Oracle® Database Appliance

Licensing Information User Manual

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A Open Source Software License Text

Preface

This document, which is part of the Program Documentation under the terms of your Oracle licensing agreement, is intended to help you understand the features, functionality, and options available for Oracle Programs.

If you have a question about your licensing needs, then contact your Oracle sales representative or the License Management Services representative at http://www.oracle.com/us/corporate/license-management-services/index.html. You can also refer to the resources listed in “Related Documents” for more information.

Audience

This book is intended for all purchasers of Oracle Database Appliance.

Documentation Accessibility

For information about Oracle's commitment to accessibility, visit the Oracle Accessibility Program website at http://www.oracle.com/pls/topic/lookup?ctx=acc&id=docacc.

Access to Oracle Support

Oracle customer access to and use of Oracle support services will be pursuant to the terms and conditions specified in their Oracle order for the applicable services.

Related Documents

For more information about Oracle Database Appliance, go to `http://www.oracle.com/goto/oda/docs` and click the appropriate release.

For more information about using Oracle Database, go to `http://docs.oracle.com/database/` and select the database release from the menu.

For more information about Oracle Integrated Lights Out Manager 3.2, see https://docs.oracle.com/cd/E37444_01/.

For more details about other Oracle products that are mentioned in Oracle Database Appliance documentation, see the Oracle Documentation home page at `http://docs.oracle.com`.

Conventions

The following text conventions are used in this document:

Convention	Meaning
boldface	Boldface type indicates graphical user interface elements associated with an action, or terms defined in text or the glossary.
italic	Italic type indicates book titles, emphasis, or placeholder variables for which you supply particular values.
`monospace`	Monospace type indicates commands within a paragraph, URLs, code in examples, text that appears on the screen, or text that you enter.

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Introduction

This Licensing Information document is a part of the product or program documentation under the terms of your Oracle license agreement and is intended to help you understand the program editions, entitlements, restrictions, prerequisites, special license rights, and/or separately licensed third party technology terms associated with the Oracle software program(s) covered by this document (the "Program(s)").

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Oracle Database Appliance Licensing Overview

This chapter provides an overview of the licensing process for each hardware platform.

Topics:

- About Licensing
  Oracle Database Appliance provides capacity-on-demand licensing.
- CPUs and Core Count
  Review this section for information about core license options for your Oracle Database Appliance hardware.
- Oracle Database Appliance KVM Hard Partitioning Compliance
  Review this section for information about Oracle Database Appliance KVM Hard Partitioning compliance.

About Licensing

Oracle Database Appliance provides capacity-on-demand licensing.

Capacity-on-demand (CoD) refers to an Oracle Database Appliance server that has a subset of its cores turned off so that the Oracle Database Enterprise Edition or Oracle Database Standard Edition 2 software license cost can be reduced. The number of cores can be reduced before or after the deployment. The number of active cores can be increased at a later time, when more capacity is needed. Oracle Database is licensed separately. Refer to *Database Licensing Information User Manual* for additional information.

When you add your hardware Support Identifier (SI) for Oracle Database Appliance to your My Oracle Support account, you establish a license for all the cores on your system. Oracle Database Appliance models can be deployed as bare metal systems or KVM-based virtualized systems. Both platform types offer capacity-on-demand licensing.

With bare-metal installations, you disable cores that you do not intend Oracle Database to use:

- For Oracle Database Appliance X11, X10, X9-2S, X9-2L, X9-2-HA, X8-2S, X8-2M, X8-2-HA, X7-2S, X7-2M, X7-2-HA: Issue the command `odacli modify-cpucore` to set the low water mark and to increase the cores.

Chapter three explains how to obtain a licensing key and record your initial license requirements with My Oracle Support. It also explains how to change the licensed core count, if necessary, later. Chapter three is appropriate for bare metal installations where your license covers the cores that you are using for Oracle Database.

Chapter four contains information about the third-party products that are included with Oracle Database Appliance.

Note:

If you use the Integrated Oracle Data Guard feature only, then you **do not** require a separate Oracle Active Data Guard license.

About License Options for Oracle Database Standard Edition 2 on Oracle Database Appliance

For the purposes of licensing Oracle Database Standard Edition 2 on Oracle Database Appliance running multi-chip modules, where each chip in a multi-chip module is counted as an occupied socket for licensing purposes, you may exceed the 2 sockets per server limit. Oracle Database Standard Edition 2 requires one processor license for every 8 enabled cores on Oracle Database Appliance running multi-chip modules. If the number of enabled cores is not divisible by 8, the quotient must be rounded up to the nearest whole number to determine the number of Oracle Database Standard Edition 2 processor licenses required.

Note:

The minimum licenses when licensing by SE2 Named User Plus (NUP) metric are 10 NUP licenses per server.

CPUs and Core Count

Review this section for information about core license options for your Oracle Database Appliance hardware.

- Oracle Database Appliance X11-HA has 2 servers, each with 2 CPUs of 32 cores each. When you deploy Oracle Database Appliance X11-HA, all 128 cores (64 cores in each server) are active with hyper-threading enabled by default.
- Oracle Database Appliance X11-L contains 2 CPUs with 32 cores for a total of 64 cores. When you deploy Oracle Database Appliance X11-L, all 64 cores are active with hyper-threading enabled by default.
- Oracle Database Appliance X11-S contains 1 CPU with 32 cores. When you deploy Oracle Database Appliance X11-S, all 32 cores are active with hyper-threading enabled by default.
- Oracle Database Appliance X10-HA has 2 servers, each with 2 CPUs of 32 cores each. When you deploy Oracle Database Appliance X10-HA, all 128 cores (64 cores in each server) are active with hyper-threading enabled by default.
- Oracle Database Appliance X10-L contains 2 CPUs with 32 cores for a total of 64 cores. When you deploy Oracle Database Appliance X10-L, all 64 cores are active with hyper-threading enabled by default.
- Oracle Database Appliance X10-S contains 1 CPU with 32 cores. When you deploy Oracle Database Appliance X10-S, all 32 cores are active with hyper-threading enabled by default.
- Oracle Database Appliance X9-2-HA has 2 servers, each with 2 CPUs of 16 cores each. When you deploy Oracle Database Appliance X9-2-HA, all 64 cores (32 cores in each server) are active with hyper-threading enabled by default.

- Oracle Database Appliance X9-2L contains 2 CPUs with 16 cores for a total of 32 cores. When you deploy Oracle Database Appliance X9-2L, all 32 cores are active with hyper-threading enabled by default.
- Oracle Database Appliance X9-2S contains 1 CPU with 16 cores. When you deploy Oracle Database Appliance X9-2S, all 16 cores are active with hyper-threading enabled by default.
- Oracle Database Appliance X8-2-HA has 2 servers, each with 2 CPUs of 16 cores each. When you deploy Oracle Database Appliance X8-2-HA, all 64 cores (32 cores in each server) are active with hyper-threading enabled by default.
- Oracle Database Appliance X8-2M contains 2 CPUs with 16 cores for a total of 32 cores. When you deploy Oracle Database Appliance X8-2M, all 32 cores are active with hyper-threading enabled by default.
- Oracle Database Appliance X8-2S contains 1 CPU with 16 cores. When you deploy Oracle Database Appliance X8-2S, all 16 cores are active with hyper-threading enabled by default.
- Oracle Database Appliance X7-2-HA has 2 servers, each with 2 CPUs of 18 cores each. When you deploy Oracle Database Appliance X7-2-HA, all 72 cores (36 cores in each server) are active with hyper-threading enabled by default.
- Oracle Database Appliance X7-2M contains 2 CPUs with 18 cores for a total of 36 cores. When you deploy Oracle Database Appliance X7-2M, all 36 cores are active with hyper-threading enabled by default.
- Oracle Database Appliance X7-2S contains 1 CPU with 10 cores. When you deploy Oracle Database Appliance X7-2S, all 10 cores are active with hyper-threading enabled by default.

Oracle Database Appliance bare metal licensing is determined by the number of enabled cores that you have on your system. The capacity-on-demand licensing feature enables you to change the enabled core count as your system resource needs change.

Initialize the number of licensed cores to the level currently required by your applications. Each server node has the same number of active cores. Later, increase the licensed core count as your applications require more capacity. Change the number of licensed cores by obtaining and applying a core key to configure your appliance, using the tables for your Oracle Database Appliance platform.

Oracle Database Appliance X11-HA Licensed Core Licensing Options

The table provides an example of how the licensed cores for each node of an Oracle Database Appliance X11-HA relate to active cores for Oracle RAC and Oracle Enterprise Edition and active cores for Oracle RAC One Node.

Table 2-1 Example of Bare Metal License Options for Oracle Database Appliance X11-HA Systems

Licensed Cores for Each Node (X11-HA Only)	Active Cores for Oracle RAC and Oracle Enterprise Edition (X11-HA Only)	Active Cores for Oracle RAC One Node (X11-HA Only)
2	4	2
4	8	4
6	12	6
8	16	8

Table 2-1 (Cont.) Example of Bare Metal License Options for Oracle Database Appliance X11-HA Systems

Licensed Cores for Each Node (X11-HA Only)	Active Cores for Oracle RAC and Oracle Enterprise Edition (X11-HA Only)	Active Cores for Oracle RAC One Node (X11-HA Only)
10	20	10
12	24	12
14	28	14
16	32	16
18	36	18
20	40	20
22	44	22
24	48	24
26	52	26
28	56	28
30	60	30
32	64	32

Oracle Database Appliance X11-L and X11-S Licensed Core Licensing Options

Table 2-2 Bare Metal License Options for all Oracle Database Appliance X11-L and X11-S Systems

Licensed Cores for Single Node (X11-S)	Licensed Cores for Single Node (X11-L)
2	2
4	4
6	6
8	8
10	10
12	12
14	14
16	16
Not applicable	18
Not applicable	20
Not applicable	22
Not applicable	24
Not applicable	26
Not applicable	28
Not applicable	30
Not applicable	32

Oracle Database Appliance X10-HA Licensed Core Licensing Options

The table provides an example of how the licensed cores for each node of an Oracle Database Appliance X10-HA relate to active cores for Oracle RAC and Oracle Enterprise Edition and active cores for Oracle RAC One Node.

