1).

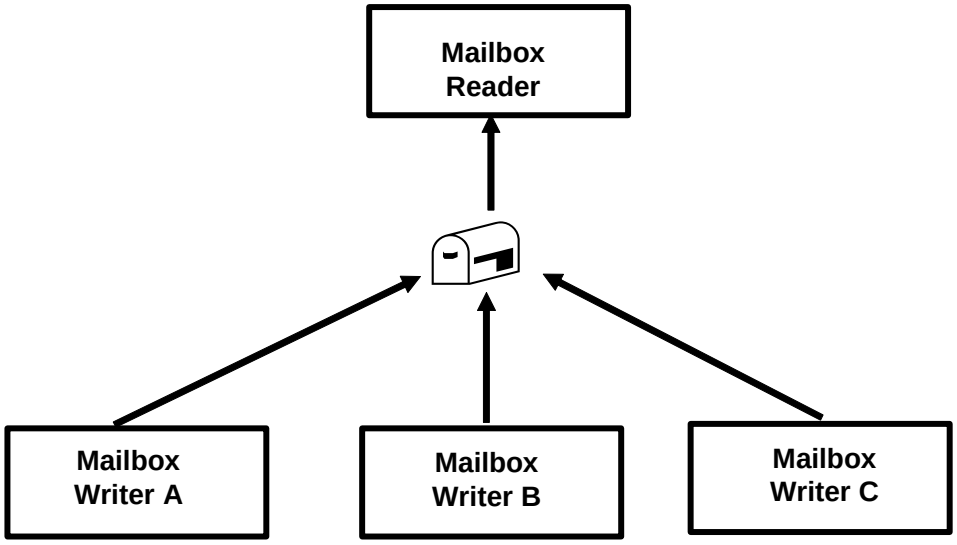

Figure 1. Sample Mailbox Design

When the writer wants to get messages back from the reader, it may use various methods, including creating a separate mailbox and passing along the mailbox unit number to the reader. The "reader" would assign a channel to the target mailbox unit and send a response as in Figure 2.

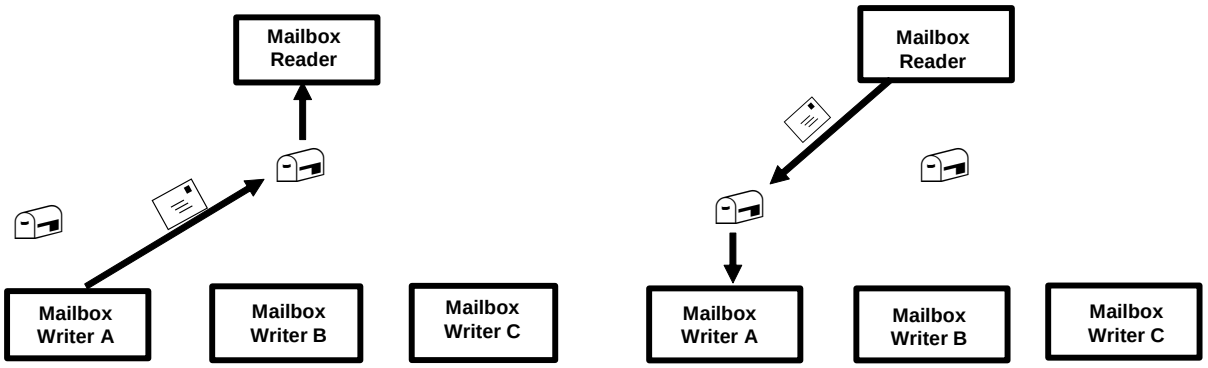

Figure 2. Communication between Mailbox Writer and Reader

In general, a mailbox read operation does not complete until there is a corresponding write operation. Similarly, write operations do not complete until there is a corresponding read operation. Applications that perform synchronous read or write operations will stall, waiting on an event flag (in the scheduling state LEF), until the counterpart operation is issued by another process.

Mailbox operations can be performed using high-level language I/O constructs, but more commonly are processed using the QIO (sys$qio) system service. The specifics of QIO operations on mailboxes are documented in chapter 4 of the *OpenVMS I/O User's Reference Manual.* Before you can issue a QIO on a device, a channel must be assigned. The channel identifies the device on your QIO system service calls. For more information on QIO and channels see chapter 23 of the *OpenVMS Programming Concepts Manual.*

Mailbox writes can be forced to complete immediately upon queuing by using a QIO system service function modifier (IO$M_NOW). This mechanism is different than performing an asynchronous QIO, in that the I/O request is not pending. What this means is that if a program that has issued a write using the IO$M_NOW modifier exits, its write stays queued to the mailbox, as long as some process on the system is interested in the mailbox (has a channel assigned to it). If a write was issued asynchronously without the IO$M_NOW modifier and the program exits, the write is canceled (when the channel to the mailbox is deassigned) and the write is lost.

Data that is written to the mailbox can be in any form and can vary in size. The mailbox driver simply treats the data as an array of bytes. The writer identifies the number of bytes being written to the mailbox. The size can vary from 0 to 64,000 bytes, dependent on the maximum message size assigned to the mailbox. The 64,000 byte limit is based on the fact that mailbox messages are allocated from non-paged dynamic memory (a.k.a. non-paged pool). Pool packets contain a word (16-bit) sized field to identify the amount of pool that the packet occupies.

The mailbox reader must supply a buffer that is large enough to hold the largest data item that will be written to the mailbox. To determine the number of bytes actually written, the reader should pass an I/O status block on a QIO to the mailbox driver. The reader can examine the size field in the I/O status block upon completion of the read.

Mailbox Creation

Before a mailbox can be used, it must be created. Mailbox creation is performed using the Create Mailbox (sys$crembx) system service. When a mailbox is created, it is assigned a name of the form MBA*u*, where *u* is a unit number assigned by OpenVMS. Prior to V8.2, OpenVMS limited the unit

numbers on mailboxes to 9999. Additionally, mailbox creation and deletion required sequential scans of all existing units, which could be a slow process. V8.2, and greater, systems were modified to support up to 32,767 mailbox units. The I/O database was optimized to speed the creation and deletion of mailboxes.

The program does not generally have knowledge of the mailbox device name that it is creating, as OpenVMS dynamically defines the name. To associate multiple processes to the same mailbox, processes usually identify the mailbox using a logical name. The logical name is passed by descriptor as the seventh argument to the sys$crembx system service call.

To create a mailbox at the DCL level you can use the command CREATE/MAILBOX.

Temporary and Permanent Mailboxes

The first parameter to sys$crembx is a flag that identifies whether the mailbox is a temporary or permanent mailbox. If the flag is set you get a permanent mailbox, otherwise you get a temporary mailbox.

Temporary mailboxes require TMPMBX privilege to create. They are deleted when all channels to the mailbox have been deassigned. The logical name passed to sys$crembx is cataloged in the logical name table identified by the logical name LNM$TEMPORARY_MAILBOX. By default, this logical name is assigned to LNM$JOB. Therefore, by default, using the logical name passed to the sys$crembx, system service associates processes in the same job to the same mailbox. Changes to this logical name are best made within the program, in user mode. Changes made at the DCL level may cause problems with SPAWN/ATTACH commands. If you do choose to change the logical name LNM$TEMPORARY_MAILBOX at the DCL level, make sure to change it in the LNM$PROCESS_DIRECTORY logical name table.

Permanent mailboxes require PRMMBX privilege to create and delete. They must be explicitly deleted using the sys$delmbx system service. The mailbox is actually deleted after all channels to the mailbox have been deassigned. The logical name passed to sys$crembx is cataloged in table identified by the logical name LNM$PERMANENT_MAILBOX. This logical name is set to LNM$SYSTEM by default.

If you are using DCL to create a mailbox, you can define that the mailbox will be temporary or permanent using the /TEMPORARY or /PERMANENT qualifiers, respectively. The default qualifier is /TEMPORARY. Just like the sys$crembx system service, you need TMPMBX privilege to create temporary mailboxes and PRMMBX privilege to create permanent mailboxes. You also need CMEXEC privilege to create a temporary mailbox. This privilege is required to allow the mailbox to be created in supervisor mode. The plan is to remove this restriction in the future. You may also need SYSNAM or GRPNAM privilege to create the logical name associated with the mailbox in the appropriate logical name table.

Permanent DCL-created mailboxes can be deleted using the DELETE/MAILBOX command. When all channels are deassigned the mailbox will go away. Currently, there is no supported way to deassign a channel to a DCL-created mailbox without logging out. Therefore, there is no supported way to delete a temporary mailbox without logging out. We at BRUDEN-OSSG, of course, have a method to get the channel deassigned.

Example 1. Viewing the Temporary and Permanent Logical Name Table Assignments

```
$ show logical/table=lnm$system_directory *mail*

(LNM$SYSTEM_DIRECTORY)

  "LNM$PERMANENT_MAILBOX" = "LNM$SYSTEM"
  "LNM$TEMPORARY_MAILBOX" = "LNM$JOB"
$
```

When the mailbox has been created, the channel number assigned to the mailbox is returned to the address passed as the second parameter to the sys$crembx system service. If multiple processes are going to be accessing the same mailbox and one process is guaranteed to create the mailbox, the rest of the processes can simply assign channels to the mailbox.

If the mailbox creator is not guaranteed to be a specific process, all processes can call the sys$crembx system service. After the mailbox has been created, the sys$crembx system service simply assigns a channel to the mailbox. Care should be taken to make sure that arguments to the sys$crembx system service match for all users of the same mailbox. If one process sets the prmflg (permanent flag) and another passes a zero for the argument, you end up creating two different mailboxes (one permanent and one temporary). Additionally, parameters used to size the mailbox and establish protections are assigned by the first process calling the service (the process that actually creates the mailbox).

Mailbox Protections

Protection on a mailbox is set when the mailbox is created. The fifth argument to sys$crembx identifies the protection mask. If the protection mask is 0, the template protection mask is used. This mask defaults to allowing all access to all UIC categories. In the protection mask, bits <15:12> identify world, bits <11:8> group, bits <7:4> owner, and bits <3:0> system access. The categories for each mode are LPWR (Logical, Physical, Write, and, Read). Bits clear allow access. Bits set deny access. Logical access is required for any other form of access. Physical access is ignored. A setting of the hex value 0xF000 would allow all access for System, Owner, and Group, denying access for the World category. The setting 0xF200 would write access for the Group category and all access for the World category.

Example 2. Sample Call to sys$crembx Disabling World Access to a given Mailbox

```
/* Assign a channel to the mailbox. */
        status = sys$crembx(0,&mbx_chan,0,0,0xF000,0,&mbx,0,0);
        check(status);
```

Example 3. Viewing the Protections from the Mailbox Created in Example 2.

```
$ SHOW DEVICE MBA28282:/FULL

Device MBA28282:, device type local memory mailbox, is online, record-oriented
    device, shareable, mailbox device.

    Error count                    0    Operations completed                0
    Owner process                  ""   Owner UIC                [JAVA,ELLIS]
```

```
    Owner process ID        00000000    Dev Prot          S:RWPL,O:RWPL,G:RWPL,W
    Reference count                1    Default buffer size                 256

$
```

In addition to the sys$crembx argument for protections, there is an IO$M_SETPROT function modifier on the IO$_SETMODE function that accepts a protection mask on the P2 argument to the sys$qio system service. You can also set up objects rights on your mailbox.

DCL-created mailboxes have protections assigned using the /PROTECTION qualifier on the CREATE/MAILBOX command.

Read/Write Only Channels

Within a program you can force read-only or write-only access on a mailbox channel (similar to a unidirectional pipe), using the flags CMB$M_READONLY or CMB$M_WRITEONLY (defined in $CMBDEF/cmbdef.h) in the eighth argument to sys$crembx. If you are assigning a channel, the flags AGN$M_READONLY or AGN$M_WRITEONLY can be used to restrict access. The restriction is only in effect for I/O requests issued within a given application.

The closest equivalent to a sys$assign system service call from DCL is an OPEN command. The CREATE/MAILBOX command does not implicitly perform an OPEN command. So, before processing a mailbox, it must have been created by some process and must be opened by all processes accessing the mailbox. DCL-created mailboxes support read-only mailboxes through the OPEN/READ command, but not write-only mailboxes.

Mailbox Sizing

To understand sizing issues that relate to mailboxes we should take a different view of a mailbox. When a mailbox is created, OpenVMS creates a data structure called a Unit Control Block (UCB) in non-paged pool. The UCB has a specialized layout that supports mailbox operations. The UCB maintains queues. There is a message queue for messages written to the mailbox. There is a reader queue that tracks read I/O requests to the mailbox. The data structures queued to reader queue are called I/O Requests Packets (IRPs).

The UCB also maintains queues to allow processes to be notified of unsolicited read or write operations (read with no pending write or write with no pending read). Processes are notified of these events through the delivery of an Asynchronous System Trap (AST), known as an *attention AST*. A similar attention AST can be delivered when space becomes available in a full mailbox.

There are also queues that allow your process to be notified when a new read or write channel is assigned to a mailbox.

The point of this discussion is that when you create a mailbox, regardless of how you size it, you are only creating the UCB for the mailbox. The sizing parameters limit the use of non-paged pool space to describe messages that are queued to the UCB. So, a more accurate view of a mailbox with three write requests and no current read looks like figure 3. The "MBOX" headers describe the layout of the message block. These symbolic offsets may not be available in earlier versions of OpenVMS. A view of a mailbox with no active writes and one read looks like figure 4.

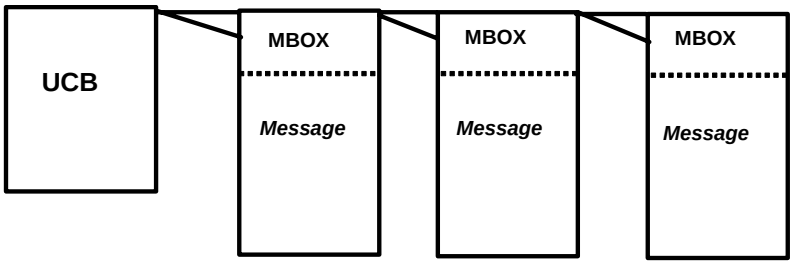

Figure 3. Mailbox with three Pending Writes

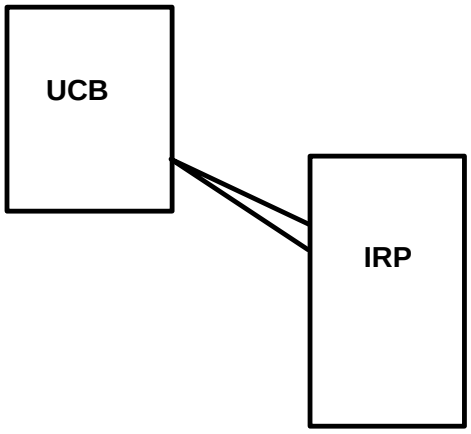

Figure 4. Mailbox with one Pending Read

When a mailbox is created, the third argument to sys$crembx is the maximum message size and the fourth argument is the mailbox buffer quota. The maximum message size restricts the size of an individual message that can be written to the mailbox. This setting can be used to set the size of the input buffer by the reader. If this size is not specified, it is set by the system parameter DEFMBXMXMSG. On the CREATE/MAILBOX command, the /MESSAGE_SIZE qualifier specifies the maximum message size.

The buffer quota is effectively the "size" of the mailbox. It is the maximum number of bytes that can be written to the mailbox. Setting a large buffer quota does not cause any space to be allocated from non-paged pool. What it does do, is allow that many bytes to be potentially allocated from non-paged pool to support mailbox writes. When an attempted write would cause a given mailbox to exceed its buffer quota, the mailbox is considered full and the write will either stall or fail. On the CREATE/MAILBOX command, the BUFFER_SIZE qualifier specifies the mailbox size.

If the buffer quota is not specified on the call to the sys$crembx system service, the setting for the system parameter DEFMBXBUFQUO is used to size the mailbox. The maximum advertised setting for this parameter is 64,000 bytes. You can override checks in SYSGEN and set the parameter to a higher setting, if you are running V7.3-1 or greater. This should be done with great caution, as it will affect the default size of all mailboxes that do not specify a non-zero buffer quota parameter on a call to sys$crembx. You can alternatively, and more safely, set a buffer quota parameter larger than 64,000 bytes as a buffer quota parameter on mailbox creation for select mailboxes.