Table 2-3 Example of Bare Metal License Options for Oracle Database Appliance X10-HA Systems

Licensed Cores for Each Node (X10-HA Only)	Active Cores for Oracle RAC and Oracle Enterprise Edition (X10-HA Only)	Active Cores for Oracle RAC One Node (X10-HA Only)
2	4	2
4	8	4
6	12	6
8	16	8
10	20	10
12	24	12
14	28	14
16	32	16
18	36	18
20	40	20
22	44	22
24	48	24
26	52	26
28	56	28
30	60	30
32	64	32

Oracle Database Appliance X10-L and X10-S Licensed Core Licensing Options

Table 2-4 Bare Metal License Options for all Oracle Database Appliance X10-L and X10-S Systems

Licensed Cores for Single Node (X10-S)	Licensed Cores for Single Node (X10-L)
2	2
4	4
6	6
8	8
10	10
12	12
14	14
16	16
Not applicable	18
Not applicable	20

Table 2-4 (Cont.) Bare Metal License Options for all Oracle Database Appliance X10-L and X10-S Systems

Licensed Cores for Single Node (X10-S)	Licensed Cores for Single Node (X10-L)
Not applicable	22
Not applicable	24
Not applicable	26
Not applicable	28
Not applicable	30
Not applicable	32

Oracle Database Appliance X9-2-HA Licensed Core Licensing Options

The table provides an example of how the licensed cores for each node of an Oracle Database Appliance X9-2-HA relate to active cores for Oracle RAC and Oracle Enterprise Edition and active cores for Oracle RAC One Node.

Table 2-5 Example of Bare Metal License Options for Oracle Database Appliance X9-2-HA Systems

Licensed Cores for Each Node (X9-2-HA Only)	Active Cores for Oracle RAC and Oracle Enterprise Edition (X9-2-HA Only)	Active Cores for Oracle RAC One Node (X9-2-HA Only)
2	4	2
4	8	4
6	12	6
8	16	8
10	20	10
12	24	12
14	28	14
16	32	16
18	36	18
20	40	20
22	44	22
24	48	24
26	52	26
28	56	28
30	60	30
32	64	32

Oracle Database Appliance X9-2L and X9-2S Licensed Core Licensing Options

Table 2-6 Bare Metal License Options for all Oracle Database Appliance X9-2L and X9-2S Systems

Licensed Cores for Single Node (X9-2S)	Licensed Cores for Single Node (X9-2L)
2	2
4	4
6	6
8	8
10	10
12	12
14	14
16	16
Not applicable	18
Not applicable	20
Not applicable	22
Not applicable	24
Not applicable	26
Not applicable	28
Not applicable	30
Not applicable	32

Oracle Database Appliance X8-2-HA Licensed Core Licensing Options

The table provides an example of how the licensed cores for each node of an Oracle Database Appliance X8-2-HA relate to active cores for Oracle RAC and Oracle Enterprise Edition and active cores for Oracle RAC One Node.

Table 2-7 Example of Bare Metal License Options for Oracle Database Appliance X8-2-HA Systems

Licensed Cores for Each Node (X8-2-HA Only)	Active Cores for Oracle RAC and Oracle Enterprise Edition (X8-2-HA Only)	Active Cores for Oracle RAC One Node (X8-2-HA Only)
2	4	2
4	8	4
6	12	6
8	16	8
10	20	10
12	24	12
14	28	14
16	32	16
18	36	18
20	40	20

Table 2-7 (Cont.) Example of Bare Metal License Options for Oracle Database Appliance X8-2-HA Systems

Licensed Cores for Each Node (X8-2-HA Only)	Active Cores for Oracle RAC and Oracle Enterprise Edition (X8-2-HA Only)	Active Cores for Oracle RAC One Node (X8-2-HA Only)
22	44	22
24	48	24
26	52	26
28	56	28
30	60	30
32	64	32

Oracle Database Appliance X8-2M and X8-2S Licensed Core Licensing Options

Table 2-8 Bare Metal License Options for all Oracle Database Appliance X8-2M and X8-2S Systems

Licensed Cores for Single Node (X8-2S)	Licensed Cores for Single Node (X8-2M)
2	2
4	4
6	6
8	8
10	10
12	12
14	14
16	16
Not applicable	18
Not applicable	20
Not applicable	22
Not applicable	24
Not applicable	26
Not applicable	28
Not applicable	30
Not applicable	32

Oracle Database Appliance X7-2-HA Licensed Core Licensing Options

The table provides an example of how the licensed cores for each node of an Oracle Database Appliance X7-2-HA relate to active cores for Oracle RAC and Oracle Enterprise Edition and active cores for Oracle RAC One Node.

Table 2-9 Example of Bare Metal License Options for Oracle Database Appliance X7-2-HA Systems

Licensed Cores for Each Node (X7-2-HA Only)	Active Cores for Oracle RAC and Oracle Enterprise Edition (X7-2-HA Only)	Active Cores for Oracle RAC One Node (X7-2-HA Only)
2	4	2
4	8	4
6	12	6
8	16	8
10	20	10
12	24	12
14	28	14
16	32	16
18	36	18
20	40	20
22	44	22
24	48	24
26	52	26
28	56	28
30	60	30
32	64	32
34	68	34
36	72	36

Oracle Database Appliance X7-2 Licensed Core Licensing Options

Table 2-10 Bare Metal License Options for all Oracle Database Appliance X7-2 Systems

Licensed Cores for Single Node (X7-2S)	Licensed Cores for Single Node (X7-2M)
2	2
4	4
6	6
8	8
10	10
Not applicable	12
Not applicable	14
Not applicable	16
Not applicable	18
Not applicable	20
Not applicable	22
Not applicable	24
Not applicable	26

Table 2-10 (Cont.) Bare Metal License Options for all Oracle Database Appliance X7-2 Systems

Licensed Cores for Single Node (X7-2S)	Licensed Cores for Single Node (X7-2M)
Not applicable	28
Not applicable	30
Not applicable	32
Not applicable	34
Not applicable	36

Oracle Database Appliance KVM Hard Partitioning Compliance

Review this section for information about Oracle Database Appliance KVM Hard Partitioning compliance.

Oracle Database Appliance DB systems and application KVMs conform to Oracle Linux KVM Hard Partitioning requirements as specified in Hard Partitioning with Oracle Linux KVM:

https://www.oracle.com/a/ocom/docs/linux/ol-kvm-hard-partitioning.pdf

Considerations for CPU Pool Subscription

CPU Pools are used for management of CPU resources only. Database license requirements are determined by KVM Hard Partitioning only.

In a DB system with a shared or internal CPU pool, the cores are pinned based on the database shape selected for the DB system. For example, if you create a DB system with `odb2`, then you must license 2 cores.

In a DB system with a shared CPU pool, consider both undersubscription and oversubscription scenarios.

- **Undersubscription:** Consider a shared CPU pool with 8 cores. If you create a DB system with `odb2` and another with `odb4`, then a total of 6 cores are used. So, although the shared CPU pool is undersubcribed, you must run the `virsh` command in each KVM or DB system to determine the pinned cores that need to be licensed. In this case, it is the same 8 cores visible to both DB systems.
- **Oversubscription:** Consider a shared CPU pool with 8 cores, and you create a DB system with `odb4` and another with `odb6`. Although the shared CPU pool is oversubscribed, you must run the `virsh` command in each KVM or DB System to determine the pinned cores that need to be licensed. In this case, it is the same 8 cores visible to both DB systems.

Note that the same CPU pool subscription policy applies to shared CPU pools for application KVMs too.

Validating the CPUs for an Oracle Database Appliance DB System and Application KVM

You must run the `virsh` command for every DB system to identify the pinned vCPUs and CPU cores licensing requirements.

To validate that the CPUs for a virtual machine are pinned to a physical thread or core, run the following command:

```
# virsh --readonly vcpuinfo VM_name --pretty
```

The following example illustrates how you can validate the CPUs for an Oracle Database Appliance DB System with the db shape `odb2` that uses 2 cores (4 vCPUs):

1. Determine the VM Name by running this command:

   ```
   # odacli describe-dbsystem -n dbs1 | grep "VM Name"
   VM Name:  x97f18b518
   ```

   In this example, the DB System name is `dbs1`.

2. Run the `virsh` command to confirm that vCPUs are pinned to physical threads or cores for `x97f18b518`:

   ```
   # virsh --readonly vcpuinfo x97f18b518 --pretty

   VCPU:           0
   CPU:            19
   State:          running
   CPU time:       79.3s
   CPU Affinity:   19,24,55,60 (out of 72)

   VCPU:           1
   CPU:            55
   State:          running
   CPU time:       71.5s
   CPU Affinity:   19,24,55,60 (out of 72)

   VCPU:           2
   CPU:            60
   State:          running
   CPU time:       71.7s
   CPU Affinity:   19,24,55,60 (out of 72)

   VCPU:           3
   CPU:            24
   State:          running
   CPU time:       73.1s
   CPU Affinity:   19,24,55,60 (out of 72)
   ----------------------------------------
   ```

   In this example, the pinned vCPUs are 19, 24, 55, and 60, out of 72.

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Capacity-On-Demand Licensing Information

This chapter provides capacity-on-demand licensing information for Oracle Database Appliance bare metal installations.

- Oracle Database Appliance Capacity-on-Demand Licensing
  Capacity-on-Demand software licensing enables you to deploy as few or as many processors in Oracle Database Appliance as your workload requires.
- Capacity-On-Demand Licensing for Oracle Database Appliance X11-S, X11-L, and X11-HA
  Review capacity-on-demand licensing for Oracle Database Appliance X11-S, X11-L, and X11-HA.
- Capacity-On-Demand Licensing for Oracle Database Appliance X10-S, X10-L, and X10-HA
  Review capacity-on-demand licensing for Oracle Database Appliance X10-S, X10-L, and X10-HA.
- Capacity-On-Demand Licensing for Oracle Database Appliance X9-2S, X9-2L, and X9-2-HA
  Review capacity-on-demand licensing for Oracle Database Appliance X9-2S, X9-2L, and X9-2-HA.
- Capacity-On-Demand Licensing for Oracle Database Appliance X8-2S, X8-2M, and X8-2-HA
  Review capacity-on-demand licensing for Oracle Database Appliance X8-2S, X8-2M, and X8-2-HA.
- Capacity-On-Demand Licensing for Oracle Database Appliance X7-2S, X7-2M, and X7-2-HA
  Review capacity-on-demand licensing for Oracle Database Appliance X7-2S, X7-2M, and X7-2-HA.

Oracle Database Appliance Capacity-on-Demand Licensing

Capacity-on-Demand software licensing enables you to deploy as few or as many processors in Oracle Database Appliance as your workload requires.

Oracle Database Appliance’s Capacity-on-Demand feature enables you to add more processor cores to scale up to increased system demands as you need to, without incurring the excessive costs and downtime usually associated with hardware upgrades. Additional cores are increased in 2-core increments.

Oracle Database Appliance Scaling Capabilities

The following table lists the scaling capacities for Oracle Database Appliance bare metal and virtualized platform deployments. The decision to use bare-metal or Oracle Database Appliance Virtualized Platform depends on your company policies and the benefits that each implementation offers your company.

Table 3-1 Oracle Database Appliance Scaling Capacities

Oracle Database Appliance Platform	Minimum Number Processor Cores	Maximum Number Processor Cores
X10-S	2	32
X10-L	2	64
X10-HA	2	128
X9-2S	2	16
X9-2L	2	32
X9-2-HA	2	64
X8-2S	2	16
X8-2M	2	32
X8-2-HA	2	64
X7-2S	2	10
X7-2M	2	36
X7-2-HA	2	72
X6-2S	2	10
X6-2M	2	20
X6-2L	2	20
X6-2-HA	2	40
X5-2	2	72
X4-2	2	48

Applications Deployed on Oracle Database Appliance and Capacity-on-Demand

All Oracle products that are deployed on Oracle Database Appliance can take advantage of Capacity-on-Demand licensing.

> **Note:**
>
> For the procedure to set the CPU Core Count, see the *Oracle Database Appliance Deployment and User Guide* for your hardware model.

Capacity-On-Demand Licensing for Oracle Database Appliance X11-S, X11-L, and X11-HA

Review capacity-on-demand licensing for Oracle Database Appliance X11-S, X11-L, and X11-HA.

For the procedure to set the CPU Core Count, see the *Oracle Database Appliance Deployment and User Guide* for your hardware model.

The following list describes the number of cores for each Oracle Database Appliance X11-S model:

- Oracle Database Appliance X11-S is a single server consisting of 32 cores.
- Oracle Database Appliance X11-L is a single server consisting of 64 cores.
- Oracle Database Appliance X11-HA consists of two servers. Each server has 64 cores, for a total of 128 cores.

By default, Oracle Database Appliance ships with all cores enabled. You can reduce the number of active cores before or after deployment. You can increase the number of active cores when additional capacity is needed. This is known as **capacity-on-demand**. Additional cores are increased in 2-core increments.

Rules and Restrictions for Setting CPU Core Count on Oracle Database Appliance X11-S, X11-L, and X11-HA Bare Metal Deployments

Review the following rules and restrictions before changing the CPU core count:

- You can change the CPU core count to a value that is a multiple of two between 2 and the maximum number of cores for the hardware model. For example, for X11-HA, between 2 and 64 cores for each server for a maximum of 128 cores.
- If you change the CPU core count, then you can subsequently only increase the CPU core count.
- You should only change the CPU core count if you need less than the maximum number of cores.

  For example, if you change the CPU core count to 8, then you can subsequently increase the CPU core count to a higher number (in increments of 2 cores), but you cannot decrease the CPU core count.
- If you want the maximum number of cores for each server (32 cores per server for X11-L and X11-HA), then use the default configuration. There is no need to set the CPU core count.

> **Note:**
>
> If you mistakenly followed the procedure to set your CPU core count to the maximum, thereby preventing you from subsequently decreasing your CPU core count, and the error is caught immediately, then contact Oracle Support.

Capacity-On-Demand Licensing for Oracle Database Appliance X10-S, X10-L, and X10-HA

Review capacity-on-demand licensing for Oracle Database Appliance X10-S, X10-L, and X10-HA.

For the procedure to set the CPU Core Count, see the *Oracle Database Appliance Deployment and User Guide* for your hardware model.

The following list describes the number of cores for each Oracle Database Appliance X10-S model:

- Oracle Database Appliance X10-S is a single server consisting of 32 cores.
- Oracle Database Appliance X10-L is a single server consisting of 64 cores.

- Oracle Database Appliance X10-HA consists of two servers. Each server has 64 cores, for a total of 128 cores.

By default, Oracle Database Appliance ships with all cores enabled. You can reduce the number of active cores before or after deployment. You can increase the number of active cores when additional capacity is needed. This is known as **capacity-on-demand**. Additional cores are increased in 2-core increments.

Rules and Restrictions for Setting CPU Core Count on Oracle Database Appliance X10-S, X10-L, and X10-HA Bare Metal Deployments

Review the following rules and restrictions before changing the CPU core count:

- You can change the CPU core count to a value that is a multiple of two between 2 and the maximum number of cores for the hardware model. For example, for X10-HA, between 2 and 64 cores for each server for a maximum of 128 cores.
- If you change the CPU core count, then you can subsequently only increase the CPU core count.
- You should only change the CPU core count if you need less than the maximum number of cores.

  For example, if you change the CPU core count to 8, then you can subsequently increase the CPU core count to a higher number (in increments of 2 cores), but you cannot decrease the CPU core count.
- If you want the maximum number of cores for each server (32 cores per server for X10-L and X10-HA), then use the default configuration. There is no need to set the CPU core count.

> **Note:**
>
> If you mistakenly followed the procedure to set your CPU core count to the maximum, thereby preventing you from subsequently decreasing your CPU core count, and the error is caught immediately, then contact Oracle Support.

Capacity-On-Demand Licensing for Oracle Database Appliance X9-2S, X9-2L, and X9-2-HA

Review capacity-on-demand licensing for Oracle Database Appliance X9-2S, X9-2L, and X9-2-HA.

For the procedure to set the CPU Core Count, see the *Oracle Database Appliance Deployment and User Guide* for your hardware model.

The following list describes the number of cores for each Oracle Database Appliance X9-2 model:

- Oracle Database Appliance X9-2S is a single server consisting of 16 cores.
- Oracle Database Appliance X9-2L is a single server consisting of 32 cores.
- Oracle Database Appliance X9-2-HA consists of two servers. Each server has 32 cores, for a total of 64 cores.

By default, Oracle Database Appliance ships with all cores enabled. You can reduce the number of active cores before or after deployment. You can increase the number of active cores when additional capacity is needed. This is known as **capacity-on-demand**. Additional cores are increased in 2-core increments.

Rules and Restrictions for Setting CPU Core Count on Oracle Database Appliance X9-2S, X9-2L, and X9-2-HA Bare Metal Deployments

Review the following rules and restrictions before changing the CPU core count:

- You can change the CPU core count to a value that is a multiple of two between 2 and the maximum number of cores for the hardware model. For example, for X9-2-HA, between 2 and 32 cores for each server for a maximum of 64 cores.
- If you change the CPU core count, then you can subsequently only increase the CPU core count.
- You should only change the CPU core count if you need less than the maximum number of cores.

  For example, if you change the CPU core count to 8, then you can subsequently increase the CPU core count to a higher number (in increments of 2 cores), but you cannot decrease the CPU core count.
- If you want the maximum number of cores for each server (32 cores per server for X9-2L and X9-2-HA), then use the default configuration. There is no need to set the CPU core count.

> **Note:**
>
> If you mistakenly followed the procedure to set your CPU core count to the maximum, thereby preventing you from subsequently decreasing your CPU core count, and the error is caught immediately, then contact Oracle Support.

Capacity-On-Demand Licensing for Oracle Database Appliance X8-2S, X8-2M, and X8-2-HA

Review capacity-on-demand licensing for Oracle Database Appliance X8-2S, X8-2M, and X8-2-HA.

For the procedure to set the CPU Core Count, see the *Oracle Database Appliance Deployment and User Guide* for your hardware model.

The following list describes the number of cores for each Oracle Database Appliance X8-2 model:

- Oracle Database Appliance X8-2S is a single server consisting of 16 cores.
- Oracle Database Appliance X8-2M is a single server consisting of 32 cores.
- Oracle Database Appliance X8-2-HA consists of two servers. Each server has 32 cores, for a total of 64 cores.