The key thing to keep in mind when setting larger buffer quota settings is that you do not exhaust non-paged pool. If you are going with higher settings for buffer quotas, compensate with correspondingly larger settings for the system parameters NPAGEDYN and NPAGEVIR.

You can monitor mailbox space usage using the IO$_SENSEMODE function to the sys$qio system service. This function receives no function dependent parameters (P1-P6). It returns the number of messages queued to the mailbox in the iosb$w_bcnt field of the I/O status block. It returns the number of message buffer bytes in the iosb$l_dev_depend field of the I/O status block. You can obtain the buffer quota and remaining buffer using the DVI$_MAILBOX_INITIAL_QUOTA and DVI$_MAILBOX_QUOTA items through the sys$getdvi system service. Example 4 shows a program that obtains and displays information on mailbox usage. There is a sample SDA extension in the SYS$EXAMPLES directory, named MBX$SDA.C, that you can build and obtain more complete information on all mailboxes on the system. We will discuss troubleshooting full mailboxes later in this article.

Example 4. Sample Program to Monitor Mailbox Usage

The following program is implemented as a foreign command. It accepts a mailbox name and displays the number of outstanding messages queued to the mailbox, the bytes in use, bytes available, and mailbox size.

```
$ type mbx_usage.c
// Sample program to display total and available mailbox space.
// Implemented as a foreign command.  Mailbox name is passed in on the command
// line
// Author: Bruce Ellis, BRUDEN-OSSG
#include <stdio.h>
#include <starlet.h>
#include <dvidef.h>
#include <iodef.h>
#include <iledef.h>
#include <iosbdef.h>
#include <descrip.h>
#include <string.h>
#include <ssdef.h>
#include <efndef.h>
#define check(S) if(!((S)&1)) sys$exit(S)

#define MBX 1
#define EXPECTED_ARGS 2
int     main(int argc, char **args)
{

        struct dsc$descriptor_s  mbx_name;
        unsigned int    mbx_size;
        unsigned int    mbx_avail;
        ile3    dvi_list[] = {{sizeof(mbx_size),DVI$_MAILBOX_INITIAL_QUOTA,
                                &mbx_size},
                        {sizeof(mbx_avail),DVI$_MAILBOX_BUFFER_QUOTA,
                                &mbx_avail}, {0,0}};
        iosb    ios;
        int     status;
        short chan;
// If we do not have a mailbox name, exit
        if(argc != EXPECTED_ARGS)
        {
                sys$exit(SS$_NOSUCHDEV);
        }
// Set up mailbox name descriptor
```

```
        mbx_name.dsc$w_length = strlen(args[MBX]);
        mbx_name.dsc$a_pointer = args[MBX];

// Get mailbox information
        status = sys$getdvi(EFN$C_ENF,0,&mbx_name,dvi_list,&ios,0,0,0,0);
        check(status);
        check(ios.iosb$w_status);
// Get more information from QIO
        status = sys$assign(&mbx_name,&chan,0,0,0);
        check(status);
        status = sys$qiow(0,chan,IO$_SENSEMODE,&ios,0,0,0,0,0,0,0,0);
        check(status);
        check(ios.iosb$w_status);
// Display info.
        printf("Mailbox size: %d\nRemaining bytes in mailbox: %d\n",
                mbx_size,mbx_avail);
        printf("Number of messages in the mailbox: %hd\nNumber of message bytes: %d\n",
              ios.iosb$w_bcnt, ios.iosb$l_dev_depend);
        return(SS$_NORMAL);
}

$
```

Compile and link the program.

```
$ cc mbx_usage
$ link mbx_usage
```

Setup a foreign command symbol to run the program.

```
$ mbu== "$sys$login:mbx_usage"
```

View a sample mailbox.

```
$ mbu MBA28605
Mailbox size: 100000
Remaining bytes in mailbox: 100000
Number of messages in the mailbox: 0
Number of message bytes: 0
$
```

Find OPCOM. Note: OPCOM reads from the mailbox MBA2:

```
$ show system/process=opcom
OpenVMS V8.3  on node ALPH40  18-NOV-2006 21:49:01.13  Uptime  55 02:47:35
  Pid    Process Name    State  Pri      I/O       CPU       Page flts  Pages
20400410 OPCOM           HIB      8      406   0 00:00:00.24       688     43
```

No current activity on MBA2:

```
$ mbu MBA2
Mailbox size: 65535
Remaining bytes in mailbox: 65535
Number of messages in the mailbox: 0
Number of message bytes: 0
```

Suspend OPCOM.

```
$ set process/suspend/id=20400410
```

Send some data to MBA2:

```
$ spawn/nowait request "Please service this request!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!"
%DCL-S-SPAWNED, process ELLIS_14466 spawned
$ spawn/nowait request "Please service this request!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!"
%DCL-S-SPAWNED, process ELLIS_28545 spawned
$ spawn/nowait request "Please service this request!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!"
%DCL-S-SPAWNED, process ELLIS_19638 spawned
$ spawn/nowait request "Please service this request!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!"
%DCL-S-SPAWNED, process ELLIS_16419 spawned
$ spawn/nowait request "Please service this request!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!"
%DCL-S-SPAWNED, process ELLIS_48996 spawned
```

View OPCOM's mailbox. Note, the activity.

```
$ mbu MBA2
Mailbox size: 65535
Remaining bytes in mailbox: 64907
The number of messages queued seems to be off by 1.  Note: a user mode AST
has been queued to OPCOM to service the completion of the first request.  The
AST could not be delivered because OPCOM was suspended.  Therefore, the
first message has been pulled from the queue to be serviced, dropping the
message count by 1.
Number of messages in the mailbox: 4
Number of message bytes: 628
$
Resume OPCOM and clean out the mailbox.
$ set process/resume /id=20400410
$ mbu MBA2
Mailbox size: 65535
Remaining bytes in mailbox: 65535
Number of messages in the mailbox: 0
Number of message bytes: 0
$
```

Mailboxes and Quotas

When a temporary mailbox is created, the creating process has the buffer quota charged against its buffered byte limit (BYTLM). In the case of permanent mailbox, no process is charged for the buffer quota. Since the quota for the mailbox has been handled, individual I/O requests are not charged against the job's BYTLM. However, for all sys$qio calls that do not use the IO$M_NOW function modifier, the process' buffered I/O limit (BIOLM) is charged. Writes issued with the IO$M_NOW modifier are not charged against the process's BIOLM, since they may persist beyond the life of the program and possibly the process that issued them.

Mailbox Processing

As we mentioned earlier, mailboxes can be read and written using high-level language constructs, but are more commonly read and written using sys$qio system service calls. If you are not familiar with programming calls to sys$qio, you should invest some time reading the *OpenVMS Programming Concepts Manual*. Common mistakes that beginners make when coding sys$qio calls include:

- Using a call to sys$qio, instead of using sys$qiow. The sys$qiow has an implicit wait until the call has been serviced. Using sys$qio calls work fine, as long as you implement waits at some point in your program, usually through a call to sys$synch. With no explicit or implicit waits, messages are queued up to the mailbox, causing it to fill and the application to hang.
- Not passing and checking the I/O status block (IOSB) parameter. Status returned on the call to sys$qio indicates whether the call was issued properly. It does not indicate whether the I/O request completed properly. Completion status is returned in the low word of the IOSB structure. This is described in the synchronization section of the *OpenVMS Programming Concepts Manual.*

Reading Mailboxes

Mailboxes are read through sys$qio using one of the function codes: IO$_READVBLK, IO$_READLBLK, or IO$_READPBLK. For mailboxes, there is no difference between the function codes. The sys$qio system service provides a uniform interface to all devices. Other devices will give different meaning to the three functions within the context of the device.

When using one of the read functions, the input buffer is passed by address in the P1 parameter to sys$qio. The size of the buffer is passed in the P2 parameter. The size should allow for the maximum message size allowed for the mailbox. If the message size allowed on a read is smaller than the amount of data written, a status of SS$_BUFFEROVF is returned in the IOSB status field. The data beyond the end of the buffer is lost.

The actual number of bytes written to the mailbox may be less than the size of the read buffer. The actual number of bytes written to the mailbox is returned in the iosb$w_bcnt field of the IOSB.

If the data in message buffers is larger than you are anticipating in the input buffer, you can preserve the data in the message buffer using the function modifier IO$M_STREAM on the read. Subsequent reads will pick up the remnant data in the message buffer.

When a read is posted on a mailbox, it will not complete until a corresponding write is issued. This can cause the application to hang if there is no current writer. In many cases, this behavior is fine and desired. In cases where the writer may have failed, this behavior may cause functional problems in the application. There are several ways to deal with this potential problem, including:

- Using the function modifier IO$M_NOW with a read function. If there are no pending writes, the read will complete immediately with a zero byte read. In my opinion, this is usually an undesirable option. It causes convoluted and potentially poor performing code.
- Using the function modifier IO$M_WRITERCHECK with a read function. This request will return a status of SS$_NOWRITER if there is no data in the mailbox and there are no write channels assigned to the mailbox. This option only works if the channel assigned by the process using it was assigned as a read-only channel. A variation of this method can be implemented using IO$M_WRITERCHECK with an IO$_SENSEMODE function.
- Using the function modifier IO$M_WRITERWAIT with the IO$_SETMODE function. The event flag set can be checked or an AST can be delivered to the process notifying it that there is a write channel assigned. As in the last bullet, this method only works with unidirectional mailboxes.
- Using a sys$setimr and an asynchronous sys$qio, then waiting for a "logical or" of the event flags. You can use the sys$readef system service to determine whether the timer expired or the read completed first and then process accordingly.

To determine whether a writer has completed a multi-write transmission, the cooperating processes can use the IO$_WRITEOF function in the context of the writer, and the reader can check for a status of SS$_ENDOFFILE in the IOSB.

On a read function, the device dependent field of the IOSB contains the process identification (PID) of the writer, unless the writer is a system process.

DCL READ commands issued on mailboxes will read their contents and store them in symbols. Be cautious of performing READ (and WRITE) commands interactively. They block execution of the supervisor mode control Y AST.

Writing Mailboxes

Mailboxes can be written using the sys$qio function codes IO$_WRITEVBLK, IO$_WRITELBLK, or IO$_WRITEPBLK. Just as on writes, these function codes have identical meanings. The write functions support a IO$M_READERCHECK function modifier that operates in similar fashion to the IO$M_WRITERCHECK on read functions.

Simple mailbox writes do not complete until a corresponding mailbox read is issued. A write to a mailbox can be forced to complete using the function modifier IO$M_NOW. A message written with this function modifier will be queued to a mailbox and control will be returned to the writer. As long as the mailbox is not deleted, the message will stay in the mailbox until it is read. You need to take caution that some process has a channel assigned to a temporary mailbox, or the mailbox will be deleted when the writer program runs down.

The IO$M_NOW function modifier should be used with care to prevent possibly filling the mailbox.

To notify the reader that we are done transmitting data, you can send an "end of file" by using the IO$_WRITEOF function code. The only effect of using this function is that a status value of SS$_ENDOFFILE is returned to the reader's IOSB. This technique is an optional method to signal that one stream of data is complete. The reader could terminate on detection of this status or could start processing another stream.

On a write function, the device dependent field of the IOSB contains the PID of the reader of the mailbox, except when the function modifier IO$M_NOW is used. In this case, the field contains 0, as the mailbox has not necessarily been read by the time the write completes.

The DCL WRITE command can be used to write to a mailbox. The qualifier /NOWAIT implements the function modifier IO$M_NOW on a WRITE.

When you issue a close on a DCL-created mailbox, there is effectively an IO$_WRITEOF function performed.

Simple Mailbox Examples

At this point, it would probably be good to take a look at a couple of simple examples that use mailboxes for communication. Example 5 illustrates a simple mailbox writer program. The program reads strings from sys$input and sends them to the mailbox named DATA_MBX. When an end of file is read from sys$input, a sys$qio is issued with a function of IO$_WRITEOF. Example 6 illustrates a simple mailbox reader program. The program reads from the data mailbox and sends output to sys$output until a write using the function code IO$_WRITEOF is detected. Example 6a is a DCL version of examples 5 and 6.

The logical name LNM$TEMPORARY_MAILBOX is assigned to the logical name LNM$GROUP in user mode. This practice allows the programs to be run from two different interactive sessions. Sample runs of the programs are shown in each example. Note: the runs from the writer were run in parallel with the reader.

Example 5. Simple Sample Mailbox Writer

```
$ type mailbox_writer.c
/*
        Simple mailbox writer.  Reads lines from standard input until
        EOF and sends to a mailbox named DATA_MBX.

        Author: Bruce Ellis, BRUDEN-OSSG
*/
#include <starlet.h>
#include <iodef.h>
#include <ssdef.h>
```

```
#include <stdio.h>
#include <iosbdef.h>
#include <descrip.h>
#include <iledef.h>
#include <lnmdef.h>
#include <string.h>
#include <lib$routines.h>

#define MBX_PROT 0xF000
#define MAX_MSG 1024
#define BUF_QUO 60000
#define LIST_END 0
#define check(S) if(!((S)&1)) sys$exit(S)

int     main(void)
{

        iosb    ios;
        int     status;

        $DESCRIPTOR(ptable,"LNM$PROCESS_DIRECTORY");
        $DESCRIPTOR(lnm,"LNM$TEMPORARY_MAILBOX");
        char    equiv[ ] = "LNM$GROUP";
        ile3    lnm_items[ ] = {{strlen(equiv),LNM$_STRING,equiv},{LIST_END}};
        $DESCRIPTOR(mbx,"DATA_MBX");
        short   chan;
        int     efn;
        char    in_buffer[BUFSIZ];
/* Create a logical name to allow the next temporary mailbox's name
   we create to be placed in the group logical name table.
*/
        status = sys$crelnm(0,&ptable,&lnm,0,lnm_items);
        check(status);
/* Create/assign a channel to the data mailbox. */
        status = sys$crembx(0,&chan,MAX_MSG,BUF_QUO,MBX_PROT,0,&mbx,0,0);
        check(status);
/* Get an available event flag number. */
        status = lib$get_ef(&efn);
        check(status);

/* Read from standard input and send to mailbox until EOF. */
        while(gets(in_buffer))
        {
        /* If input buffer is too large, abort. */
                if(strlen(in_buffer)>MAX_MSG)
                {
                        sys$exit(SS$_BUFFEROVF);
                }
                status = sys$qiow(efn,chan,IO$_WRITEVBLK,&ios,0,0,
                        in_buffer,strlen(in_buffer),0,0,0,0);
                check(status);
                check(ios.iosb$w_status);
        }
/* Send an EOF to the mailbox. */
        status = sys$qiow(efn,chan,IO$_WRITEOF,&ios,0,0,
                0,0,0,0,0,0);
        check(status);
        check(ios.iosb$w_status);

        return(SS$_NORMAL);
```

```
}

$
$ cc mailbox_writer
$ link  mailbox_writer
$ r mailbox_writer
Bruce Ellis was here
Welcome to Mailboxes from BRUDEN-OSSG
We have lot's of great guys and a great Guy on board.
Control-Z was entered on the next line.
 Exit
$
```