By default, Oracle Database Appliance ships with all cores enabled. You can reduce the number of active cores before or after deployment. You can increase the number of active cores when additional capacity is needed. This is known as **capacity-on-demand**. Additional cores are increased in 2-core increments.

Rules and Restrictions for Setting CPU Core Count on Oracle Database Appliance X8-2S, X8-2M, and X8-2-HA Bare Metal Deployments

Review the following rules and restrictions before changing the CPU core count:

- You can change the CPU core count to a value that is a multiple of two between 2 and the maximum number of cores for the hardware model. For example, for X8-2-HA, between 2 and 32 cores for each server for a maximum of 64 cores.
- If you change the CPU core count, then you can subsequently only increase the CPU core count.
- You should only change the CPU core count if you need less than the maximum number of cores.

  For example, if you change the CPU core count to 8, then you can subsequently increase the CPU core count to a higher number (in increments of 2 cores), but you cannot decrease the CPU core count.
- If you want the maximum number of cores for each server (32 cores per server for X8-2M and X8-2-HA), then use the default configuration. There is no need to set the CPU core count.

> **Note:**
>
> If you mistakenly followed the procedure to set your CPU core count to the maximum, thereby preventing you from subsequently decreasing your CPU core count, and the error is caught immediately, then contact Oracle Support.

Capacity-On-Demand Licensing for Oracle Database Appliance X7-2S, X7-2M, and X7-2-HA

Review capacity-on-demand licensing for Oracle Database Appliance X7-2S, X7-2M, and X7-2-HA.

For the procedure to se the CPU Core Count, see the *Oracle Database Appliance Deployment and User Guide* for your hardware model.

The following list describes the number of cores for each Oracle Database Appliance X7-2 model:

- Oracle Database Appliance X7-2S is a single server consisting of 10 cores.
- Oracle Database Appliance X7-2M is a single server consisting of 36 cores.
- Oracle Database Appliance X7-2-HA consists of two servers. Each server has 36 cores, for a total of 72 cores.

By default, Oracle Database Appliance ships with all cores enabled. You can reduce the number of active cores before or after deployment. You can increase the number of active cores when additional capacity is needed. This is known as **capacity-on-demand**. Additional cores are increased in 2-core increments.

Rules and Restrictions for Setting CPU Core Count on Oracle Database Appliance X7-2S, X7-2M, and X7-2-HA Bare Metal Deployments

Review the following rules and restrictions before changing the CPU core count:

- You can change the CPU core count to a value that is a multiple of two between 2 and the maximum number of cores for the hardware model. For example, for X7-2-HA, between 2 and 36 cores for each server for a maximum of 72 cores.
- If you change the CPU core count, then you can subsequently only increase the CPU core count.
- You should only change the CPU core count if you need less than the maximum number of cores.

  For example, if you change the CPU core count to 8, then you can subsequently increase the CPU core count to a higher number (in increments of 2 cores), but you cannot decrease the CPU core count.
- If you want the maximum number of cores for each server (36 cores per server for X7-2M and X7-2-HA), then use the default configuration. There is no need to set the CPU core count.

> **Note:**
>
> If you mistakenly followed the procedure to set your CPU core count to the maximum, thereby preventing you from subsequently decreasing your CPU core count, and the error is caught immediately, then contact Oracle Support.

4

Third-Party Product Licenses for This Release

This chapter contains the licenses for the third-party products that are included with Oracle Database Appliance for this release.

- Oracle Database Third-Party Licensing Information
  Understand licensing information about third-party products used by Oracle Database.
- Other Third-Party Product Licenses
  Review other third-party product licenses for Oracle Database Appliance.
- Written Offer for Source Code

Oracle Database Third-Party Licensing Information

Understand licensing information about third-party products used by Oracle Database.

Oracle Database Appliance includes Oracle Database19c. To view the licenses for these third-party products, refer to the release-specific *Oracle Database Licensing Information User Manual*.

Related Topics

- Licensing Information User Manual Oracle Database 21c
- Licensing Information User Manual Oracle Database 19c

Other Third-Party Product Licenses

Review other third-party product licenses for Oracle Database Appliance.

Required notices for open source or other separately licensed software products or components distributed in Oracle Database Appliance release 19.26 are identified in the following table along with the applicable licensing information. Additional notices and/or licenses may be found in the included documentation or readme files of the individual third party software.

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### Contributors to the Porter Stemmer

- Martin Porter
- Vivake Gupta
- Barry Wilkins
- Hiranmay Ghosh
- Chris Emerson

### Authors of snowball arabic stemmer algorithm

- Assem Chelli
- Abdelkrim Aries
- Lakhdar Benzahia



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?????????????????????????????????????????????????
???????????????????????????????????
 nltk has dependencies on following libraries:

    nltk needs "click"
        "click" needs "importlib-metadata"
            "importlib-metadata" needs "typing-
extensions"
                "typing-extensions" doesn't have
any dependencies
            "importlib-metadata" needs "zipp"
                "zipp" doesn't have any
dependencies
    nltk needs "joblib"
        "joblib" doesn't have any dependencies
    nltk needs "regex"
        "regex" doesn't have any dependencies
    nltk needs "tqdm"
        "tqdm" doesn't have any dependencies
?????????????????????????????????????????????????
```

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?????????????????????????????????????????????????
?????????????????????????????????????????????????
?????????????????????
package_name: click
license_type: BSD License
copyright: Copyright 2014 Pallets
license_text:
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versions of the
software.

In May 2000, Guido and the Python core
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In October of the same
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the Python Software
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was formed, a
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    Release         Derived     Year
Owner       GPL-

from                                    compatible?
(1)

    0.9.0 thru 1.2              1991-1995
CWI         yes
    1.3 thru 1.5.2  1.2         1995-1999
CNRI        yes
    1.6             1.5.2       2000
CNRI        no
    2.0             1.6         2000
BeOpen.com  no
    1.6.1           1.6         2001
CNRI        yes (2)
    2.1             2.0+1.6.1   2001
PSF         no
    2.0.1           2.0+1.6.1   2001
PSF         yes
    2.1.1           2.1+2.0.1   2001
PSF         yes
    2.1.2           2.1.1       2002
PSF         yes
    2.1.3           2.1.2       2002
PSF         yes
    2.2 and above   2.1.1       2001-now
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		interfaces specified for a particular programming language, one that is widely used among developers working in that language. The "System Libraries" of an executable work include anything, other than the work as a whole, that (a) is included in the normal form of packaging a Major Component, but which is not part of that Major Component, and (b) serves only to enable use of the work with that Major Component, or to implement a Standard Interface for which an implementation is available to the public in source code form. A "Major Component", in this context, means a major essential component (kernel, window system, and so on) of the specific operating system (if any) on which the executable work runs, or a compiler used to produce the work, or an object code interpreter used to run it. The "Corresponding Source" for a work in object code form means all the source code needed to generate, install, and (for an executable work) run the object code and to modify the work, including scripts to control those activities. However, it does not include the work's System Libraries, or general-purpose tools or generally available free programs which are used unmodified in performing those activities but which are not part of the work. For example, Corresponding Source includes interface definition files associated with source files for the work, and the source code for shared libraries and dynamically linked subprograms that the work is specifically designed to require, such as by intimate data communication or control flow between those subprograms and other parts of the work. The Corresponding Source need not include anything that users can regenerate automatically from other parts of the Corresponding Source.

Table 4-1 (Cont.) Open Source or Other Separately Licensed Software

Provider	Component	Licensing Information

```
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code form is that
same work.

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Provider	Component	Licensing Information

```
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enforcing, against the work's
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forbid circumvention of
technological measures.

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section 7 apply to the code;
keep intact all notices of the absence of any
warranty; and give all
recipients a copy of this License along with the
Program.

  You may charge any price or no price for each
copy that you convey,
and you may offer support or warranty protection
for a fee.

  5. Conveying Modified Source Versions.

  You may convey a work based on the Program, or
the modifications to
produce it from the Program, in the form of
source code under the
terms of section 4, provided that you also meet
all of these conditions:

    a) The work must carry prominent notices
stating that you modified
    it, and giving a relevant date.
```

Table 4-1 (Cont.) Open Source or Other Separately Licensed Software

Provider	Component	Licensing Information
		b) The work must carry prominent notices stating that it is released under this License and any conditions added under section 7. This requirement modifies the requirement in section 4 to "keep intact all notices". c) You must license the entire work, as a whole, under this License to anyone who comes into possession of a copy. This License will therefore apply, along with any applicable section 7 additional terms, to the whole of the work, and all its parts, regardless of how they are packaged. This License gives no permission to license the work in any other way, but it does not invalidate such permission if you have separately received it. d) If the work has interactive user interfaces, each must display Appropriate Legal Notices; however, if the Program has interactive interfaces that do not display Appropriate Legal Notices, your work need not make them do so. A compilation of a covered work with other separate and independent works, which are not by their nature extensions of the covered work, and which are not combined with it such as to form a larger program, in or on a volume of a storage or distribution medium, is called an "aggregate" if the compilation and its resulting copyright are not used to limit the access or legal rights of the compilation's users beyond what the individual works permit. Inclusion of a covered work in an aggregate does not cause this License to apply to the other parts of the aggregate. 6. Conveying Non-Source Forms. You may convey a covered work in object code form under the terms of sections 4 and 5, provided that you also

Table 4-1 (Cont.) Open Source or Other Separately Licensed Software

Provider	Component	Licensing Information

```
convey the
machine-readable Corresponding Source under the
terms of this License,
in one of these ways:

    a) Convey the object code in, or embodied
in, a physical product
    (including a physical distribution medium),
accompanied by the
    Corresponding Source fixed on a durable
physical medium
    customarily used for software interchange.

    b) Convey the object code in, or embodied
in, a physical product
    (including a physical distribution medium),
accompanied by a
    written offer, valid for at least three
years and valid for as
    long as you offer spare parts or customer
support for that product
    model, to give anyone who possesses the
object code either (1) a
    copy of the Corresponding Source for all the
software in the
    product that is covered by this License, on
a durable physical
    medium customarily used for software
interchange, for a price no
    more than your reasonable cost of physically
performing this
    conveying of source, or (2) access to copy
the
    Corresponding Source from a network server
at no charge.

    c) Convey individual copies of the object
code with a copy of the
    written offer to provide the Corresponding
Source.  This
    alternative is allowed only occasionally and
noncommercially, and
    only if you received the object code with
such an offer, in accord
    with subsection 6b.

    d) Convey the object code by offering access
from a designated
    place (gratis or for a charge), and offer
equivalent access to the
    Corresponding Source in the same way through
the same place at no
    further charge.  You need not require
recipients to copy the
    Corresponding Source along with the object
```

Table 4-1 (Cont.) Open Source or Other Separately Licensed Software

Provider	Component	Licensing Information

```
code.  If the place to
    copy the object code is a network server,
the Corresponding Source
    may be on a different server (operated by
you or a third party)
    that supports equivalent copying facilities,
provided you maintain
    clear directions next to the object code
saying where to find the
    Corresponding Source.  Regardless of what
server hosts the
    Corresponding Source, you remain obligated
to ensure that it is
    available for as long as needed to satisfy
these requirements.

    e) Convey the object code using peer-to-peer
transmission, provided
    you inform other peers where the object code
and Corresponding
    Source of the work are being offered to the
general public at no
    charge under subsection 6d.

  A separable portion of the object code, whose
source code is excluded
from the Corresponding Source as a System
Library, need not be
included in conveying the object code work.

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product", which means any
tangible personal property which is normally
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or household purposes, or (2) anything designed
or sold for incorporation
into a dwelling.  In determining whether a
product is a consumer product,
doubtful cases shall be resolved in favor of
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product received by a particular user, "normally
used" refers to a
typical or common use of that class of product,
regardless of the status
of the particular user or of the way in which
the particular user
actually uses, or expects or is expected to use,
the product.  A product
is a consumer product regardless of whether the
product has substantial
commercial, industrial or non-consumer uses,
unless such uses represent
the only significant mode of use of the product.

  "Installation Information" for a User Product
```

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Provider	Component	Licensing Information
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Provider	Component	Licensing Information

```
unpacking, reading or copying.

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    Notices displayed by works containing it; or

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origin of that material, or
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Provider	Component	Licensing Information
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Table 4-1   (Cont.) Open Source or Other Separately Licensed Software

Provider	Component	Licensing Information

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    under certain conditions; type `show c' for
details.

The hypothetical commands `show w' and `show c'
should show the appropriate
parts of the General Public License.  Of course,
your program's commands
might be different; for a GUI interface, you
would use an "about box".

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program, if necessary.
```

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```
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.

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Public License instead of this License.  But
first, please read
.



Name: libquadmath
Files: scipy.libs/libquadmath*.so
Description: dynamically linked to files
compiled with gcc
Availability: https://gcc.gnu.org/git/?
p=gcc.git;a=tree;f=libquadmath
License: LGPL-2.1-or-later

    GCC Quad-Precision Math Library
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*************************************************
****************************

\documentclass[letterpaper,12pt]{article}
```

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Provider	Component	Licensing Information

```
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\usepackage{verbatim}
\usepackage{amsmath}
\usepackage{supertabular}
\usepackage{array}

\def\T{{\hbox{\scriptsize{\rm T}}}}
\def\epsilon{\varepsilon}
\def\bigoh{\mathcal{O}}
\def\phi{\varphi}
\def\st{{\hbox{\scriptsize{\rm st}}}}
\def\th{{\hbox{\scriptsize{\rm th}}}}
\def\x{\mathbf{x}}


\title{ID: A software package for low-rank
approximation
       of matrices via interpolative
decompositions, Version 0.4}
\author{Per-Gunnar Martinsson, Vladimir Rokhlin,\
\
        Yoel Shkolnisky, and Mark Tygert}


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}

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\tableofcontents

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```

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Provider	Component	Licensing Information

```
\medskip

\centerline{\Large \bf IMPORTANT}

\medskip

\hrule

\medskip

\noindent At the minimum, please read
Subsection~\ref{warning}
and Section~\ref{naming} below, and beware that
the {\it N.B.}'s
in the source code comments highlight key
information about the routines;
{\it N.B.} stands for {\it nota bene} (Latin for
``note well'').

\medskip

\hrule

\bigskip



\section{Introduction}

This software distribution provides Fortran
routines
for computing low-rank approximations to
matrices,
in the forms of interpolative decompositions
(IDs)
and singular value decompositions (SVDs).
The routines use algorithms based on the ID.
The ID is also commonly known as
the approximation obtained via skeletonization,
the approximation obtained via subsampling,
and the approximation obtained via subset
selection.
The ID provides many advantages in many
applications,
and we suspect that it will become increasingly
popular
once tools for its computation become more
widely available.
This software distribution includes some such
tools,
as well as tools for computing low-rank
approximations
in the form of SVDs.
Section~\ref{defs} below defines IDs and SVDs,
```

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```
and provides references to detailed discussions
of the algorithms
used in this software package.

Please beware that normalized power iterations
are better suited than
the software in this distribution
for computing principal component analyses
in the typical case when the square of the
signal-to-noise ratio
is not orders of magnitude greater than both
dimensions
of the data matrix; see~\cite{halko-martinsson-
tropp}.

The algorithms used in this distribution have
been optimized
for accuracy, efficiency, and reliability;
as a somewhat counterintuitive consequence, many
must be randomized.
All randomized codes in this software package
succeed
with overwhelmingly high probability (see, for
example,
\cite{halko-martinsson-tropp}).
The truly paranoid are welcome to use the
routines {\tt idd\_diffsnorm}
and {\tt idz\_diffsnorm} to evaluate rapidly the
quality
of the approximations produced by the randomized
algorithms
(as done, for example, in the files
{\tt idd\_a\_test.f}, {\tt idd\_r\_test.f}, {\tt
idz\_a\_test.f},
and {\tt idz\_r\_test.f} in the {\tt test}
subdirectory
of the main directory {\tt id\_dist}).
In most circumstances, evaluating the quality of
an approximation
via routines {\tt idd\_diffsnorm} or {\tt
idz\_diffsnorm} is much faster
than forming the approximation to be evaluated.
Still, we are unaware
of any instance in which a properly-compiled
routine failed to produce
an accurate approximation.
To facilitate successful compilation, we
encourage the user
to read the instructions in the next section,
and to read Section~\ref{naming}, too.



\section{Compilation instructions}
```

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```
Followed in numerical order, the subsections of
this section
provide step-by-step instructions for compiling
the software
under a Unix-compatible operating system.


\subsection{Beware that default command-line
flags may not be
            sufficient for compiling the source
codes!}
\label{warning}

The Fortran source codes in this distribution
pass {\tt real*8}
variables as integer variables, integers as {\tt
real*8}'s,
{\tt real*8}'s as {\tt complex*16}'s, and so on.
This is common practice in numerical codes, and
is not an error;
be sure to provide the relevant command-line
flags to the compiler
(for example, run {\tt fort77} and {\tt f2c}
with the flag {\tt -!P}).
When following the compilation instructions
in Subsection~\ref{makefile_edit} below,
be sure to set {\tt FFLAGS} appropriately.


\subsection{Install LAPACK}

The SVD routines in this distribution depend on
LAPACK.
Before compiling the present distribution,
create the LAPACK and BLAS archive (library)
{\tt .a} files;
information about installing LAPACK is available
at {\tt http://www.netlib.org/lapack/} (and
several other web sites).


\subsection{Decompress and untar the file {\tt
id\_dist.tar.gz}}

At the command line, decompress and untar the
file
{\tt id\_dist.tar.gz} by issuing a command such
as
{\tt tar -xvvzf id\_dist.tar.gz}.
This will create a directory named {\tt
id\_dist}.


\subsection{Edit the Makefile}
```

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```
\label{makefile_edit}

The directory {\tt id\_dist} contains a file
named {\tt Makefile}.
In {\tt Makefile}, set the following:
%
\begin{itemize}
\item {\tt FC} is the Fortran compiler.
\item {\tt FFLAGS} is the set of command-line
flags
      (specifying optimization settings, for
example)
      for the Fortran compiler specified by {\tt
FC};
      please heed the warning in
Subsection~\ref{warning} above!
\item {\tt BLAS\_LIB} is the file-system path to
the BLAS archive
      (library) {\tt .a} file.
\item {\tt LAPACK\_LIB} is the file-system path
to the LAPACK archive
      (library) {\tt .a} file.
\item {\tt ARCH} is the archiver utility
(usually {\tt ar}).
\item {\tt ARCHFLAGS} is the set of command-line
flags
      for the archiver specified by {\tt ARCH}
needed
      to create an archive (usually {\tt cr}).
\item {\tt RANLIB} is to be set to {\tt ranlib}
      when {\tt ranlib} is available, and is to
be set to {\tt echo}
      when {\tt ranlib} is not available.
\end{itemize}