Example 6. Simple Sample Mailbox Reader

```
$ type mailbox_reader.c
/*
        Example of a simple mailbox reader.
        The program reads from a mailbox named DATA_MBX and
        displays the data on sys$output until the writer issues
        an IO$_WRITEOF function.

        Author: Bruce Ellis, BRUDEN-OSSG
*/

#include <starlet.h>
#include <iodef.h>
#include <ssdef.h>
#include <stdio.h>
#include <iosbdef.h>
#include <descrip.h>
#include <iledef.h>
#include <lnmdef.h>
#include <string.h>
#include <lib$routines.h>

#define MBX_PROT 0xF000
#define MAX_MSG 1024
#define BUF_QUO 60000
#define LIST_END 0
#define check(S) if(!((S)&1)) sys$exit(S)

int     main(void)
{

        iosb    ios;
        int     status;

        $DESCRIPTOR(ptable,"LNM$PROCESS_DIRECTORY");
        $DESCRIPTOR(lnm,"LNM$TEMPORARY_MAILBOX");
        char    equiv[ ] = "LNM$GROUP";
        ile3    lnm_items[ ] = {{strlen(equiv),LNM$_STRING,equiv},{LIST_END}};
        $DESCRIPTOR(mbx,"DATA_MBX");
        short   chan;
        char    buffer[MAX_MSG + 1];
        int     efn;
```

```
        int     i;

/* Create a logical name to allow the next temporary mailbox's name
   we create to be placed in the group logical name table.
*/
        status = sys$crelnm(0,&ptable,&lnm,0,lnm_items);
        check(status);
/* Create/assign a channel to the listener mailbox. */
        status = sys$crembx(0,&chan,MAX_MSG,BUF_QUO,MBX_PROT,0,&mbx,0,0);
        check(status);
/* Get an available event flag number. */
        status = lib$get_ef(&efn);
        check(status);

        i=1;
/* Read and display until EOF. */
        do
        {
                status = sys$qiow(efn,chan,IO$_READVBLK,&ios,0,0,
                        buffer,MAX_MSG,0,0,0,0);
                check(status);
                if(ios.iosb$w_status != SS$_ENDOFFILE)
                {
                        check(ios.iosb$w_status);
                        buffer[ios.iosb$w_bcnt] = '\0';
                        printf("Message %08d: %s\n",i,buffer);
                        i++;
                }
        } while(ios.iosb$w_status != SS$_ENDOFFILE);

        return(SS$_NORMAL);
}

$
$ cc mailbox_reader
$ link mailbox_reader
$ show logical data_mbx
   "DATA_MBX" = "MBA29808:" (LNM$GROUP_000042)
$ show device data_mbx/full

Device MBA29808:, device type local memory mailbox, is online, record-oriented
    device, shareable, mailbox device.

    Error count                    0    Operations completed                 0
    Owner process                 ""    Owner UIC                  [JAVA,ELLIS]
    Owner process ID        00000000    Dev Prot         S:RWPL,O:RWPL,G:RWPL,W
    Reference count                1    Default buffer size                1024

$
$ r mailbox_reader
Message 00000001: Bruce Ellis was here
Message 00000002: Welcome to Mailboxes from BRUDEN-OSSG
Message 00000003: We have lot's of great guys and a great Guy on board.
$
```

Example 6a. Sample DCL Mailbox Writer and Reader

```
$
```

```
This is from session 1.
$
$ type temp_talker.com
$ on error then goto done
$ on control_y then goto done
$ !
$ !Create the logical name in the group logical name table.
$ define/table=lnm$process_directory lnm$temporary_mailbox lnm$group
$
$ ! create the temporary mailbox
$ create/mailbox/log bru_mbx
$
$ !Go back to standard temporary mailbox logical names
$ define/table=lnm$process_directory lnm$temporary_mailbox lnm$group
$
$ !Open the mailbox for write
$ open/write bmbx bru_mbx
$
$ !Read from the keyboard and send to the mailbox until EOF
$ read_loop:
$       read/prompt="Message: "/end=done sys$command record
$       write/now bmbx record
$       goto read_loop
$ done:
$
$ close bmbx
$
$
$ @temp_talker
%CREATE-I-CREATED, MBA33594: created
%DCL-I-SUPERSEDE, previous value of LNM$TEMPORARY_MAILBOX has been superseded
Message: Bruce Ellis was here
Message: We would not have CREATE/MAILBOX
Message: without a wonderful "Guy" at
Message: BRUDEN-OSSG
Control-Z entered here.
Message: *EXIT*
$
The logical name and device name are still there.
$ show logical bru_mbx
   "BRU_MBX" = "MBA33594:" (LNM$GROUP_000042)
$ show device mba33594

Device                  Device          Error
 Name                   Status          Count
MBA33594:               Online              0
$
$ deas_mbx=" $ SYS$SYSDEVICE:[ELLIS]DEAS_DCL_MBX_CHAN"
$ deas_mbx bru_mbx  !This feature is not currently available.
The mailbox does not go away until ALL channels are deassigned.
$ show device mba33594

Device                  Device          Error
 Name                   Status          Count
MBA33594:               Online              0
$
This is after the next session did the deassign.
$ show logical bru_mbx
%SHOW-S-NOTRAN, no translation for logical name BRU_MBX
```

```
$ show device mba33594
%SYSTEM-W-NOSUCHDEV, no such device available
$
*****************************************************************************************
This is from a separate session.

$ type temp_listener.com
$
$ on error then goto done
$ on control_y then goto done
$ !
$ !Create the logical name in the group logical name table.
$ define/table=lnm$process_directory lnm$temporary_mailbox lnm$group
$
$ ! create the temporary mailbox
$ create/mailbox/log bru_mbx
$
$ !Go back to standard temporary mailbox logical names
$ define/table=lnm$process_directory lnm$temporary_mailbox lnm$group
$
$ i=1
$ !Open the mailbox and read and echo until end of file
$ open/read  bmbx bru_mbx
$ read_loop:
$       read/end=done bmbx   record
$       write sys$output f$fao("Message !8ZL: !AS",i,record)
$       goto read_loop
$ done:
$ close bmbx
$
$ @temp_listener
%CREATE-I-CREATED, MBA33594: created
%DCL-I-SUPERSEDE, previous value of LNM$TEMPORARY_MAILBOX has been superseded
Message 00000001: Bruce Ellis was here
Message 00000001: We would not have CREATE/MAILBOX
Message 00000001: without a wonderful "Guy" at
Message 00000001: BRUDEN-OSSG
$
$
$ deas_mbx=="$ SYS$SYSDEVICE:[ELLIS]DEAS_DCL_MBX_CHAN"
$
$ show logical bru_mbx
   "BRU_MBX" = "MBA33594:" (LNM$GROUP_000042)
$ show device bru_mbx

Device                  Device          Error
 Name                   Status          Count
MBA33594:               Online              0
$
$ deas_mbx bru_mbx  !This feature is not currently available.
$  show logical bru_mbx
%SHOW-S-NOTRAN, no translation for logical name BRU_MBX
$ show device MBA33594:
%SYSTEM-W-NOSUCHDEV, no such device available
$
```

Example 7 provides a variation on the mailbox reader that uses the IO$M_STREAM function modifier on input. The same writer as example 5 was used in the sample run, with the same output provided.

Example 7. Sample Streaming Reads

```
$ type mailbox_streamer.c
/*
        Example of a simple mailbox reader.
        The program reads from a mailbox named DATA_MBX and
        displays the data on sys$output until the writer issues
        an IO$_WRITEOF function.

        Author: Bruce Ellis, BRUDEN-OSSG
*/

#include <starlet.h>
#include <iodef.h>
#include <ssdef.h>
#include <stdio.h>
#include <iosbdef.h>
#include <descrip.h>
#include <iledef.h>
#include <lnmdef.h>
#include <string.h>
#include <lib$routines.h>

#define MBX_PROT 0xF000
#define MAX_MSG 1024
#define BUF_QUO 60000
#define LIST_END 0
#define check(S) if(!((S)&1)) sys$exit(S)
Force 10 byte reads.
#define READ_SIZE 10

int     main(void)
{

        iosb    ios;
        int     status;

        $DESCRIPTOR(ptable,"LNM$PROCESS_DIRECTORY");
        $DESCRIPTOR(lnm,"LNM$TEMPORARY_MAILBOX");
        char    equiv[ ] = "LNM$GROUP";
        ile3    lnm_items[ ] = {{strlen(equiv),LNM$_STRING,equiv},{LIST_END}};
        $DESCRIPTOR(mbx,"DATA_MBX");
        short   chan;
        char    buffer[MAX_MSG + 1];
        int     efn;
        int     i;

/* Create a logical name to allow the next temporary mailbox's name
   we create to be placed in the group logical name table.
*/
        status = sys$crelnm(0,&ptable,&lnm,0,lnm_items);
        check(status);
/* Create/assign a channel to the listener mailbox. */
        status = sys$crembx(0,&chan,MAX_MSG,BUF_QUO,MBX_PROT,0,&mbx,0,0);
```

```
        check(status);
/* Get an available event flag number. */
        status = lib$get_ef(&efn);
        check(status);

        i=1;
/* Read and display until EOF. */
        do
        {
Allow the data to be streamed.
                status = sys$qiow(efn,chan,IO$_READVBLK|IO$M_STREAM,&ios,0,0,
                        buffer,READ_SIZE,0,0,0,0);
                check(status);
                if(ios.iosb$w_status != SS$_ENDOFFILE)
                {
                        check(ios.iosb$w_status);
                        buffer[ios.iosb$w_bcnt] = '\0';
                        printf("Message %08d: %s\n",i,buffer);
                        i++;
                }
        } while(ios.iosb$w_status != SS$_ENDOFFILE);

        return(SS$_NORMAL);
}

$
$ cc mailbox_streamer
$ link mailbox_streamer
The MAILBOX_WRITER program was run at the same time as the mailbox streamer.  The same data was entered when the program ran.
$ r mailbox_streamer
Note: each line is truncated at 10 bytes, but no data is lost.
Message 00000001: Bruce Elli
Message 00000002: s was here
Message 00000003: Welcome to
Message 00000004:  Mailboxes
Message 00000005:  from BRUD
Message 00000006: EN-OSSG
Message 00000007: We have lo
Message 00000008: t's of gre
Message 00000009: at guys an
Message 00000010: d a great
Message 00000011: Guy on boa
Message 00000012: rd.
$
```

Full Mailboxes

When a mailbox becomes full, two different actions can occur. By default, processes attempting to write to a full mailbox will stall in the RWMBX variation of MWAIT state. It should be possible to delete the process in current versions of OpenVMS. You may want, however, to investigate the cause of the mailbox becoming full to prevent this behavior in the future.

The hang is intended to be a good behavior. The hope is that the mailbox will eventually be read and the process will automatically be released from the stalled RWMBX scheduling state. Indeed, a poorly designed mailbox reader that spends too much time processing data before performing the next mailbox read can cause processes to bounce in and out of RWMBX state. In this case, you would like

to tune the reader application. If this is not a possible action, you can consider increasing the buffer quota (BUFQUO) setting on the mailbox.

However, the mailbox reader may be stalled in an involuntary wait state, unable to read the mailbox. It may also be the case that the reader has disappeared from the system entirely, due to some internal failure in the application. Example 8 shows processes stalled in RWMBX wait state.

Example 8. Sample RWMBX Wait States

```
$ show sys/sub
OpenVMS V8.3  on node ALPH40  19-NOV-2006 20:17:26.91  Uptime  56 01:15:55
  Pid    Process Name    State  Pri      I/O       CPU       Page flts  Pages
2040043B DTGREET         LEF      4      814   0 00:00:01.44       590    692  S
20400D55 ELLIS_21769     RWAST    6      165   0 00:00:00.13       241    206  S
$ spawn/nowait r mbx_w
%DCL-S-SPAWNED, process ELLIS_35375 spawned
$ spawn/nowait r mbx_w
%DCL-S-SPAWNED, process ELLIS_36751 spawned
$ spawn/nowait r mbx_w
%DCL-S-SPAWNED, process ELLIS_37285 spawned
$ spawn/nowait r mbx_w
%DCL-S-SPAWNED, process ELLIS_27951 spawned
$ spawn/nowait r mbx_w
%DCL-S-SPAWNED, process ELLIS_57898 spawned
$ spawn/nowait r mbx_w
%DCL-S-SPAWNED, process ELLIS_36551 spawned
$ spawn/nowait r mbx_w
%DCL-S-SPAWNED, process ELLIS_19782 spawned
$ sh sys/sub
OpenVMS V8.3  on node ALPH40  19-NOV-2006 20:17:40.95  Uptime  56 01:16:09
  Pid    Process Name    State  Pri      I/O       CPU       Page flts  Pages
2040043B DTGREET         LEF      4      814   0 00:00:01.44       590    692  S
20400D55 ELLIS_21769     RWAST    6      165   0 00:00:00.15       241    206  S
20400D8C ELLIS_35375     LEF      6       17   0 00:00:00.02       241    206  S
20400D8D ELLIS_36751     LEF      6       18   0 00:00:00.02       241    206  S
20400D8E ELLIS_37285     LEF      6       17   0 00:00:00.01       241    206  S
20400D8F ELLIS_27951     LEF      6       17   0 00:00:00.04       241    206  S
20400D90 ELLIS_57898     LEF      6       19   0 00:00:00.02       241    206  S
20400D91 ELLIS_36551     LEF      6       15   0 00:00:00.02       241    206  S
20400D92 ELLIS_19782     LEF      6       14   0 00:00:00.01       241    206  S
$ spawn/nowait r mbx_w
%DCL-S-SPAWNED, process ELLIS_32782 spawned
$ sh sys/sub
OpenVMS V8.3  on node ALPH40  19-NOV-2006 20:21:25.18  Uptime  56 01:19:53
  Pid    Process Name    State  Pri      I/O       CPU       Page flts  Pages
2040043B DTGREET         LEF      4      814   0 00:00:01.44       590    692  S
20400D55 ELLIS_21769     RWAST    6      165   0 00:00:00.15       241    206  S
20400D8C ELLIS_35375     RWMBX    6      144   0 00:00:00.02       241    206  S
20400D8D ELLIS_36751     RWMBX    6      128   0 00:00:00.02       241    206  S
20400D8E ELLIS_37285     RWMBX    6      143   0 00:00:00.01       241    206  S
20400D8F ELLIS_27951     RWMBX    6      131   0 00:00:00.04       241    206  S
20400D90 ELLIS_57898     RWMBX    6      145   0 00:00:00.02       241    206  S
20400D91 ELLIS_36551     RWMBX    6      143   0 00:00:00.02       241    206  S
20400D92 ELLIS_19782     RWMBX    6      142   0 00:00:00.01       241    206  S
20400D93 ELLIS_32782     RWMBX    6       12   0 00:00:00.01       241    206  S
$
```

It may also be the case that a race condition is entered under a heavy load, such that a system that generally does not have processes stalling in RWAST state starts to see this state show up. The ideal solution would be to locate the cause of the race condition and correct it. In some cases, it is cheaper and faster to simply increase the size of the mailbox (BUFQUO).

Troubleshooting Full Mailbox Problems

The two most common problems associated with mailboxes are probably:

1. Processes stalling in RWMBX variation of MWAIT state due to a full mailbox.
2. Processes stalling in RWAST variation of MWAIT state due to exhaustion of buffered I/O limit (BIOLM). This is most commonly caused by improper use of asynchronous sys$qio calls.

In this article we will address RWMBX issues.

When you find a process in RWMBX state, you will likely first want to know which mailbox the process is attempting to write. In the System Dump Analyzer (SDA) you can get into the context of the target process by issuing a SET PROCESS command. If the process has a channel assigned to one mailbox, the process is pretty straightforward. You would just issue a SHOW PROCESS/CHANNEL command.

If there are several channels assigned, you will need to determine which channel is associated with the call to sys$qio. Once in the context of the stalled process, you can view the parameters passed to the sys$qio system service by examining registers. The channel number of the device is passed as the second parameter. On HP AlphaServer systems, you would examine register R17 to determine the second parameter being passed to sys$qio. On an HP Integrity server system examine R33 to determine the second parameter passed to sys$qio. The contents of the appropriate register will give you the channel number for the full mailbox that the process is attempting to write.

You can next issue a SHOW PROCESS/CHANNEL command to determine which channels are assigned by the process. The full mailbox should have a channel number that matches the hexadecimal value that you obtained from the register.

Once you know the device name, you may want to map it to the logical name associated with the mailbox. The UCB for the mailbox contains a pointer to the logical name associated with the mailbox. You can format this address using a type of LNMB (Logical Name Block).

See Example 9 (AlphaServer) or Example 10 (Itanium server) for an illustration of these steps.

Example 9. Locating the Channel Number for a Write to a Full Mailbox (Alpha)

```
View one of the processes in RWMBX state.
SDA> show summary/process=ELLIS_55216


Current process summary
-----------------------
 Extended Indx Process name    Username     State   Pri PCB/KTB    PHD    Wkset
-- PID -- ---- --------------- ------------ ------- --- -------- -------- ------
 20400D9F 019F ELLIS_55216     ELLIS        RWMBX     6 823D08C0 84B74000    206
Set context to the target process.
SDA> set process ELLIS_55216
```

Identify the channel associated with the QIO.

```
SDA> examine r17
R17:  00000000.000000D0   "Ð......."
```

Map the channel number to the mailbox device.

```
SDA> show process/channel

Process index: 019F   Name: ELLIS_55216       Extended PID: 20400D9F
------------------------------------------------------------------


                          Process active channels
                          -----------------------

Channel    CCB     Window     Status    Device/file accessed
-------    ---     ------     ------    --------------------
  0010  7FF7C000  00000000              $1$DGA642:
  0020  7FF7C020  8246F8C0              $1$DGA642:[ELLIS]MBX_W.EXE;7
  0030  7FF7C040  81F5D500              $1$DGA642:[VMS$COMMON.SYSEXE]DCL.EXE;1 (section file)
  0040  7FF7C060  00000000              TNA57:
  0050  7FF7C080  00000000              TNA57:
  0060  7FF7C0A0  81F4EA40              $1$DGA642:[VMS$COMMON.SYSLIB]DCLTABLES.EXE;775 (section file)
  0070  7FF7C0C0  81F4ECC0              $1$DGA642:[VMS$COMMON.SYSLIB]LIBOTS.EXE;1 (section file)
  0080  7FF7C0E0  81F53080              $1$DGA642:[VMS$COMMON.SYSLIB]DECC$SHR_EV56.EXE;1 (section file)
  0090  7FF7C100  81F52900              $1$DGA642:[VMS$COMMON.SYSLIB]DPML$SHR.EXE;1 (section file)
  00A0  7FF7C120  81F51140              $1$DGA642:[VMS$COMMON.SYSLIB]CMA$TIS_SHR.EXE;1 (section file)
  00B0  7FF7C140  81F4EC40              $1$DGA642:[VMS$COMMON.SYSLIB]LIBRTL.EXE;1 (section file)
  00C0  7FF7C160  00000000              TNA57:
  00D0  7FF7C180  00000000  Busy        MBA30202:

  Total number of open channels : 13.
SDA>
```

View the mailbox I/O database information.

```
SDA> show device mba30202

I/O data structures
-------------------
MBA30202                                    MBX                UCB: 821362C0

Device status:   88000010 online,exfunc_supp,iopost_local
Characteristics: 0C150001 rec,shr,avl,mbx,idv,odv
                 00000000
SUD Status       00000000

Owner UIC [000042,000042]   Operation count          0   ORB address    823C7300
      PID        00000000   Error count              0   DDB address    81853780
Class/Type          A0/01   Reference count         10   DDT address    818E3740
Def. buf. size       256    BOFF               00000000   SUD address    8246F6C0
DEVDEPEND        0000037C   Byte count         00000000   CRB address    818537F0
```

The logical name block address is in the "LNM address field".

```
DEVDEPND2        00000000   SVAPTE             00000000   LNM address    85322870
DEVDEPND3        00000000   DEVSTS             00000002   I/O wait queue 82136378
FLCK index             0B
DLCK address     824A7980
Charge PID       00030183

       *** I/O request queue is empty ***
SDA> read sysdef
SDA> form 85322870/typ=lnmb
FFFFFFFF.85322870   LNMB$L_FLINK                          850942B0
FFFFFFFF.85322874   LNMB$L_BLINK                853211D0
FFFFFFFF.85322878   LNMB$W_SIZE                           0080
```

```
FFFFFFFF.8532287A   LNMB$B_TYPE                          40
FFFFFFFF.8532287B   LNMB$B_PAD                         00
FFFFFFFF.8532287C   LNMB$L_ACMODE              00000003
FFFFFFFF.85322880   LNMB$L_TABLE                      85322A08    LNM+00198
FFFFFFFF.85322884   LNMB$L_LNMX                853228A0          LNM+00030
FFFFFFFF.85322888   LNMB$L_FLAGS                      00000000
                    LNMB$R_BITS
                    LNMB$R_FLAG_BITS
FFFFFFFF.8532288C   LNMB$L_NAMELEN             00000009
FFFFFFFF.85322890   LNMB$T_NAME                            42
View the mailbox logical name.  The length of 9 identifies the characters for the name.  Everything beyond the first 9 characters, in this case, is garbage.
SDA> examine 85322890;9
30303430 325F4878 626D5F65 63757242  Bruce_mbxH_20400     FFFFFFFF.85322890
SDA>
```

Example 10. Locating the Channel Number for a Write to a Full Mailbox (IA64)

```
View one of the processes in RWMBX state.
SDA> show summary/proc=ELLIS_56220

Current process summary
-----------------------
 Extended Indx Process name    Username     State   Pri PCB/KTB    PHD    Wkset
-- PID -- ---- --------------- ------------ ------- --- -------- -------- ------
 218004C6 00C6 ELLIS_56220     ELLIS        RWMBX     6 8555BF00 8C12C000    265
Set context to the target process.
SDA> set proc ELLIS_56220
Identify the channel associated with the QIO.
SDA> examine r33
R33:  00000000.000000D0   "Ð......."
SDA>
Map the channel number to the mailbox device.
SDA> show process/channel


Process index: 00C6   Name: ELLIS_56220       Extended PID: 218004C6
------------------------------------------------------------------


                          Process active channels
                          -----------------------


Channel    CCB     Window     Status    Device/file accessed
-------    ---     ------     ------    --------------------
  0010  7FF26000  00000000               $1$DGA242:
  0020  7FF26020  8555CA80               $1$DGA242:[ELLIS]MBX_W.EXE;2
  0030  7FF26040  853BC840               $1$DGA242:[VMS$COMMON.SYSEXE]DCL.EXE;1 (section file)
  0040  7FF26060  00000000               TNA3:
  0050  7FF26080  00000000               TNA3:
  0060  7FF260A0  853AF9C0               $1$DGA242:[VMS$COMMON.SYSLIB]DCLTABLES.EXE;381 (section file)
  0070  7FF260C0  853AFCC0               $1$DGA242:[VMS$COMMON.SYSLIB]LIBOTS.EXE;1 (section file)
  0080  7FF260E0  853B4140               $1$DGA242:[VMS$COMMON.SYSLIB]DECC$SHR.EXE;1 (section file)
  0090  7FF26100  853B37C0               $1$DGA242:[VMS$COMMON.SYSLIB]DPML$SHR.EXE;1 (section file)
  00A0  7FF26120  853B2040               $1$DGA242:[VMS$COMMON.SYSLIB]CMA$TIS_SHR.EXE;1 (section file)
  00B0  7FF26140  853AFB40               $1$DGA242:[VMS$COMMON.SYSLIB]LIBRTL.EXE;1 (section file)
  00C0  7FF26160  00000000               TNA3:
  00D0  7FF26180  00000000  Busy         MBA6706:
```

```
  Total number of open channels : 13.
SDA>
SDA>
View the mailbox I/O database information.
SDA> show device mba6706

I/O data structures
-------------------
MBA6706                                    MBX              UCB: 85417E80

Device status:   88000010 online,exfunc_supp,iopost_local
Characteristics: 0C150001 rec,shr,avl,mbx,idv,odv
                 00000000
SUD Status       00000000

Owner UIC [000042,000042]   Operation count          0   ORB address    8541E780
      PID        00000000   Error count              0   DDB address    841ADB80
Class/Type          A0/01   Reference count         10   DDT address    84248B40
Def. buf. size       256    BOFF               00000000   SUD address    85265280
DEVDEPEND        0000037C   Byte count         00000000   CRB address    841ADBF0
The logical name block address is in the "LNM address field".
DEVDEPND2        00000000   SVAPTE             00000000   LNM address    8D1A65E0
DEVDEPND3        00000000   DEVSTS             00000002   I/O wait queue 85417FB0
FLCK index             0B
DLCK address     85519CC0
Charge PID       000100BC

       *** I/O request queue is empty ***
SDA>
SDA> format  8D1A65E0/type=lnmb
FFFFFFFF.8D1A65E0   LNMB$L_FLINK                        8CDCBCF0
FFFFFFFF.8D1A65E4   LNMB$L_BLINK                8D1A9EF0
FFFFFFFF.8D1A65E8   LNMB$W_SIZE                      0070
FFFFFFFF.8D1A65EA   LNMB$B_TYPE                     40
FFFFFFFF.8D1A65EB   LNMB$B_PAD                      00
FFFFFFFF.8D1A65EC   LNMB$L_ACMODE          00000003
FFFFFFFF.8D1A65F0   LNMB$L_TABLE                    8D267A98
FFFFFFFF.8D1A65F4   LNMB$L_LNMX            8D1A6610          LNM+00030
FFFFFFFF.8D1A65F8   LNMB$L_FLAGS                    00000000
                    LNMB$R_BITS
                    LNMB$R_FLAG_BITS
View the mailbox logical name.  The length of 9 identifies the characters for
the name.  Everything beyond the first 9 characters, in this case, is garbage.
FFFFFFFF.8D1A65FC   LNMB$L_NAMELEN         00000009
FFFFFFFF.8D1A6600   LNMB$T_NAME                      42
SDA> examine 8D1A6600;9
00000000 00000078 626D5F65 63757242  Bruce_mbx.......     FFFFFFFF.8D1A6600
SDA>
```

The UCB for a mailbox device has fields that are of specific interest when troubleshooting full mailboxes. The first two longwords in a mailbox UCB (UCBL_MB_MSGQFL / UCBL_MB_MSGQBL) contain the message queue forward and backward links. You can walk these links and view the messages queued to the mailbox. The symbol table file SYSDEF.STB contains MBOX symbol definitions that help you interpret these fields. These symbol definitions are not available in older versions of OpenVMS.

Fields that track read (UCB$L_MB_R_AST) and write (UCB$L_MB_W_AST) attention ASTs are after the message queues and size and type fields. If the mailbox driver is currently servicing an I/O request, the field UCB$L_IRP contains a pointer to the IRP.

Immediately after the base UCB, the mailbox driver maintains:

- Counts of read (UCB$L_MB_READERREFC) and write (UCB$L_MB_WRITERREFC) channels that have been assigned to the mailbox.
- A reader queue for outstanding reads that have been queued to the mailbox. (UCB$L_MB_READQFL/UCB$L_MB_READQBL)
- Queues for mailbox waits for write/read channels to be assigned. (UCB$L_MB_WRITERWAITQFL/UCB$L_MB_WRITERWAITQBL and UCB$L_MB_READERWAITQFL/ UCB$L_MB_READERWAITQBL)
- Queues for mailbox waits for all write/read channels to be deassigned. (UCB$L_MB_NOWRITERWAITQFL/ UCB$L_MB_NOWRITERWAITQBL and UCB$L_MB_NOREADERWAITQFL/ UCB$L_MB_NOREADERWAITQBL)
- A list of ACBs for process notification that mailbox room is available. (UCB$L_MB_ROOM_NOTIFY)
- A pointer to the logical name block for the mailbox. (UCB$L_LOGADR)
- The available mailbox size. (UCB$L_MB_BUFQUO)
- The initial mailbox size (Initial BUFQUO). (UCB$L_MB_INIQUO)

After you issue a SHOW DEVICE command on the mailbox a symbol named UCB contains the address of the UCB for the mailbox. To view relative elements on the message queue, you can issue FORMAT @UCB commands. For each "@" character in the command you move forward to that relative message, e.g., FORMAT @@@@UCB formats the fourth message in the message queue. To determine the number of messages queued to the mailbox, issue the command VALIDATE QUEUE UCB. Example 11 illustrates walking the message queue for a given mailbox. The example works the same way on AlphaServer and Integrity server systems.

Example 11. Walking Mailbox Message Queues

View the first message on the message queue.

```
SDA> form @ucb
FFFFFFFF.854CFE80   MBOX_MSG$L_FLINK                8541FC80
                    MBOX_MSG$PS_ADDR
FFFFFFFF.854CFE84   MBOX_MSG$L_BLINK     85417E80            UCB
                    MBOX_MSG$PS_UVA32
FFFFFFFF.854CFE88   MBOX_MSG$W_MBZ                   0000
FFFFFFFF.854CFE8A   MBOX_MSG$B_TYPE                  79
FFFFFFFF.854CFE8B   MBOX_MSG$B_SUBTYPE               53
FFFFFFFF.854CFE8C   MBOX_MSG$L_FUNCTION  00000020
FFFFFFFF.854CFE90   MBOX_MSG$PQ_UVA64    00000000.DEAD0001
FFFFFFFF.854CFE98   MBOX_MSG$L_SIZE                  000000C0
FFFFFFFF.854CFE9C   MBOX_MSG$L_IRP       85262E80
FFFFFFFF.854CFEA0   MBOX_MSG$L_NOREADERWAITQFL       00000000
FFFFFFFF.854CFEA4   MBOX_MSG$L_NOREADERWAITQBL  00000000
```

This is the internal process ID of the process that issued this message.

```
FFFFFFFF.854CFEA8   MBOX_MSG$L_PID                   000100BE   SYS$K_VERSION_16+0007E
FFFFFFFF.854CFEAC   MBOX_MSG$L_DATASTART  854CFEB8
FFFFFFFF.854CFEB0   MBOX_MSG$W_DATASIZE                 0070
```

```
FFFFFFFF.854CFEB2   MBOX_MSG$W_BUFQUOCHARGE              0001
FFFFFFFF.854CFEB4   MBOX_MSG$L_THREAD_PID          218004BE
                    MBOX_MSG$C_LENGTH
Here is the message data.
FFFFFFFF.854CFEB8   MBOX_MSG$R_DATA                 00005F53.494C4C45
SDA> examine 854CFEB8;70
65623430 30383132 00005F53 494C4C45  ELLIS_..218004be     FFFFFFFF.854CFEB8
35383338 33323732 39303134 33303242  B203410927238385     FFFFFFFF.854CFEC8
39323930 33323936 37323330 35363936  6965032769230929     FFFFFFFF.854CFED8
33363534 31303532 37383732 39363138  8169278725014563     FFFFFFFF.854CFEE8
31383330 33363734 33323330 35383738  8785032347630381     FFFFFFFF.854CFEF8
35363138 35303730 31323930 33303734  4703092107058165     FFFFFFFF.854CFF08
31303136 33363734 33303134 39383738  8789410347636101     FFFFFFFF.854CFF18
SDA>
The next message in the queue.
SDA> form @@UCB
FFFFFFFF.8541FC80   MBOX_MSG$L_FLINK                    854CE480
                    MBOX_MSG$PS_ADDR
FFFFFFFF.8541FC84   MBOX_MSG$L_BLINK              854CFE80
                    MBOX_MSG$PS_UVA32
FFFFFFFF.8541FC88   MBOX_MSG$W_MBZ                      0000
FFFFFFFF.8541FC8A   MBOX_MSG$B_TYPE                    79
FFFFFFFF.8541FC8B   MBOX_MSG$B_SUBTYPE                 53
FFFFFFFF.8541FC8C   MBOX_MSG$L_FUNCTION         00000020
FFFFFFFF.8541FC90   MBOX_MSG$PQ_UVA64           00000000.DEAD0001
FFFFFFFF.8541FC98   MBOX_MSG$L_SIZE                    000000C0
FFFFFFFF.8541FC9C   MBOX_MSG$L_IRP              85261E00
FFFFFFFF.8541FCA0   MBOX_MSG$L_NOREADERWAITQFL         00000000
FFFFFFFF.8541FCA4   MBOX_MSG$L_NOREADERWAITQBL   00000000
FFFFFFFF.8541FCA8   MBOX_MSG$L_PID                     000100BF    SYS$K_V
ERSION_16+0007F
FFFFFFFF.8541FCAC   MBOX_MSG$L_DATASTART         8541FCB8
FFFFFFFF.8541FCB0   MBOX_MSG$W_DATASIZE                 0070
FFFFFFFF.8541FCB2   MBOX_MSG$W_BUFQUOCHARGE             0001
FFFFFFFF.8541FCB4   MBOX_MSG$L_THREAD_PID        218004BF
                    MBOX_MSG$C_LENGTH

FFFFFFFF.8541FCB8   MBOX_MSG$R_DATA              00005F53.494C4C45
The third message...
SDA> form @@@UCB
FFFFFFFF.854CE480   MBOX_MSG$L_FLINK                    854C9140
                    MBOX_MSG$PS_ADDR
FFFFFFFF.854CE484   MBOX_MSG$L_BLINK              8541FC80
                    MBOX_MSG$PS_UVA32
FFFFFFFF.854CE488   MBOX_MSG$W_MBZ                      0000
FFFFFFFF.854CE48A   MBOX_MSG$B_TYPE                    79
FFFFFFFF.854CE48B   MBOX_MSG$B_SUBTYPE                 53
FFFFFFFF.854CE48C   MBOX_MSG$L_FUNCTION         00000020
FFFFFFFF.854CE490   MBOX_MSG$PQ_UVA64           00000000.DEAD0001
FFFFFFFF.854CE498   MBOX_MSG$L_SIZE                    000000C0
FFFFFFFF.854CE49C   MBOX_MSG$L_IRP              854D1640
FFFFFFFF.854CE4A0   MBOX_MSG$L_NOREADERWAITQFL         00000000
FFFFFFFF.854CE4A4   MBOX_MSG$L_NOREADERWAITQBL   00000000
FFFFFFFF.854CE4A8   MBOX_MSG$L_PID                     000100C0    SYS$K_V
ERSION_16+00080
FFFFFFFF.854CE4AC   MBOX_MSG$L_DATASTART         854CE4B8
FFFFFFFF.854CE4B0   MBOX_MSG$W_DATASIZE                 0070
FFFFFFFF.854CE4B2   MBOX_MSG$W_BUFQUOCHARGE             0001
FFFFFFFF.854CE4B4   MBOX_MSG$L_THREAD_PID        218004C0
```

```
                    MBOX_MSG$C_LENGTH

FFFFFFFF.854CE4B8   MBOX_MSG$R_DATA                  00005F53.494C4C45
Determine the number of messages queued to the mailbox.
SDA> validate queue ucb
Queue is complete, total of 892 elements in the queue
SDA>
```