\subsection{Make and test the libraries}

At the command line in a shell that adheres
to the Bourne shell conventions for redirection,
issue the command
``{\tt make clean; make}'' to both create the
archive (library)
{\tt id\_lib.a} and test it.
(In most modern Unix distributions, {\tt sh} is
the Bourne shell,
or else is fully compatible with the Bourne
shell;
the Korn shell {\tt ksh} and the Bourne-again
shell {\tt bash}
also use the Bourne shell conventions for
redirection.)
{\tt make} places the file {\tt id\_lib.a}
in the directory {\tt id\_dist}; the archive
(library) file
```

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```
{\tt id\_lib.a} contains machine code for all
user-callable routines
in this distribution.



\section{Naming conventions}
\label{naming}

The names of routines and files in this
distribution
start with prefixes, followed by an underscore
(``\_'').
The prefixes are two to four characters in
length,
and have the following meanings:
%
\begin{itemize}
\item The first two letters are always ``{\tt
id}'',
      the name of this distribution.
\item The third letter (when present) is either
``{\tt d}''
      or ``{\tt z}'';
      ``{\tt d}'' stands for double precision
({\tt real*8}),
      and ``{\tt z}'' stands for double complex
({\tt complex*16}).
\item The fourth letter (when present) is either
``{\tt r}''
      or ``{\tt p}'';
      ``{\tt r}'' stands for specified rank,
      and ``{\tt p}'' stands for specified
precision.
      The specified rank routines require the
user to provide
      the rank of the approximation to be
constructed,
      while the specified precision routines
adjust the rank adaptively
      to attain the desired precision.
\end{itemize}

For example, {\tt iddr\_aid} is a {\tt real*8}
routine which computes
an approximation of specified rank.
{\tt idz\_snorm} is a {\tt complex*16} routine.
{\tt id\_randperm} is yet another routine in
this distribution.



\section{Example programs}

For examples of how to use the user-callable
```

Table 4-1 (Cont.) Open Source or Other Separately Licensed Software

Provider	Component	Licensing Information

```
routines
in this distribution, see the source codes in
subdirectory {\tt test}
of the main directory {\tt id\_dist}.



\section{Directory structure}

The main {\tt id\_dist} directory contains a
Makefile,
the auxiliary text files {\tt README.txt} and
{\tt size.txt},
and the following subdirectories, described in
the subsections below:
%
\begin{enumerate}
\item {\tt bin}
\item {\tt development}
\item {\tt doc}
\item {\tt src}
\item {\tt test}
\item {\tt tmp}
\end{enumerate}
%
If a ``{\tt make all}'' command has completed
successfully,
then the main {\tt id\_dist} directory will also
contain
an archive (library) file {\tt id\_lib.a}
containing machine code
for all of the user-callable routines.


\subsection{Subdirectory {\tt bin}}

Once all of the libraries have been made via the
Makefile
in the main {\tt id\_dist} directory,
the subdirectory {\tt bin} will contain object
files (machine code),
each compiled from the corresponding file of
source code
in the subdirectory {\tt src} of {\tt id\_dist}.


\subsection{Subdirectory {\tt development}}

Each Fortran file in the subdirectory {\tt
development}
(except for {\tt dfft.f} and {\tt prini.f})
specifies its dependencies at the top, then
provides a main program
for testing and debugging, and finally provides
source code
```

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```
for a library of user-callable subroutines.
The Fortran file {\tt dfft.f} is a copy of P. N.
Swarztrauber's FFTPACK library
for computing fast Fourier transforms.
The Fortran file {\tt prini.f} is a copy of V.
Rokhlin's library
of formatted printing routines.
Both {\tt dfft.f} (version 4) and {\tt prini.f}
are in the public domain.
The shell script {\tt RUNME.sh} runs shell
scripts {\tt make\_src.sh}
and {\tt make\_test.sh}, which fill the
subdirectories {\tt src}
and {\tt test} of the main directory {\tt
id\_dist}
with source codes for user-callable routines
and with the main program testing codes.


\subsection{Subdirectory {\tt doc}}

Subdirectory {\tt doc} contains this
documentation,
supplementing comments in the source codes.


\subsection{Subdirectory {\tt src}}

The files in the subdirectory {\tt src} provide
source code
for software libraries. Each file in the
subdirectory {\tt src}
(except for {\tt dfft.f} and {\tt prini.f}) is
the bottom part of the corresponding file
in the subdirectory {\tt development} of {\tt
id\_dist}.
The file {\tt dfft.f} is just a copy
of P. N. Swarztrauber's FFTPACK library
for computing fast Fourier transforms.
The file {\tt prini.f} is a copy of V. Rokhlin's
library
of formatted printing routines.
Both {\tt dfft.f} (version 4) and {\tt prini.f}
are in the public domain.


\subsection{Subdirectory {\tt test}}

The files in subdirectory {\tt test} provide
source code
for testing and debugging. Each file in
subdirectory {\tt test} is
the top part of the corresponding file
in subdirectory {\tt development} of {\tt
id\_dist},
```

Table 4-1 (Cont.) Open Source or Other Separately Licensed Software

Provider	Component	Licensing Information

```
and provides a main program and a list of its
dependencies.
These codes provide examples of how to call the
user-callable routines.



\section{Catalog of the routines}

The main routines for decomposing {\tt real*8}
matrices are:
%
\begin{enumerate}
%
\item IDs of arbitrary (generally dense)
matrices:
{\tt iddp\_id}, {\tt iddr\_id}, {\tt iddp\_aid},
{\tt iddr\_aid}
%
\item IDs of matrices that may be rapidly
applied to arbitrary vectors
(as may the matrices' transposes):
{\tt iddp\_rid}, {\tt iddr\_rid}
%
\item SVDs of arbitrary (generally dense)
matrices:
{\tt iddp\_svd}, {\tt iddr\_svd}, {\tt
iddp\_asvd},\\{\tt iddr\_asvd}
%
\item SVDs of matrices that may be rapidly
applied to arbitrary vectors
(as may the matrices' transposes):
{\tt iddp\_rsvd}, {\tt iddr\_rsvd}
%
\end{enumerate}

Similarly, the main routines for decomposing
{\tt complex*16} matrices
are:
%
\begin{enumerate}
%
\item IDs of arbitrary (generally dense)
matrices:
{\tt idzp\_id}, {\tt idzr\_id}, {\tt idzp\_aid},
{\tt idzr\_aid}
%
\item IDs of matrices that may be rapidly
applied to arbitrary vectors
(as may the matrices' adjoints):
{\tt idzp\_rid}, {\tt idzr\_rid}
%
\item SVDs of arbitrary (generally dense)
matrices:
{\tt idzp\_svd}, {\tt idzr\_svd}, {\tt
```

Table 4-1 (Cont.) Open Source or Other Separately Licensed Software

Provider	Component	Licensing Information

```
idzp\_asvd},\\{\tt idzr\_asvd}
%
\item SVDs of matrices that may be rapidly
applied to arbitrary vectors
(as may the matrices' adjoints):
{\tt idzp\_rsvd}, {\tt idzr\_rsvd}
%
\end{enumerate}

This distribution also includes routines for
constructing pivoted $QR$
decompositions (in {\tt idd\_qrpiv.f} and {\tt
idz\_qrpiv.f}), for
estimating the spectral norms of matrices that
may be applied rapidly
to arbitrary vectors as may their adjoints (in
{\tt idd\_snorm.f}
and {\tt idz\_snorm.f}), for converting IDs to
SVDs (in
{\tt idd\_id2svd.f} and {\tt idz\_id2svd.f}),
and for computing rapidly
arbitrary subsets of the entries of the discrete
Fourier transforms
of vectors (in {\tt idd\_sfft.f} and {\tt
idz\_sfft.f}).


\subsection{List of the routines}

The following is an alphabetical list of the
routines
in this distribution, together with brief
descriptions
of their functionality and the names of the
files containing
the routines' source code:

\begin{center}
%
\tablehead{\bf Routine & \bf Description & \bf
Source file \\}
\tabletail{\hline}
%
\begin{supertabular}{>{\raggedright}p{1.2in}
p{.53\textwidth} l}
%
\hline
{\tt id\_frand} & generates pseudorandom numbers
drawn uniformly from
the interval $[0,1]$; this routine is more
efficient than routine
{\tt id\_srand}, but cannot generate fewer than
55 pseudorandom numbers
per call & {\tt id\_rand.f} \\\hline
%
```

Table 4-1 (Cont.) Open Source or Other Separately Licensed Software

Provider	Component	Licensing Information
		{\tt id_frandi} & initializes the seed values for routine {\tt id_frand} to specified values & {\tt id_rand.f} \\\hline % {\tt id_frando} & initializes the seed values for routine {\tt id_frand} to their original, default values & {\tt id_rand.f} \\\hline % {\tt id_randperm} & generates a uniformly random permutation & {\tt id_rand.f} \\\hline % {\tt id_srand} & generates pseudorandom numbers drawn uniformly from the interval $[0,1]$; this routine is less efficient than routine {\tt id_frand}, but can generate fewer than 55 pseudorandom numbers per call & {\tt id_rand.f} \\\hline % {\tt id_srandi} & initializes the seed values for routine {\tt id_srand} to specified values & {\tt id_rand.f} \\\hline % {\tt id_srando} & initializes the seed values for routine {\tt id_srand} to their original, default values & {\tt id_rand.f} \\\hline % {\tt idd_copycols} & collects together selected columns of a matrix & {\tt idd_id.f} \\\hline % {\tt idd_diffsnorm} & estimates the spectral norm of the difference between two matrices specified by routines for applying the matrices and their transposes to arbitrary vectors; this routine uses the power method with a random starting vector & {\tt idd_snorm.f} \\\hline % {\tt idd_enorm} & calculates the Euclidean norm of a vector & {\tt idd_snorm.f} \\\hline % {\tt idd_estrank} & estimates the numerical rank of an arbitrary (generally dense) matrix to a specified precision; this routine is

Table 4-1 (Cont.) Open Source or Other Separately Licensed Software

Provider	Component	Licensing Information
		randomized, and must be initialized with routine {\tt idd_frmi} & {\tt iddp_aid.f} \\\hline % {\tt idd_frm} & transforms a vector into a vector which is sufficiently scrambled to be subsampled, via a composition of Rokhlin's random transform, random subselection, and a fast Fourier transform & {\tt idd_frm.f} \\\hline % {\tt idd_frmi} & initializes routine {\tt idd_frm} & {\tt idd_frm.f} \\\hline % {\tt idd_getcols} & collects together selected columns of a matrix specified by a routine for applying the matrix to arbitrary vectors & {\tt idd_id.f} \\\hline % {\tt idd_house} & calculates the vector and scalar needed to apply the Householder transformation reflecting a given vector into its first entry & {\tt idd_house.f} \\\hline % {\tt idd_houseapp} & applies a Householder matrix to a vector & {\tt idd_house.f} \\\hline % {\tt idd_id2svd} & converts an approximation to a matrix in the form of an ID into an approximation in the form of an SVD & {\tt idd_id2svd.f} \\\hline % {\tt idd_ldiv} & finds the greatest integer less than or equal to a specified integer, that is divisible by another (larger) specified integer & {\tt idd_sfft.f} \\\hline % {\tt idd_pairsamps} & calculates the indices of the pairs of integers that the individual integers in a specified set belong to & {\tt idd_frm.f} \\\hline % {\tt idd_permmult} & multiplies together a bunch of permutations & {\tt idd_qrpiv.f} \\\hline % {\tt idd_qinqr} & reconstructs the $Q$ matrix

Table 4-1 (Cont.) Open Source or Other Separately Licensed Software

Provider	Component	Licensing Information
		in a $QR$ decomposition from the output of routines {\tt iddp_qrpiv} or {\tt iddr_qrpiv} & {\tt idd_qrpiv.f} \\\hline % {\tt idd_qrmatmat} & applies to multiple vectors collected together as a matrix the $Q$ matrix (or its transpose) in the $QR$ decomposition of a matrix, as described by the output of routines {\tt iddp_qrpiv} or {\tt iddr_qrpiv}; to apply $Q$ (or its transpose) to a single vector without having to provide a work array, use routine {\tt idd_qrmatvec} instead & {\tt idd_qrpiv.f} \\\hline % {\tt idd_qrmatvec} & applies to a single vector the $Q$ matrix (or its transpose) in the $QR$ decomposition of a matrix, as described by the output of routines {\tt iddp_qrpiv} or {\tt iddr_qrpiv}; to apply $Q$ (or its transpose) to several vectors efficiently, use routine {\tt idd_qrmatmat} instead & {\tt idd_qrpiv.f} \\\hline % {\tt idd_random_} {\tt transf} & applies rapidly a random orthogonal matrix to a user-supplied vector & {\tt id_rtrans.f} \\\hline % {\tt idd_random_ transf_init} & \raggedright initializes routines {\tt idd_random_transf} and {\tt idd_random_transf_inverse} & {\tt id_rtrans.f} \\\hline % {\tt idd_random_} {\tt transf_inverse} & applies rapidly the inverse of the operator applied by routine {\tt idd_random_transf} & {\tt id_rtrans.f} \\ \hline % {\tt idd_reconid} & reconstructs a matrix from its ID & {\tt idd_id.f} \\\hline % {\tt idd_reconint} & constructs $P$ in the ID $A = B \, P$, where the columns of $B$ are a subset of the columns of $A$, and $P$ is the

Table 4-1 (Cont.) Open Source or Other Separately Licensed Software

Provider	Component	Licensing Information
		projection coefficient matrix, given {\tt list}, {\tt krank}, and {\tt proj} output by routines {\tt iddr_id}, {\tt iddp_id}, {\tt iddr_aid}, {\tt iddp_aid}, {\tt iddr_rid}, or {\tt iddp_rid} & {\tt idd_id.f} \\\hline % {\tt idd_sfft} & rapidly computes a subset of the entries of the discrete Fourier transform of a vector, composed with permutation matrices both on input and on output & {\tt idd_sfft.f} \\\hline % {\tt idd_sffti} & initializes routine {\tt idd_sfft} & {\tt idd_sfft.f} \\\hline % {\tt idd_sfrm} & transforms a vector into a scrambled vector of specified length, via a composition of Rokhlin's random transform, random subselection, and a fast Fourier transform & {\tt idd_frm.f} \\\hline % {\tt idd_sfrmi} & initializes routine {\tt idd_sfrm} & {\tt idd_frm.f} \\\hline % {\tt idd_snorm} & estimates the spectral norm of a matrix specified by routines for applying the matrix and its transpose to arbitrary vectors; this routine uses the power method with a random starting vector & {\tt idd_snorm.f} \\\hline % {\tt iddp_aid} & computes the ID of an arbitrary (generally dense) matrix, to a specified precision; this routine is randomized, and must be initialized with routine {\tt idd_frmi} & {\tt iddp_aid.f} \\\hline % {\tt iddp_asvd} & computes the SVD of an arbitrary (generally dense) matrix, to a specified precision; this routine is randomized, and must be initialized with routine {\tt idd_frmi} & {\tt iddp_asvd.f} \\\hline %

Table 4-1 (Cont.) Open Source or Other Separately Licensed Software

Provider	Component	Licensing Information
		{\tt iddp_id} & computes the ID of an arbitrary (generally dense) matrix, to a specified precision; this routine is often less efficient than routine {\tt iddp_aid} & {\tt idd_id.f} \\ \hline % {\tt iddp_qrpiv} & computes the pivoted $QR$ decomposition of an arbitrary (generally dense) matrix via Householder transformations, stopping at a specified precision of the decomposition & {\tt idd_qrpiv.f} \\\hline % {\tt iddp_rid} & computes the ID, to a specified precision, of a matrix specified by a routine for applying its transpose to arbitrary vectors; this routine is randomized & {\tt iddp_rid.f} \\\hline % {\tt iddp_rsvd} & computes the SVD, to a specified precision, of a matrix specified by routines for applying the matrix and its transpose to arbitrary vectors; this routine is randomized & {\tt iddp_rsvd.f} \\\hline % {\tt iddp_svd} & computes the SVD of an arbitrary (generally dense) matrix, to a specified precision; this routine is often less efficient than routine {\tt iddp_asvd} & {\tt idd_svd.f} \\\hline % {\tt iddr_aid} & computes the ID of an arbitrary (generally dense) matrix, to a specified rank; this routine is randomized, and must be initialized by routine {\tt iddr_aidi} & {\tt iddr_aid.f} \\\hline % {\tt iddr_aidi} & initializes routine {\tt iddr_aid} & {\tt iddr_aid.f} \\\hline % {\tt iddr_asvd} & computes the SVD of an arbitrary (generally dense) matrix, to a specified rank; this routine is randomized, and must be initialized with routine {\tt idd_aidi} & {\tt iddr_asvd.f} \\\hline

Table 4-1 (Cont.) Open Source or Other Separately Licensed Software

Provider	Component	Licensing Information

```
%
{\tt iddr\_id} & computes the ID of an arbitrary
(generally dense)
matrix, to a specified rank; this routine is
often less efficient than
routine {\tt iddr\_aid} & {\tt idd\_id.f} \\
\hline
%
{\tt iddr\_qrpiv} & computes the pivoted $QR$
decomposition of an
arbitrary (generally dense) matrix via
Householder transformations,
stopping at a specified rank of the
decomposition & {\tt idd\_qrpiv.f}
\\\hline
%
{\tt iddr\_rid} & computes the ID, to a
specified rank, of a matrix
specified by a routine for applying its
transpose to arbitrary vectors;
this routine is randomized & {\tt iddr\_rid.f} \\
\hline
%
{\tt iddr\_rsvd} & computes the SVD, to a
specified rank, of a matrix
specified by routines for applying the matrix
and its transpose to
arbitrary vectors; this routine is randomized &
{\tt iddr\_rsvd.f}
\\\hline
%
{\tt iddr\_svd} & computes the SVD of an
arbitrary (generally dense)
matrix, to a specified rank; this routine is
often less efficient than
routine {\tt iddr\_asvd} & {\tt idd\_svd.f} \\
\hline
%
{\tt idz\_copycols} & collects together selected
columns of a matrix &
{\tt idz\_id.f} \\\hline
%
{\tt idz\_diffsnorm} & estimates the spectral
norm of the difference
between two matrices specified by routines for
applying the matrices
and their adjoints to arbitrary vectors; this
routine uses the power
method with a random starting vector & {\tt
idz\_snorm.f} \\\hline
%
{\tt idz\_enorm} & calculates the Euclidean norm
of a vector &
{\tt idz\_snorm.f} \\\hline
%
```

Table 4-1 (Cont.) Open Source or Other Separately Licensed Software

Provider	Component	Licensing Information
		{\tt idz_estrank} & estimates the numerical rank of an arbitrary (generally dense) matrix to a specified precision; this routine is randomized, and must be initialized with routine {\tt idz_frmi} & {\tt idzp_aid.f} \\\hline % {\tt idz_frm} & transforms a vector into a vector which is sufficiently scrambled to be subsampled, via a composition of Rokhlin's random transform, random subselection, and a fast Fourier transform & {\tt idz_frm.f} \\\hline % {\tt idz_frmi} & initializes routine {\tt idz_frm} & {\tt idz_frm.f} \\\hline % {\tt idz_getcols} & collects together selected columns of a matrix specified by a routine for applying the matrix to arbitrary vectors & {\tt idz_id.f} \\\hline % {\tt idz_house} & calculates the vector and scalar needed to apply the Householder transformation reflecting a given vector into its first entry & {\tt idz_house.f} \\\hline % {\tt idz_houseapp} & applies a Householder matrix to a vector & {\tt idz_house.f} \\\hline % {\tt idz_id2svd} & converts an approximation to a matrix in the form of an ID into an approximation in the form of an SVD & {\tt idz_id2svd.f} \\\hline % {\tt idz_ldiv} & finds the greatest integer less than or equal to a specified integer, that is divisible by another (larger) specified integer & {\tt idz_sfft.f} \\\hline % {\tt idz_permmult} & multiplies together a bunch of permutations & {\tt idz_qrpiv.f} \\\hline % {\tt idz_qinqr} & reconstructs the $Q$ matrix in a $QR$ decomposition from the output of routines {\tt idzp_qrpiv} or

Table 4-1 (Cont.) Open Source or Other Separately Licensed Software

Provider	Component	Licensing Information