Once you have determined how many messages are in the queue and which processes are sending them, you will need to determine what happened to the mailbox reader. Is it hung in a resource wait state? Has it encountered a race condition that caused it to ignore the mailbox? Has the process died for some reason?

To identify where in the code the process has stalled, you can view call frames and walk back to the source of the call. Doing so requires that you have access to link maps and machine code listings for the program that the hung process was running.

On HP AlphaServer systems, the return address of the caller is stored in r26 when the sys$qio code is entered. If a sys$qiow was called, that, in turn, made the call to sys$qio; you will need to view call frames to locate the caller of sys$qiow. Once you know the return PC, you can take it to the map file for the program and find the program section that contains the given PC. You would then subtract the base address of the containing program section to determine the location counter for the machine code that contains the return address from the call. The location counter can be taken to the listing file to locate the machine code instruction for the return from the call.

From the return instruction, you can back up one instruction at a time in the listing file, looking for a source line number. In a 132 column display, the source line number will be all the way to the right and will have a ";" prefix in front of the source line number. This will get you to the source code and you can determine what is happening in the context of the program. Example 12 illustrates mapping the call back to the source in the sys$qio case on an AlphaServer system. Example 13 does the same for the sys$qiow case on an AlphaServer system.

Example 12. Mapping the Return PC to Source for a Process in RWMBX (sys$qio case on AlphaServer)

```
SDA> sh summary


Current process summary
-----------------------
 Extended Indx Process name    Username     State   Pri PCB/KTB    PHD    Wkset
-- PID -- ---- --------------- ------------ ------- --- -------- -------- ------
 20400401 0001 SWAPPER         SYSTEM       HIB      16 818E5DC8 818E5800      0
 20400407 0007 CLUSTER_SERVER  SYSTEM       HIB      13 81DEE600 84B2C000    113
...
 2040043B 003B DTGREET         SYSTEM       LEF       4 81DB9640 84B2A000    692
 204008B8 00B8 TCPIP$BOOTP_1   TCPIP$BOOTP  LEF      10 8223D1C0 84B62000    280
 20400DAD 01AD _TNA58:         ELLIS        CUR 002   6 8222F780 84B54000    659
 20400DC5 01C5 ELLIS_14353     ELLIS        RWMBX     6 822EFC40 84B32000    206
 20400DC6 01C6 ELLIS_29302     ELLIS        RWMBX     6 821D79C0 84B52000    206
 20400DC7 01C7 ELLIS_7240      ELLIS        RWMBX     6 822E8200 84B58000    206
 20400DC8 01C8 ELLIS_61712     ELLIS        RWMBX     6 821B1140 84B60000    206
 20400DC9 01C9 ELLIS_31360     ELLIS        RWMBX     6 821D6CC0 84B64000    206
 20400DCA 01CA ELLIS_60365     ELLIS        RWMBX     6 823D08C0 84B66000    210
SDA> set process/index=1c8
SDA> read/executive
```

View the call frames looking for a call to sys$qiow.

```
SDA> show call/summary

Call Frame Summary
------------------
```

There is no call frame for sys$qiow. Therefore, we will need to look for the return PC in r26.

```
     Frame Type           Frame Address          Return PC         Procedure Entry
--------------------    -----------------    -----------------    -----------------
Stack Frame             00000000.7AE09990    00000000.00020064    00000000.000200A0
SYS$K_VERSION_08+00080
Stack Frame             00000000.7AE09AA0    FFFFFFFF.80385CE4    00000000.00020000
SYS$K_VERSION_06
Stack Frame             00000000.7AE09B30    00000000.7AF6C058    FFFFFFFF.80385B50
SYS$IMGSTA_C
Stack Frame             00000000.7AE09BB0    00000000.7AF6BE88    00000000.7AF6BE9C  DCL+81E9C
Cannot display further call frames (Bottom of stack)
SDA> examine r26
```

This is the return PC.

```
R26:  00000000.000202A4   "¤......."
```

Verify that the instruction preceding the return PC is a jump to subroutine (JSR).

```
SDA> examine/inst 202a4-4
SYS$K_VERSION_08+00280:          JSR             R26,(R26)
SDA>
```

Determine the image that the process is running.

```
SDA> show summary/image/process= ELLIS_61712

Current process summary
-----------------------
 Extended Indx Process name    Username     State   Pri PCB/KTB    PHD    Wkset
-- PID -- ---- --------------- ------------ ------- --- -------- -------- ------
 20400DC8 01C8 ELLIS_61712     ELLIS        RWMBX     6 821B1140 84B60000    210
          $1$DGA642:[ELLIS]MBX_W.EXE;9
SDA> EXIT
$
```

View the map file, looking for the program section containing the PC.

```
$ type mbx_w.map
                                                    19-NOV-2006 22:37       Linker A13-03                Page
1

                                      +------------------------+
                                      ! Object Module Synopsis !
                                      +------------------------+

Module Name     Ident            Bytes     File  Creation Date      Creator
-----------     -----            -----     -----  -------------     -------
MBX_W            V1.0             2377 SYS$SYSDEVICE:[ELLIS]MBX_W.OBJ;7    19-NOV-2006 22:37  Compaq C V6.5-001

                                     +--------------------------+
                                     ! Program Section Synopsis !
                                     +--------------------------+

Psect Name      Module Name      Base     End          Length          Align               Attributes
----------      -----------      ----     ---          ------          -----               ----------
$LINK$                           00010000 000101BF 000001C0 (       448.) OCTA4 NOPIC,CON,REL,LCL,NOSHR,NOEXE,NOWRT,NOVEC,  MOD
                MBX_W            00010000 000101BF 000001C0 (       448.) OCTA4
$LITERAL$                        000101C0 000101E4 00000025 (        37.) OCTA4   PIC,CON,REL,LCL,  SHR,NOEXE,NOWRT,NOVEC,  MOD
                MBX_W            000101C0 000101E4 00000025 (        37.) OCTA4
$READONLY$                       000101F0 000101FF 00000010 (        16.) OCTA4   PIC,CON,REL,LCL,  SHR,NOEXE,NOWRT,NOVEC,  MOD
                MBX_W            000101F0 000101FF 00000010 (        16.) OCTA4
CR_VALS                          00010200 0001020F 00000010 (        16.) OCTA4 NOPIC,OVR,REL,GBL,NOSHR,NOEXE,NOWRT,NOVEC,  MOD
```

```
            MBX_W           00010200 0001020F 00000010 (        16.) OCTA4
Here is the Program Section containing the return PC.  The base of the
program section is at 20000, so the offset into module MBX_W for the point of
the call is 202a0.
$CODE$                      00020000 0002072B 0000072C (      1836.) OCTA4   PIC,CON,REL,LCL,  SHR,  EXE,NOWRT,NOVEC,  MOD
            MBX_W           00020000 0002072B 0000072C (      1836.) OCTA4
$BSS$                       00030000 00030017 00000018 (        24.) OCTA4 NOPIC,CON,REL,LCL,NOSHR,NOEXE,  WRT,NOVEC,NOMOD
            MBX_W           00030000 00030017 00000018 (        24.) OCTA4
...
$ edit mbx_w.lis
First search for the location counter 000002a0.  We find it below, then back to
the source line number.
D3400089    0258            BSR     R26, GEN_BUFF                                                   ; 021837
Source line number 21835 should be the location that the call to sys$qio was
made.
A7420078    025C            LDQ     R26, 120(R2)                                                    ; 021835
47E41410    0260            MOV     32, R16
47E70411    0264            MOV     R7, R17
47E61412    0268            MOV     48, R18
B41E0000    026C            STQ     R0, (SP)
47EE1400    0270            MOV     112, R0
B7FE0010    0274            STQ     R31, 16(SP)
227D0028    0278            LDA     R19, mb_ios     ; R19, 40(FP)
B41E0008    027C            STQ     R0, 8(SP)
B7FE0018    0280            STQ     R31, 24(SP)
47FF0414    0284            CLR     R20
47FF0415    0288            CLR     R21
B7FE0020    028C            STQ     R31, 32(SP)
B7FE0028    0290            STQ     R31, 40(SP)
47E19419    0294            MOV     12, R2
A7620080    0298            LDQ     R27, 128(R2)
2FFE0000    029C            UNOP
6B5A4000    02A0            JSR     R26, SYS$QIO     ; R26, R26
A742FFA8    02A4            LDQ     R26, -88(R2)                                                    ; 021838
F0000004    02A8            BLBS    R0, L$21
47E00410    02AC            MOV     R0, status  ; R0, R16                                           ; 021835

Now we search for the source line.
     1   21823 /* Assign a channel to the mailbox. */
     1   21824         status = sys$crembx(0,&mbx_chan,0,0,0,0,&mbx,0,0);
     1   21825         check(status);
     1   21826
     1   21827 /* Write messages to the mailbox. */
     1   21828         for(i=0;i<500;i++)
     2   21829         {
     2   21830
     2   21831                 stall = ten_ms * ((rand()%300)+1);
     2   21832                 status = sys$setimr(TEFN,&stall,0,0,0);
     2   21833                 check(status);
     2   21834                 sys$waitfr(TEFN);
Here is the point of the call.
     2   21835                 status = sys$qio(MEFN,mbx_chan,IO$_WRITEVBLK,
     2   21836                         &mb_ios,0,0,
     2   21837                         gen_buff(&mrec,&id,count++),sizeof(mrec),0,0,0,0);
     2   21838                 check(status);
     2   21839                 //check(mb_ios.iosb$w_status);
     1   21840         }
     1   21841                 stall = ten_ms * 300*1000*100;
```

Example 13. Locating the Return PC for a Process in RWMBX (sys$qiow case on AlphaServer)

```
In this case, the call to sys$qiow does show up in the call frames.  Once we
have the return PC, the steps are the same as in example 12.
SDA> set proc/index=1ca
SDA> show call/summary

Call Frame Summary
------------------

     Frame Type          Frame Address         Return PC         Procedure Entry
--------------------   -----------------   -----------------   -----------------
Stack Frame            00000000.7AE09930   00000000.000202A4    FFFFFFFF.80114BD0  SYS$QIOW_C
Stack Frame            00000000.7AE09990   00000000.00020064    00000000.000200A0  SYS$K_VERSION_08+00080
Stack Frame            00000000.7AE09AA0   FFFFFFFF.80385CE4    00000000.00020000  SYS$K_VERSION_06
Stack Frame            00000000.7AE09B30   00000000.7AF6C058    FFFFFFFF.80385B50  SYS$IMGSTA_C
Stack Frame            00000000.7AE09BB0   00000000.7AF6BE88    00000000.7AF6BE9C  DCL+81E9C
Cannot display further call frames (Bottom of stack)
SDA>
```

Full mailboxes should be rare in a well-designed application. Hopefully, the steps above will help you out in the rare case that you need to troubleshoot an RWMBX hang.

Designing Applications that Operate Asynchronously Using Mailboxes

For some, a picture is worth a thousand words. For others, seeing code in a complete application helps clarify the concept. The following example illustrates most of the concepts described in this article.

It is rare that an application uses mailboxes for the sole purpose of doing mailbox communication. To illustrate operating asynchronously in an OpenVMS environment, we designed a series of functions and programs to sample the Program Counter, the Buffered and Direct I/O counts for any given application. This data, along with a time stamp, will be logged to a file.

The data will be captured by an Asynchronous System Trap (AST) routine that will be called based on timer expiration. The data we are capturing could be used to profile the performance characteristics of any application. This specific data is not as relevant as the design considerations. Note that the same approach could be used to sample other forms of real-time data.

This example illustrates:

1. Requesting timers
2. AST routines
3. Local Event Flags
4. The "I/O" status block
5. Getting Job/Process information
6. Obtaining a time stamp
7. Using item list entries (ile3 structures)
8. Processing Mailboxes
9. Process creation
10. Creating Mailboxes
11. QIO Interface to the mailbox

From a design perspective, we attempt to maintain data encapsulation through the use of structures that describe the context of operations, such as samples, files, I/O, etc. The structures are passed as parameters to procedures and external/common storage is avoided. This method improves the ability to debug, maintain, and extend the application.

We attempt to minimize "noise" and "drift" in the main sampler process by creating a background process that will:

- Create a temporary mailbox for communication with the parent process.
- Create the log file, whose name is passed from the parent process.
- Accept samples from the mailbox and write them to the log file, until an EOF is sent from the parent.

All mailbox I/O is processed asynchronously.

The file is synched in the background by the child process and the drift is reduced on the samples.

You may want to be able to view the data in real-time. The PC_LOGGER is designed to write the samples to a "listener" mailbox. This mailbox can be read by a listener process that may be logged in on another terminal session. The listener can then display the data in real-time.

The listener process will be logged in separately from the process in which the sampler is being run. Therefore, the mailbox logical name presents a problem. Normally, temporary mailbox names are entered into the job logical name table.

In the listener and the logger the logical name LNM$TEMPORARY_MAILBOX is equated to LNM$GROUP to make the mailbox logical name visible to other processes in the UIC group. The logical name is placed in the logical name table LNM$PROCESS_DIRECTORY.
Since the logical name is created in user mode, it goes away when the images run down, so as to not impact other images run by this process.

It is important to note that the logical name is created AFTER the logger mailbox is created/channel assigned. So, the logger mailbox logical name still goes into the job logical name table.

The listener mailbox is implemented as write-only by the logger and read-only by the listener. This method allows us to simply send the message to the mailbox from the logger. If there is no reader (listener), the mailbox write completes immediately with a status of SS$_NOREADER. When this status is received, we "shrug our shoulders" and try again next time. Similarly, the listener will abort if there is no writer.

When we are done the application design looks like figure 5.

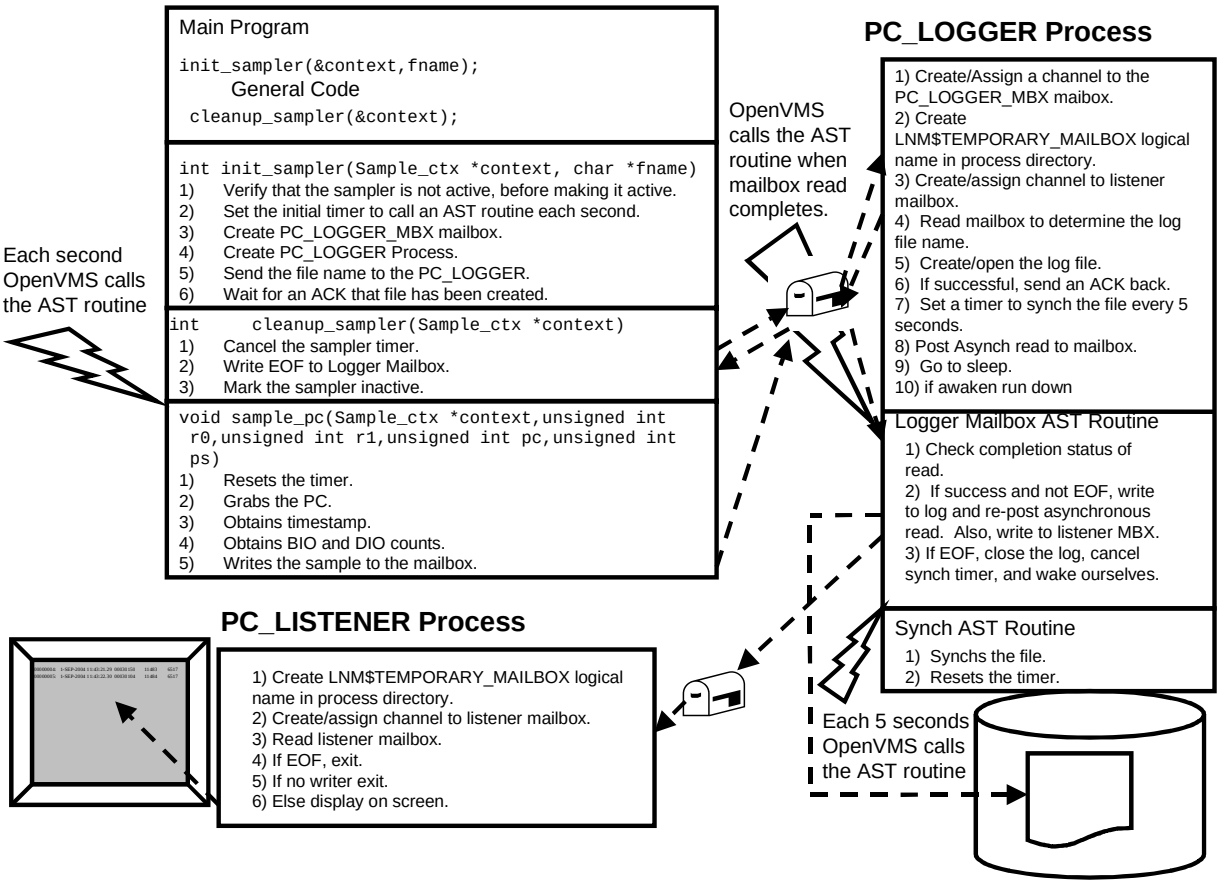

Figure 5. PC Sampler "System Design"

Example 14. The PC_SAMPLER Header File

```
$ type pc_sampler2.h
#include <stdio.h>
/*
        Context for our PC sampler.
        File pointer for where to write the data.
        Delta time for our sampling interval.
*/

typedef struct pc_sample_ctx
{
        __int64 delta;
        int     c_pid;
        int     sample_no;
        short   mbx_chan;
} Sample_ctx;

/* Profile data */
typedef struct sample_data
{
        __int64 time_stamp;
        int     pc;
```

```
        int     bio;
        int     dio;
        int     sample_no;
} Samp;
#define CPU_TIMER 1
int     init_sampler(Sample_ctx *,char *);
void    sample_pc(Sample_ctx *, unsigned int, unsigned int,
                        unsigned int, unsigned int);
int     cleanup_sampler(Sample_ctx *);

$
$
```

Example 15. PC Sampler Test and Stub Programs

```
$ type pc_tester2.c
#include <stdio.h>
#include <stdlib.h>
#include "pc_sampler2.h"
void    stub(void);
int     main(void)
{
        int     i;
        Sample_ctx ctx;

        init_sampler(&ctx,"sample.data");


        for(i=0;i<1000000000;i++)
        {
                stub();
        }

        cleanup_sampler(&ctx);
}
$
$ type stub.c
void    stub(void) {;}
$
```

Example 16. PC Sampler Routines

```
$ type pc_sampler3.c
/* Set of routines to sample program counters at
        1 second (CPU time) intervals and send the PC and time of
        sample to a logger process created by this routine.
*/
#include "pc_sampler2.h"
#include <starlet.h>
#include <stdio.h>
#include <ssdef.h>
#include <iodef.h>
#include <iosbdef.h>
#include <string.h>
#include <descrip.h>
```

```
#include <rmsdef.h>
#include <iledef.h>
#include <jpidef.h>
#define JPI_LISTEND 0
#define check(S) if(!((S)&1)) sys$exit(S)

/* Flag to indicate that the sample is active. */
static  int     active = 0;
/* Sample interval is a constant 1 second. */
static const __int64 sample_interval = -10000000;
#define BASE_PRI 4
#define MBX_EFN 32
#define ACK_SIZE 4
#define TERM_MAX 255

/*
        Initialize the PC Sampler:
        1)      Verify that the sampler is not active, before making it active
        2)      Set the initial timer.
        3)      Create a mailbox.
        4)      Create a child process to log messages.
*/
int     init_sampler(Sample_ctx *context, char *fname)
{
        int     status;
        $DESCRIPTOR(mbx_name,"PC_LOGGER_MBX");
        $DESCRIPTOR(image,"PC_LOGGER2");
        char    ack_buffer[ACK_SIZE];
        iosb    ios;
        char    terminal[TERM_MAX+1];
        $DESCRIPTOR(term,terminal);
        ile3    term_list[] = {{TERM_MAX,JPI$_TERMINAL,terminal,
                        &term.dsc$w_length},{0,0}};
/* If the sampler is already active, return a failure status,
        else make it active.
*/
        if(!active)
        {
                active = 1;
        }
        else
        {
                fprintf(stderr,"Sampler is already active.\n");
        }
/*
        Create the mailbox for communications with the child.
*/
        status = sys$crembx(0,&context->mbx_chan,0,0,0,0,&mbx_name,0,0);
        check(status);

/* Call SYS$GETJPI to obtain our terminal name. */
        status = sys$getjpiw(0,0,0,term_list,&ios,0,0);
        check(status);
        check(ios.iosb$w_status);

/* Create the child logger process. */
        status = sys$creprc(&context->c_pid,&image,0,&term,&term,
                        0,0,&image,BASE_PRI,0,0,0,0,0,0);
        check(status);
/* Send the file name to the child. */
```

```
        status = sys$qiow(MBX_EFN,context->mbx_chan,IO$_WRITEVBLK,&ios,
                          0,0,fname,strlen(fname),0,0,0,0);
        check(status);
        check(ios.iosb$w_status);
/* Read the same mailbox for an acknowledgment that the file was created
   properly.
*/
        status = sys$qiow(MBX_EFN,context->mbx_chan,IO$_READVBLK,&ios,
                          0,0,ack_buffer,ACK_SIZE,0,0,0,0);
        check(status);
        check(ios.iosb$w_status);
        ack_buffer[ios.iosb$w_bcnt] = '\0';

/* Make sure the child created the log file properly.  If not, return
   error.
*/
        if(strcmp(ack_buffer,"ACK") != 0)
        {
                return(RMS$_FNF);
        }
/* Save collection interval in context block. */
        context->delta = sample_interval;
        context->sample_no = 0;
/* Set a timer for collections. */
        status = sys$setimr(0,&context->delta,sample_pc,context,CPU_TIMER);
        check(status);
}

/*********************************
        Sampler AST Routine.
        1)      Grabs the PC.
        2)      Writes the PC and a timestamp to collection log process
                through mailbox.
        3)      Resets the timer.
*********************************/
void    sample_pc(Sample_ctx *context,unsigned int r0,unsigned int r1,
                        unsigned int pc,unsigned int ps)
{
        int     wrt_cnt;
        static Samp     sample;
        int     status;
        ile3    jpi_items[] = {
                                {sizeof(sample.bio),JPI$_BUFIO,
                                 &sample.bio},
                                {sizeof(sample.dio),JPI$_DIRIO,
                                 &sample.dio},
                                {0,JPI_LISTEND}
                               };
        iosb    ios;

/* Reset the timer. */
        status = sys$setimr(0,&context->delta,sample_pc,context,CPU_TIMER);
        check(status);
/* Save the sample PC. */
        sample.pc = pc;
/* Obtain a timestamp. */
        status = sys$gettim(&sample.time_stamp);
        check(status);
/* Call SYS$GETJPI to obtain our buffered and direct I/O counts. */
        status = sys$getjpiw(0,0,0,jpi_items,&ios,0,0);
```

```
        check(status);
        check(ios.iosb$w_status);

/* Update and copy the sample number. */
        sample.sample_no = ++(context->sample_no);
/* Write our collection data to the log file. */
        status = sys$qiow(MBX_EFN,context->mbx_chan,IO$_WRITEVBLK|IO$M_NOW,
                          &ios,0,0,
                          &sample,sizeof(sample),0,0,0,0);
        check(status);
        check(ios.iosb$w_status);
}
/*********************************
        Cleanup the PC sampler by:
        1)      Cancelling the sampler timer.
        2)      Marking the sampler inactive.
        3)      Sending EOF status to the child.
*********************************/
int     cleanup_sampler(Sample_ctx *context)
{
        int     status;
        iosb    ios;
/* Cancel the timer. */
        status = sys$cantim(context,0);
        check(status);
/* Notify the logger to close the file. */
        status = sys$qiow(MBX_EFN,context->mbx_chan,IO$_WRITEOF,&ios,
                          0,0,0,0,0,0,0,0);
        check(status);
        check(ios.iosb$w_status);

/* Mark the sampler inactive. */
        active = 0;
        return(status);
}
$
```

Example 17. PC_LOGGER Header File

```
Header file for the PC Sample logger.
$ type pc_logger.h
#include <stdio.h>
#include "pc_sampler2.h"
typedef struct mbx_context
{
        FILE *fp;
        Samp    *samp_buffer;
        iosb    ios;
        short chan;
} Mbx_ctx;
$
```

Example 18. PC_LOGGER Code

```
$ type pc_logger2.c
/*
        Program to accept PC_Sample data and write it
        to a log file.
        The logger will send the data to a listener.
*/
#include <starlet.h>
#include <iodef.h>
#include <stdio.h>
#include <iosbdef.h>
#include <descrip.h>
#include <iledef.h>
#include <lnmdef.h>
#include <cmbdef.h>
#include <string.h>
#include "pc_logger2.h"
#include <ssdef.h>
#define check(S) if(!((S)&1)) sys$exit(S)
#define LIST_END 0
#define MAX_FNAME 255
void    synch_ast(Mbx_ctx *);
void    mbx_ast(Mbx_ctx *);

int     main(void)
{
        int     status;
        Mbx_ctx ctx;
        Samp    sample;
        char    fname[MAX_FNAME+1];
        char    nak[] = "NAK";
        char    ack[] = "ACK";
        char    *msg;
        __int64 synch_time = (__int64) -50000000;
        $DESCRIPTOR(mbx_name,"PC_LOGGER_MBX");
/* Descriptors to allow temporary mailbox names to be placed in the
   group logical name table.
*/
        $DESCRIPTOR(ptable,"LNM$PROCESS_DIRECTORY");
        $DESCRIPTOR(lnm,"LNM$TEMPORARY_MAILBOX");
        char    equiv[ ] = "LNM$GROUP";
        ile3    lnm_items[ ] = {{strlen(equiv),LNM$_STRING,equiv},{LIST_END}};
        $DESCRIPTOR(l_mbx,"PC_LISTENER_MBX");

/* Create /assign a channel to a temporary mailbox for log data. */
        status = sys$crembx(0,&ctx.chan,0,0,0,0,&mbx_name,0,0);
        check(status);

/* Read the mailbox to determine the target (log) file name. */
        status = sys$qiow(0,ctx.chan,IO$_READVBLK,&ctx.ios,0,0,
                          fname,MAX_FNAME,0,0,0,0);
        check(status);
        check(ctx.ios.iosb$w_status);
        fname[ctx.ios.iosb$w_bcnt] = '\0';
/* Open/create the file. */
        ctx.fp = fopen(fname,"w");


/* Send an ACK/NAK dependent on the creation status. */
```

```
        if(!ctx.fp)
        {
                msg = nak;
        }
        else
        {
                msg = ack;
        }
        status = sys$qiow(0,ctx.chan,IO$_WRITEVBLK,&ctx.ios,0,0,
                        msg,strlen(msg),0,0,0,0);
        check(status);
        check(ctx.ios.iosb$w_status);

/* Create a logical name to allow the next temporary mailbox's name
   we create to be placed in the group logical name table.
*/
        status = sys$crelnm(0,&ptable,&lnm,0,lnm_items);
        check(status);
/* Create/assign a channel to the listener mailbox. */
        status = sys$crembx(0,&ctx.l_chan,0,0,0,0,&l_mbx,CMB$M_WRITEONLY,0);
        check(status);

/* Set a timer for synching the file. */
        status = sys$setimr(0,&synch_time,synch_ast,&ctx,0);
        check(status);
/* set up shared context for the sample buffer. */
        ctx.samp_buffer = &sample;

/* Post an asynchronous read to the mailbox. */
        status = sys$qio(0,ctx.chan,IO$_READVBLK,&ctx.ios,mbx_ast,&ctx,
                        ctx.samp_buffer,sizeof(*(ctx.samp_buffer)),0,0,0,0);
        check(status);

/* Go to sleep. */
        sys$hiber();

/* If we are waken, run down. */
        return(SS$_NORMAL);
}

/* AST routine to read the mailbox. */
#define EXP_OBJECTS_WRITTEN 1
void    mbx_ast(Mbx_ctx *ctx)
{
        int     write_cnt;
        int     status;
/* Check to see if the qio completed properly. */

        switch(ctx->ios.iosb$w_status)
        {
                case SS$_ENDOFFILE:
                        fclose(ctx->fp);
                        status = sys$wake(0,0);
                        check(status);
                        status = sys$cantim(0,0);
                        check(status);
                /* Send EOF to listener. */
                        status = sys$qiow(0,ctx->l_chan,
                                        IO$_WRITEOF|IO$M_READERCHECK,
                                        &ctx->l_ios,0,0,
```

```
                                        0,0,0,0,0,0);
                        check(status);
                        if(ctx->l_ios.iosb$w_status == SS$_NOREADER)
                        {
                /* Ignore if no reader. */
                                ;
                        }
                        else
                        {
                                check(ctx->l_ios.iosb$w_status);
                        }

                        break;

                default:
                        check(ctx->ios.iosb$w_status);
                        write_cnt = fwrite(ctx->samp_buffer,
                                        sizeof(*(ctx->samp_buffer)),
                                        1,ctx->fp);
                        if(write_cnt != EXP_OBJECTS_WRITTEN)
                        {
                                fprintf(stderr,"Write error!\n");
                        }
                /* Post another read to the mailbox. */
                        status = sys$qio(0,ctx->chan,IO$_READVBLK,
                                        &ctx->ios,mbx_ast,ctx,
                                        ctx->samp_buffer,
                                        sizeof(*(ctx->samp_buffer)),0,0,0,0);
                        check(status);
                /* Send buffer to listener. */
                        status = sys$qiow(0,ctx->l_chan,
                                        IO$_WRITEVBLK|IO$M_READERCHECK,
                                        &ctx->l_ios,0,0,
                                        ctx->samp_buffer,
                                        sizeof(*(ctx->samp_buffer)),0,0,0,0);
                        check(status);
                        if(ctx->l_ios.iosb$w_status == SS$_NOREADER)
                        {
                /* Ignore if no reader. */
                                ;
                        }
                        else
                        {
                                check(ctx->l_ios.iosb$w_status);
                        }
                        break;
        }
}

#include <unistd.h>
/* AST routine to synch the file every 5 seconds. */
void    synch_ast(Mbx_ctx *ctx)
{
        __int64 synch_time = -50000000;
        int     status;

/* Synch the file. */
        fsync(fileno(ctx->fp));
/* Reset a timer for synching the file. */
        status = sys$setimr(0,&synch_time,synch_ast,ctx,0);
```

```
        check(status);
}
$
```

Example 19. Code to Dump Samples

```
This code is implemented as a foreign command.
$
$ type dump_samples.c
/***************************************
        Program to dump output from PC Sampler log file.
        Foreign comand setup by using the DCL command:
        $ PC_DUMP == "$dev[dir]DUMP_SAMPLES.EXE"
***************************************/
#include <stdio.h>
#include <stdlib.h>
#include <descrip.h>   // This is from SYS$LIBRARY:DECCRTLDEF.TLB
#include <starlet.h>
#include <ssdef.h>
#include "pc_sampler1.h"
#define EXPECTED_ARGS 2
#define NO_ARGS 1
#define FILE_ARG 1
#define TIME_STR_LEN 23
#define LINES_PER_PAGE 24
#define CMD_ARG 1
#define check(S) if(!((S)&1)) sys$exit(S)
/* Get parameter(s) from the command line. */
int     main(int argc, char **args)
{

/* File pointer for the data file. */
        FILE *fp;
        int     i;
/* Structure for the sample data. */
        Samp    sample;
        int     items_read;
        int     status;
/* String to hold the text representation of the time stamp. */
        char    time_str[TIME_STR_LEN+1];
        $DESCRIPTOR(time_dsc,time_str);
/* Process the command line argument(s). */
        switch(argc)
        {
                default:
                        fprintf(stderr,"Bad command format!"
                                "\nUse: PC_DUMP file-name\n");
                        exit(SS$_INSFARG);
                        break;
                case    EXPECTED_ARGS:
        /* Open the data file. */
                        fp = fopen(args[FILE_ARG],"r");
                        if(!fp)
                        {
                                fprintf(stderr,"Bad input file name.\n");
                                perror(args[CMD_ARG]);
```

```
                                exit(EXIT_FAILURE);
                        }
        }
        i = 0;
/* Read until EOF or error and display the samples. */
        while((items_read = fread(&sample,sizeof(sample),1,fp)) == 1)
        {
                status = sys$asctim(&time_dsc.dsc$w_length,&time_dsc,
                                &sample.time_stamp,0);
                check(status);
/* Convert the string returned to a C-style string. */
                time_str[time_dsc.dsc$w_length] = '\0';
/* Print a header after each 24 lines. */
                if(i%LINES_PER_PAGE == 0)
                {
                        printf("%-8s  %-23s  %-8s  %-10s  %-10s\n",
                                "Sample","Time of Sample","PC","BIO","DIO");
                        printf("%-8s  %-23s  %-8s  %-10s  %-10s\n",
                                "------","--------------","--","---","---");
                }
                printf("%08d:  %23s  %08x  %10d  %-10d\n",
                        ++i,time_str,sample.pc,sample.bio,sample.dio);
        }
/* Make sure we hit the end of file. */
        if(feof(fp))
        {
                puts("***** No more data *****");
        }
        else
        {
                fprintf(stderr,"Error reading %s\n",args[FILE_ARG]);
                exit(EXIT_FAILURE);
        }
        return(EXIT_SUCCESS);
}

$
$
$ cc dump_samples
$ link dump_samples
$
```

Define a foreign command for the sample dumper.

```
$ pc_dump == "$SYS$SYSDEVICE:[ELLIS.NASA]dump_samples"
$
```

Validate that the code generates an error when no sample file name is provided.

```
$ pc_dump
Bad command format!
Use: PC_DUMP file-name
%SYSTEM-F-INSFARG, insufficient call arguments
$
```

Example 20. PC_LISTENER Code

```
$ type pc_listener.c
/************************************
        PC_LISTENER
        listens to PC_LISTENER_MBX mailbox and displays samples.
        If no PC_LOGGER is active, aborts
************************************/
#include <descrip.h>
#include <cmbdef.h>
#include <stdio.h>
#include <starlet.h>
#include <iosbdef.h>
#include <iodef.h>
#include <ssdef.h>
#include <lnmdef.h>
#include <iledef.h>
#include <string.h>
#define check(S) if(!((S)&1)) sys$exit(S)
#include "pc_sampler3.h"
#define TIME_STR_LEN 23
#define LIST_END 0
int     main(void)
{
/* Mailbox name. */
        $DESCRIPTOR(mbx,"PC_LISTENER_MBX");
        int     status;
        iosb    ios;
        short chan;
        __int64 stall = (__int64) -20000000;
        Samp    buffer;
/* String yo hold the text representation of the time stamp. */
        char    time_str[TIME_STR_LEN+1];
        $DESCRIPTOR(time_dsc,time_str);
        $DESCRIPTOR(ptable,"LNM$PROCESS_DIRECTORY");
        $DESCRIPTOR(lnm,"LNM$TEMPORARY_MAILBOX");
        char    equiv[] = "LNM$GROUP";
        ile3    lnm_items[] = {{strlen(equiv),LNM$_STRING,equiv},{LIST_END}};
/*
        Create a logical name to cause the mailbox name to be placed
        in the group logical name table.
*/
        status = sys$crelnm(0,&ptable,&lnm,0,lnm_items);
        check(status);
/* Create/assign a table to the mailbox. */
        status = sys$crembx(0,&chan,0,0,0,0,&mbx,CMB$M_READONLY,0);
        check(status);

/* Read the mailbox using SYS$QIO until EOF. */
        do
        {
                status = sys$qiow(0,chan,IO$_READVBLK|IO$M_WRITERCHECK,&ios,
                                0,0,&buffer,sizeof(buffer),0,0,0,0);
                check(status);
                switch(ios.iosb$w_status)
                {
                        case SS$_ENDOFFILE:
```

```
                                puts("***  No more Data *** ");
                                break;
                        case SS$_NOWRITER:
                                fprintf(stderr,"Logger is not active.  "
                                        "Try again later.\n");
                                sys$exit(SS$_NOLISTENER);
                                break;
                        default:
                                check(ios.iosb$w_status);
/* Send the message to the screen. */
                                status = sys$asctim(&time_dsc.dsc$w_length,
                                        &time_dsc,
                                        &buffer.time_stamp,0);
                                check(status);
/* Convert the time string returned to a C-style string. */
                                time_str[time_dsc.dsc$w_length] = '\0';
                                printf("%08d:  %23s  %08x  %10d  %10d\n",
                                        buffer.sample_no,time_str,
                                        buffer.pc,buffer.bio,
                                        buffer.dio);
                }
        } while(ios.iosb$w_status != SS$_ENDOFFILE);
        return(SS$_NORMAL);
}
```

Example 21. Build Process

```
$
$ cc pc_tester
$ cc stub
$ cc pc_sampler3
$ link pc_tester,stub,pc_sampler3
$
$ cc pc_logger2
$ link pc_logger2
$
$ cc pc_listener
$ link pc_listener
$
```

Example 22. Sample Runs

```
$ r pc_tester
$ pc_dump sample.data
Sample    Time of Sample           PC        BIO         DIO
------    --------------           --        ---         ---
00000001:   1-SEP-2004 23:39:00.33  000300f0        3013  4625
00000002:   1-SEP-2004 23:39:01.33  00030110        3014  4625
00000003:   1-SEP-2004 23:39:02.33  00030150        3015  4625
00000004:   1-SEP-2004 23:39:03.34  00030150        3016  4625
00000005:   1-SEP-2004 23:39:04.34  00030104        3017  4625
00000006:   1-SEP-2004 23:39:05.34  00030110        3018  4625
```

```
00000007:   1-SEP-2004 23:39:06.34  00030150        3019  4625
00000008:   1-SEP-2004 23:39:07.34  000300f0        3020  4625
00000009:   1-SEP-2004 23:39:08.36  00030150        3021  4625
00000010:   1-SEP-2004 23:39:09.36  00030100        3022  4625
00000011:   1-SEP-2004 23:39:10.36  00030110        3023  4625
00000012:   1-SEP-2004 23:39:11.36  00030150        3024  4625
00000013:   1-SEP-2004 23:39:12.36  00030110        3025  4625
00000014:   1-SEP-2004 23:39:13.36  00030104        3026  4625
***** No more data *****
$
```

The Listener is run independently from another terminal session and picks up the data as it comes in.

Example 23. Sample PC_LISTENER Runs

```
$ r pc_listener
00000010:   1-SEP-2004 23:39:09.36  00030100        3022        4625
00000011:   1-SEP-2004 23:39:10.36  00030110        3023        4625
00000012:   1-SEP-2004 23:39:11.36  00030150        3024        4625
00000013:   1-SEP-2004 23:39:12.36  00030110        3025        4625
00000014:   1-SEP-2004 23:39:13.36  00030104        3026        4625
***  No more Data ***
$
Sample run with the sampler inactive.
$ r pc_listener
Logger is not active.  Try again later.
%SYSTEM-F-NOLISTENER, specified remote system process not listening
$
$ r pc_tester
$ pc_dump sample.data
Sample    Time of Sample           PC        BIO         DIO
------    --------------           --        ---         ---
00000001:   1-SEP-2004 23:40:05.92  00030104        3113  4631
00000002:   1-SEP-2004 23:40:06.92  00030100        3114  4631
00000003:   1-SEP-2004 23:40:07.93  00030104        3115  4631
00000004:   1-SEP-2004 23:40:08.93  00030150        3116  4631
00000005:   1-SEP-2004 23:40:09.93  000300f0        3117  4631
00000006:   1-SEP-2004 23:40:10.93  00030150        3118  4631
00000007:   1-SEP-2004 23:40:11.94  000300f0        3119  4631
00000008:   1-SEP-2004 23:40:12.94  000300f0        3120  4631
00000009:   1-SEP-2004 23:40:13.94  00030150        3121  4631
00000010:   1-SEP-2004 23:40:14.94  00030100        3122  4631
00000011:   1-SEP-2004 23:40:15.94  000300f0        3123  4631
00000012:   1-SEP-2004 23:40:16.94  00030110        3124  4631
00000013:   1-SEP-2004 23:40:17.94  000300f0        3125  4631
00000014:   1-SEP-2004 23:40:18.95  00030150        3126  4631
***** No more data *****
$
```

Again, this is run from another session.

```
$ r pc_listener
00000007:   1-SEP-2004 23:40:11.94  000300f0        3119        4631
00000008:   1-SEP-2004 23:40:12.94  000300f0        3120        4631
00000009:   1-SEP-2004 23:40:13.94  00030150        3121        4631
00000010:   1-SEP-2004 23:40:14.94  00030100        3122        4631
```

```
00000011:   1-SEP-2004 23:40:15.94  000300f0       3123       4631
00000012:   1-SEP-2004 23:40:16.94  00030110       3124       4631
00000013:   1-SEP-2004 23:40:17.94  000300f0       3125       4631
00000014:   1-SEP-2004 23:40:18.95  00030150       3126       4631
***  No more Data ***
$
```

For more information

On Mailboxes go to: http://h71000.www7.hp.com/doc/os83_index.html
Consult the following Manuals:
HP OpenVMS I/O User's Reference Manual
HP OpenVMS Programming Concepts Manual
HP OpenVMS System Services Reference Manual

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OpenVMS Technical Journal V9

Simplifying Maintenance with DCL

Bruce Claremont, Software Migration & OpenVMS Consultant

Overview

An important element of effective software application maintenance and a crucial component of job retention is expedient problem resolution. Key to resolving a problem is effective identification of its cause. A couple of decades ago I developed a standardized wrapper for OpenVMS DCL procedures that proved an effective assistant in locating processing problems. I have successfully deployed this code at many sites and continue to use it to this day. I offer it here as a means to ease the burden for those of you maintaining batch and interactive DCL processes in production environments.

Introduction

A key component to effective software maintenance is quick problem identification. OpenVMS users are fortunate in this regard in that DCL provides a nice set of commands to facilitate error capture and reporting. This document presents a DCL procedure template that demonstrates how to take advantage of those commands. You will also get a look at my basic coding philosophy, which is:

- *KISS* (Keep It Simple Sweetie ;)
- Be consistent
- Use comments!

DCL Procedure Template Overview

The template is designed to be applied to new and existing procedures. The template is very simple and does not limit procedure functionality. It enforces structured programming techniques via a single point of entry and exit. It also enforces implementation of return status values and a standard error handling routine.

Figure 1 presents the template in its entirety. Subsequent sections discuss the template components in detail.

Figure 1: DCL Procedure Template

```
$ IF F$MODE() .EQS. "BATCH" THEN SET VERIFY    !Always the first line!
$!-----------------------------------------
$! proc.COM
$!     procedure description
$!     Created:  id, mmm-yyyy
$!     Modified:  id, mmm-yyyy
$!     -
$!-------------------------------------------------------------------------------
$!     STANDARD PROCEDURE INITIALIZATION SECTION
$!
$ _BATCH = 0
$ IF F$MODE() .EQS. "BATCH" THEN _BATCH = 1
$ _BELL[0,8] = %X7
$ _STATUS = 1                           !Return Status
$ SAY := WRITE SYS$COMMAND
$ ASK := READ SYS$COMMAND -
       /END_OF_FILE=CANCEL_PROCEDURE -
       /PROMPT="
$ ON ERROR THEN GOTO ERROR_TRAP         !Standard abort trapping.
$ ON CONTROL_Y THEN GOTO ERROR_TRAP
$ IF _BATCH THEN SAY = "!"              !If a batch process, convert info
$!                                       messages to comments.
$!-------------------------------------------------------------------------------
$!     PROCEDURE BODY
       .
       .
       .
$!-------------------------------------------------------------------------------
$!     STANDARD PROCEDURE TERMINATION CODE
$!
$ END_PROCEDURE:
$!     *** Procedure specific termination code goes here. ***
$!
$ EXIT '_STATUS'
$!
$ ERROR_TRAP:
$!     *** Procedure specific error handling code goes here. ***
$!
$ IF .NOT. _BATCH
$   THEN
$ CONT_PROMPT:
$      SAY _BELL, "Procedure: ", F$ENVIRONMENT("PROCEDURE")
$      ASK "Procedure aborted by a <Ctrl^Y> or error.  Enter 0 to continue: " _QST
$      IF _QST .NES. "0" THEN GOTO CONT_PROMPT
$  ENDIF
$!
$!-------------------------------------------------------------------------------
$ CANCEL_PROCEDURE:
$!     STANDARD ABORT HANDLING CODE (Don't mess with this)
$!
$!     If this is the primary procedure (depth=0) and it is a batch procedure,
$!     have it exit with an error status (2) if it has terminated abnormally.
$!
$ IF _BATCH .AND. F$ENVIRONMENT("DEPTH") .LE. 0
$   THEN
$      _STATUS = 2
$   ELSE
$      _STATUS = 3
$  ENDIF
$ GOTO END_PROCEDURE
```

Detailed Template Walk-Through

The following sections provide a detailed walk-through of the DCL procedure template shown in Figure 1. The template components are explained, as is the reasoning behind them.

Any template is only effective if it is associated with a set of rules. What follows are the DCL coding policies I enforce when using this template. They might seem restrictive at first glance, but they are actually quite simple and easy to live with. They provide a fringe benefit in that they encourage structured coding practices.

Standardized Procedure Development Rules

- No EXIT statements are permitted within the body of the procedure. Only one EXIT statement appears in any procedure and its location is pre-set in the termination code.
- All procedure termination runs through the END_PROCEDURE section.
- If the procedure is terminated abnormally for any reason, it must run through the ERROR_TRAP section.
- If the procedure is cancelled for any reason, it must run through the CANCEL_PROCEDURE section.
- Avoid using the following commands and lexical function:
  - `SET NOVERIFY` or `F$VERIFY(0)`

    I require that batch jobs create log files. You will find that government accountability mandates do too. Turning off verification prevents data from being written to the log files.
  - `ON` *`condition`* `THEN CONTINUE`

    If a procedure generates an error, it is required to report the problem. Continuing from an error condition without a notification event is not allowed.
  - `SET NOON`

    Do not use the SET NOON command to disable error trapping within a procedure. Its sole purpose is to reset error-trapping protocols in special circumstances. Any time the SET NOON command is used, it should be immediately followed by these two lines of code:

    ```
    $ ON ERROR THEN GOTO ERROR_TRAP          !Standard abort trapping.
    $ ON CONTROL_Y THEN GOTO ERROR_TRAP
    ```

    These commands preserve standard error trapping functionality in the procedure.
- Use the ON *condition* commands with care. When special traps are created in procedures, ensure that they use the standard error routine to terminate the procedure. When the need for a special trap has passed, insert the following instruction:

```
$ SET NOON
$ ON ERROR THEN GOTO ERROR_TRAP             !Standard abort trapping.
$ ON CONTROL_Y THEN GOTO ERROR_TRAP
```

- An important aspect of the template's design is to capture and control procedure aborts. This is particularly important when using nested procedures (a procedure called by another procedure). To preserve exit control, all nested procedure calls should be immediately followed by this command line:

```
$ IF $STATUS .EQ. 3 THEN GOTO CANCEL_PROCEDURE
```

Example:

```
$ @PAYROLL:SINKORSWIM.COM
$ IF $STATUS .EQ. 3 THEN GOTO CANCEL_PROCEDURE
```

The `IF $STATUS` command line allows nested procedures that have generated an error to exit in a controlled fashion, preserving the error control capability.

Procedure Initialization

Now we will take a look at what I call the *procedure initialization section*. This is a short section of DCL code (a *snippet* in modern parlance) that goes at the beginning of each command procedure. It establishes a standard set of symbols and error control functions.

Figure 2: Procedure Initialization Section

```
$ IF F$MODE() .EQS. "BATCH" THEN SET VERIFY    !Always the first line!
$!----------------------------------------
$! proc.COM
$!     procedure description
$!     Created:   id, mmm-yyyy
$!     Modified:  id, mmm-yyyy
$!     -
$!-------------------------------------------------------------------------------
$!     STANDARD PROCEDURE INITIALIZATION SECTION
$!
$ _BATCH = 0
$ IF F$MODE() .EQS. "BATCH" THEN _BATCH = 1
$ _BELL[0,8] = %X7
$ _STATUS = 1                              !Return Status
$ SAY := WRITE SYS$COMMAND
$ ASK := READ SYS$COMMAND -
       /END_OF_FILE=CANCEL_PROCEDURE -
       /PROMPT="
$ ON ERROR THEN GOTO ERROR_TRAP            !Standard abort trapping.
$ ON CONTROL_Y THEN GOTO ERROR_TRAP
$ IF _BATCH THEN SAY = "!"                 !If a batch process, convert info
$!                                          messages to comments.
$!-------------------------------------------------------------------------------
$!     PROCEDURE BODY
```

- $ IF F$MODE() .EQS. "BATCH" THEN SET VERIFY

  In our coding polices, we state that batch procedures must always log the commands they execute. The F$MODE() lexical function on the template's first line ensures that the procedure will turn on verification if it is running in a batch process. If the procedure is being run interactively, it will preserve the verification mode in effect when it is executed. This line must always be the first line in the procedure.

  Why the insistence on having this as the first line? If some miscreant has disabled logging in a batch procedure that calls this one, ensuring that the mode is set to VERIFY in the first line guaranties that you will see the comment lines that follow in the resultant log file. These very nicely inform you what procedure is running which immensely simplifies process diagnostics.

- Introductory Comments

- Next comes a set of introductory comments. These include the procedure name, a brief description of the procedure's purpose, and creation and modification information. At Migration Specialties, we are firm believers in the judicious use of comments in code. In

fact, if you are employing coders that do not use comments, you should fire them and hire us. This isn't just a shameless marketing plug; it's sound business practice. Well-commented code speeds problem assessment and resolution.

- Standard Symbols

  Now it's time to define our standard symbols.

```
$ _BATCH = 0
$ IF F$MODE() .EQS. "BATCH" THEN _BATCH = 1
$ _BELL[0,8]    = %X7
$ _STATUS = 1                          !Return Status
$ SAY := WRITE SYS$COMMAND
$ ASK := READ SYS$COMMAND -
   /END_OF_FILE=CANCEL_PROCEDURE -
   /PROMPT="
```

  - **_BATCH**: Signifies the calling mode. 0 = Interactive; 1 = Batch.
  - **_BELL**: Symbolic representation of the control character (^G) that sounds a beep on a VT compatible terminal.
  - **_STATUS**: The _STATUS symbol is used to permit exiting of nested procedures in a controlled fashion when an error is encountered.
  - **SAY**: A symbolic representation of the command WRITE SYS$COMMAND. In other words, a shortcut. It is more common to see this shortcut defined as WRITE SYS$OUTPUT. I use SYS$COMMAND so output will appear on the display even if the procedure is executed with output redirected via the /OUTPUT qualifier.
  - **ASK**: A shortcut for an interactive READ command. Here SYS$COMMAND is used instead of SYS$INPUT to avoid problems with calls from nested procedures and batch procedures.

    Note the use of the /END_OF_FILE qualifier. Its usage tells the procedure to branch to the CANCEL_PROCEDURE label if a user enters a <Ctrl^Z> at an interactive prompt. <Ctrl^Z> is a common way to exit utilities in VMS, so using it in your procedures preserves operational continuity. Your users won't notice, and that's a good thing.

    Usage of both the SAY and ASK symbolic commands is demonstrated in the Error Trapping section later on in this document.

  So what's with the use of the underscore (_) as a symbol prefix? This is a technique I developed to avoid conflicts with existing symbols on client systems. For example, a client might be using a symbol called STATUS, and I do not want to confuse their STATUS symbol with mine, so I prefixed mine with an underscore; i.e., _STATUS.

  All right, so why didn't I prefix SAY and ASK with an underscore? It has been my experience that these are commonly used command symbols so making mine unique was not necessary.

  Ah ha! You have already seen room for improvement, haven't you? These commands could be placed in their own command procedure, defined as global instead of local symbols. Then all you would need to do is call this "setup" procedure to acquire all your standard symbol definitions. You are absolutely right and that is what I normally do. I

have declared these symbols inline for clarity in this article. Creating a standard setup configuration for command procedures is gist for another article.[1]

- ON ERROR & ON CONTROL_Y

  These commands are the heart of the error and abort control functionality the template provides.

```
$ ON ERROR THEN GOTO ERROR_TRAP             !Standard abort trapping.
$ ON CONTROL_Y THEN GOTO ERROR_TRAP
```

  Both ON ERROR and ON CONTROL_Y hand off process errors and user aborts (like entry of a <Ctrl^C>) to the label ERROR_TRAP. This turns control of the procedure over to the error trap routine, which ensures execution of problem notification and controlled exit routines. More details on these functions appear in the Error Trapping section.

- Changing Output to Comments

```
$ IF _BATCH THEN SAY = "!"           !If a batch process, convert info
$!                                    messages to comments.
```

  This is a little trick I use to allow a procedure to be run interchangeably as an interactive or batch process. When run interactively, the text in the SAY lines is displayed on the user's terminal. When run as a batch job, the SAY lines appear in the log file as comments. Not using this technique does no harm, but the batch log files will be messier, which doesn't aid problem diagnosis. Remember this old adage that I just made up: *cleanliness leads to clarity*.

That's it for the *procedure initialization section*. Once tailored to meet your specific requirements, the procedure initialization code should be identical for all production procedures.

Procedure Body

Between the *procedure initialization* and *procedure termination sections* lies the *procedure body*. Within the bounds of the coding rules listed at the beginning of this document, anything goes in the *procedure body*. Don't forget to comment your code; your job might depend upon it.

Also, don't forget to include the following line after any nested procedure calls in the procedure body. The reason for this will be explained in the Canceling a Procedure section.

```
$ IF $STATUS .EQ. 3 THEN GOTO CANCEL_PROCEDURE
```

Procedure Termination Section

Even shorter than the *procedure initialization section*, the *procedure termination section* serves as the common, *and only*, exit point for the procedure.

Figure 3: Procedure Termination Section

```
$!------------------------------------------------------------------------
$!     STANDARD PROCEDURE TERMINATION CODE (Modify with care)
```

[1] If you think I'm getting rich by grinding out multiple articles for the HP Technical Journal, check out the pay scale for authors. We do it because we love OpenVMS and enjoy sharing information.


```
$!
$ END_PROCEDURE:
$!
$!     *** Any procedure specific termination code goes here. ***
$!
$      EXIT '_STATUS'
```

This section of the template is where all procedure termination takes place. This is the only place in the procedure where an EXIT statement is allowed. Any code in the body of the procedure that exits normally should do so by executing a GOTO END_PROCEDURE command.

Any special instructions that need to be executed prior to procedure termination should also appear in this section. For example, deletion of temporary work files could take place here as part of the procedure clean-up process. The code in this section is executed every time the procedure terminates, regardless of whether the termination is normal or abnormal, so be careful with any code added to this section. Abnormal terminations are discussed in the Error Trap and Canceling a Procedure sections.

But wait! If you had a general set of wind-down commands you wanted to execute, wouldn't this be a great place to put the call to such a procedure? Absolutely! This is why standardized code is so useful.

Note that the _STATUS value is passed to the calling procedure with the EXIT command. The _STATUS value will be read by the calling procedure as the standard system symbol $STATUS. This is how we let the calling procedure know the termination state of the nested procedure. Possible return status values are:

1. Success
2. Error
3. Abnormal termination

More on _STATUS code setting and usage appears in the **Error! Reference source not found.** section.

Error Trapping

Thus far, the template has primarily provided a standardized initialization and coding schema. Now we are getting into the sections that handle things when problems occur.

Figure 4: Procedure Error Trapping Section

```
$ ERROR_TRAP:
$!     *** Procedure specific error handling code goes here. ***
$!
$ IF .NOT. _BATCH
$   THEN
$ CONT_PROMPT:
$      SAY _BELL, "Procedure: ", F$ENVIRONMENT("PROCEDURE")
$      ASK "Procedure aborted by a <Ctrl^Y> or error.  Enter 0 to continue: " _QST
$      IF _QST .NES. "0" THEN GOTO CONT_PROMPT
$  ENDIF
```

The ERROR_TRAP section provides a standard mechanism for capturing and reporting errors. This is where procedure control branches when an unexpected processing error occurs or a

user deliberately aborts a procedure. This is the target of the ON ERROR and ON CONTROL_Y commands in the initialization section.

Any special recovery code that is not implemented in the body of the procedure can be placed immediately following the ERROR_TRAP label. The recommended coding standard is to implement specialized error trapping within the procedure body and then initiate termination by executing the GOTO ERROR_TRAP command.

Using this template, interactive processes that encounter an error display an error message on the user's screen and pause for user confirmation before terminating. The purpose of this is to preserve the original error message on the screen, allowing users to see and report the message. Forcing entry of a zero to continue prevents errors from being missed because the user pressed the <Return> key multiple times.

This template does not demonstrate error logging and reporting for batch jobs. Adding this functionality is as simple as adding an ELSE clause to the IF .NOT. _BATCH statement. You will find a more comprehensive example in the article *Using OpenVMS to Meet a Sarbanes-Oxley Mandate*, available at this link:

http://www.migrationspecialties.com/pdf/Using%20OpenVMS%20to%20Meet%20a%20Sarbanes-Oxley%20Mandate2.pdf

Canceling a Procedure

We have arrived at the final section of the template. The CANCEL_PROCEDURE label is where execution control is passed if:

- A <Ctrl^Z> is used to terminate an ASK statement.
- A nested procedure exits abnormally ($STATUS = 3).
- The process stream needs to be cancelled immediately; i.e., a decision process in the body of the procedure executed a GOTO CANCEL_PROCEDURE statement.
- An error or abort is processed via the error trap section.

Figure 5: Procedure Cancellation Section

```
$ CANCEL_PROCEDURE:
$!     STANDARD ABORT HANDLING CODE (Don't mess with this)
$!
$!     If this is the primary procedure (depth=0) and it is a batch procedure,
$!     have it exit with an error status (2) if it has terminated abnormally.
$!
$ IF _BATCH .AND. F$ENVIRONMENT("DEPTH") .LE. 0
$   THEN
$      _STATUS = 2
$   ELSE
$      _STATUS = 3
$  ENDIF
$ GOTO END_PROCEDURE
```

CAUTION: The next few paragraphs reference the template defined symbol _STATUS and the standard system return status symbol $STATUS. Pay attention to the symbol names, as distinguishing between the two symbols is important.

The procedure cancellation section's job is to ensure that nested procedures exit in a controlled fashion. This is where using the IF $STATUS check immediately after nested procedure calls comes into play:

```
$ IF $STATUS .EQ. 3 THEN GOTO CANCEL_PROCEDURE
```

If a nested procedure encounters an error or abort, it reports it, then exits with the standard system return status symbol $STATUS set to 3 via the _STATUS declaration in the EXIT statement ($ EXIT '_STATUS'). Setting $STATUS to 3 achieves two objectives:

1. Setting $STATUS to an odd numeric value (3) allows the nested procedure to exit without generating another error. Setting $STATUS to 2 or another even value would generate an error in the calling procedure, resulting in another trip through the calling procedure ERROR_TRAP section. We want to avoid this, both for efficiency and to prevent further aggravating users. I know it can be hard, but we are here to serve and protect the users.
2. The IF $STATUS check immediately following the nested procedure call queries the return status. If a 3 is returned, it signifies an abnormal termination initiated by the nested procedure. Control is immediately passed to the CANCEL_PROCEDURE label in the calling procedure.

If this is an interactive procedure, that's the end of the decision process. The procedure stack will unwind, passing a return status of 3 up the line until the command line or calling menu is reached.

In the case of a batch process, an additional check is needed. We want the batch process to exit with an error status so that the job information is retained via the /RETAIN=ERROR function of the queue manager. (You do have RETAIN=ERROR set on all your batch queues, right?!) Consequently, as the stack of nested batch procedures unwinds, each procedure in the stack uses the lexical function F$ENVIRONMENT("DEPTH") to determine if it was the first procedure called. When the first procedure is reached, _STATUS is set to 2 to force an error condition via the system symbol $STATUS when the primary procedure terminates.

Well, you might ask, why not just blow up batch processes at the point the error occurred? You could. That is how most non-standardized procedures work. However, doing so prevents any automated clean-up from occurring, which adds to the time needed to recover from a problem, detracting from our goals of quick, efficient problem resolution. It also precludes using a standard template for both batch and interactive procedures, which by now you have come to realize is a really valuable tool.

Conclusion

That's it! Hard to believe such simple concepts took so many pages to explain. It just goes to show the power of a few well-placed DCL commands. I have found the use of the techniques described here to be extremely helpful in facilitating quick problem identification and resolution. I hope you find them equally useful.

Your comments and feedback are welcome. Those attached to large denomination bills will get a quicker response.

About the author: Bruce Claremont has been working with OpenVMS since 1983. He has extensive programming, project management, and system management experience. He founded

Migration Specialties in 1992 and continues to deliver OpenVMS and application migration services along with CHARON-VAX and CHARON-AXP hardware emulation ports. More information about Migration Specialties products and services can be found at *www.MigrationSpecialties.com*.

For more information

For real world examples of DCL procedure templates, check out these two articles:

- ODS-2/ISO-9660 CD Creation

  http://www.migrationspecialties.com/pdf/ODS-ISO.pdf

- *Using OpenVMS to Meet a Sarbanes-Oxley Mandate*

  http://www.migrationspecialties.com/pdf/Using%20OpenVMS%20to%20Meet%20a%20Sarbanes-Oxley%20Mandate2.pdf