```
{\tt idzr\_qrpiv} &
{\tt idz\_qrpiv.f} \\\hline
%
{\tt idz\_qrmatmat} & applies to multiple
vectors collected together as
a matrix the $Q$ matrix (or its adjoint) in
the $QR$ decomposition of
a matrix, as described by the output of routines
{\tt idzp\_qrpiv} or
{\tt idzr\_qrpiv}; to apply $Q$ (or its adjoint)
to a single vector
without having to provide a work array, use
routine {\tt idz\_qrmatvec}
instead & {\tt idz\_qrpiv.f} \\\hline
%
{\tt idz\_qrmatvec} & applies to a single vector
the $Q$ matrix (or its
adjoint) in the $QR$ decomposition of a matrix,
as described by the
output of routines {\tt idzp\_qrpiv} or {\tt
idzr\_qrpiv}; to apply $Q$
(or its adjoint) to several vectors efficiently,
use routine
{\tt idz\_qrmatmat} instead & {\tt idz\_qrpiv.f}
\\\hline
%
{\tt idz\_random\_ transf} & applies rapidly a
random unitary matrix to
a user-supplied vector & {\tt id\_rtrans.f} \\
\hline
%
{\tt idz\_random\_ transf\_init} & \raggedright
initializes routines
{\tt idz\_random\_transf} and {\tt
idz\_random\_transf\_inverse} &
{\tt id\_rtrans.f} \\\hline
%
{\tt idz\_random\_ transf\_inverse} & applies
rapidly the inverse of
the operator applied by routine {\tt
idz\_random\_transf} &
{\tt id\_rtrans.f} \\\hline
%
{\tt idz\_reconid} & reconstructs a matrix from
its ID &
{\tt idz\_id.f} \\\hline
%
{\tt idz\_reconint} & constructs $P$ in the
ID $A = B \, P$, where the
columns of $B$ are a subset of the columns
of $A$, and $P$ is the
projection coefficient matrix, given {\tt list},
{\tt krank}, and
{\tt proj} output by routines {\tt idzr\_id},
{\tt idzp\_id},
```

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Provider	Component	Licensing Information
		{\tt idzr_aid}, {\tt idzp_aid}, {\tt idzr_rid}, or {\tt idzp_rid} & {\tt idz_id.f} \\\hline % {\tt idz_sfft} & rapidly computes a subset of the entries of the discrete Fourier transform of a vector, composed with permutation matrices both on input and on output & {\tt idz_sfft.f} \\\hline % {\tt idz_sffti} & initializes routine {\tt idz_sfft} & {\tt idz_sfft.f} \\\hline % {\tt idz_sfrm} & transforms a vector into a scrambled vector of specified length, via a composition of Rokhlin's random transform, random subselection, and a fast Fourier transform & {\tt idz_frm.f} \\\hline % {\tt idz_sfrmi} & initializes routine {\tt idz_sfrm} & {\tt idz_frm.f} \\\hline % {\tt idz_snorm} & estimates the spectral norm of a matrix specified by routines for applying the matrix and its adjoint to arbitrary vectors; this routine uses the power method with a random starting vector & {\tt idz_snorm.f} \\\hline % {\tt idzp_aid} & computes the ID of an arbitrary (generally dense) matrix, to a specified precision; this routine is randomized, and must be initialized with routine {\tt idz_frmi} & {\tt idzp_aid.f} \\\hline % {\tt idzp_asvd} & computes the SVD of an arbitrary (generally dense) matrix, to a specified precision; this routine is randomized, and must be initialized with routine {\tt idz_frmi} & {\tt idzp_asvd.f} \\\hline % {\tt idzp_id} & computes the ID of an arbitrary (generally dense) matrix, to a specified precision; this routine is often less efficient

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Provider	Component	Licensing Information

```
than routine {\tt idzp\_aid} & {\tt idz\_id.f} \\
\hline
%
{\tt idzp\_qrpiv} & computes the pivoted $QR$
decomposition of an
arbitrary (generally dense) matrix via
Householder transformations,
stopping at a specified precision of the
decomposition &
{\tt idz\_qrpiv.f} \\\hline
%
{\tt idzp\_rid} & computes the ID, to a
specified precision, of a
matrix specified by a routine for applying its
adjoint to arbitrary
vectors; this routine is randomized & {\tt
idzp\_rid.f} \\\hline
%
{\tt idzp\_rsvd} & computes the SVD, to a
specified precision, of a
matrix specified by routines for applying the
matrix and its adjoint
to arbitrary vectors; this routine is randomized
& {\tt idzp\_rsvd.f}
\\\hline
%
{\tt idzp\_svd} & computes the SVD of an
arbitrary (generally dense)
matrix, to a specified precision; this routine
is often less efficient
than routine {\tt idzp\_asvd} & {\tt idz\_svd.f}
\\\hline
%
{\tt idzr\_aid} & computes the ID of an
arbitrary (generally dense)
matrix, to a specified rank; this routine is
randomized, and must be
initialized by routine {\tt idzr\_aidi} & {\tt
idzr\_aid.f} \\\hline
%
{\tt idzr\_aidi} & initializes routine {\tt
idzr\_aid} &
{\tt idzr\_aid.f} \\\hline
%
{\tt idzr\_asvd} & computes the SVD of an
arbitrary (generally dense)
matrix, to a specified rank; this routine is
randomized, and must be
initialized with routine {\tt idz\_aidi} & {\tt
idzr\_asvd.f}
\\\hline
%
{\tt idzr\_id} & computes the ID of an arbitrary
(generally dense)
matrix, to a specified rank; this routine is
```

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```
often less efficient than
routine {\tt idzr\_aid} & {\tt idz\_id.f} \\
\hline
%
{\tt idzr\_qrpiv} & computes the pivoted $QR$
decomposition of an
arbitrary (generally dense) matrix via
Householder transformations,
stopping at a specified rank of the
decomposition & {\tt idz\_qrpiv.f}
\\\hline
%
{\tt idzr\_rid} & computes the ID, to a
specified rank, of a matrix
specified by a routine for applying its adjoint
to arbitrary vectors;
this routine is randomized & {\tt idzr\_rid.f} \\
\hline
%
{\tt idzr\_rsvd} & computes the SVD, to a
specified rank, of a matrix
specified by routines for applying the matrix
and its adjoint to
arbitrary vectors; this routine is randomized &
{\tt idzr\_rsvd.f}
\\\hline
%
{\tt idzr\_svd} & computes the SVD of an
arbitrary (generally dense)
matrix, to a specified rank; this routine is
often less efficient than
routine {\tt idzr\_asvd} & {\tt idz\_svd.f} \\
%
\end{supertabular}
\end{center}



\section{Documentation in the source codes}

Each routine in the source codes includes
documentation
in the comments immediately following the
declaration
of the subroutine's calling sequence.
This documentation describes the purpose of the
routine,
the input and output variables, and the required
work arrays (if any).
This documentation also cites relevant
references.
Please pay attention to the {\it N.B.}'s;
{\it N.B.} stands for {\it nota bene} (Latin for
``note well'')
and highlights important information about the
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```
routines.



\section{Notation and decompositions}
\label{defs}

This section sets notational conventions employed
in this documentation and the associated
software,
and defines both the singular value
decomposition (SVD)
and the interpolative decomposition (ID).
For information concerning other mathematical
objects
used in the code (such as Householder
transformations,
pivoted $QR$ decompositions, and discrete and
fast Fourier transforms
--- DFTs and FFTs), see, for
example,~\cite{golub-van_loan}.
For detailed descriptions and proofs of the
mathematical facts
discussed in the present section, see, for
example,
\cite{golub-van_loan} and the references
in~\cite{halko-martinsson-tropp}.

Throughout this document and the accompanying
software distribution,
$\| \x \|$ always denotes the Euclidean norm of
the vector $\x$,
and $\| A \|$ always denotes the spectral norm
of the matrix $A$.
Subsection~\ref{Euclidean} below defines the
Euclidean norm;
Subsection~\ref{spectral} below defines the
spectral norm.
We use $A^*$ to denote the adjoint of the
matrix $A$.


\subsection{Euclidean norm}
\label{Euclidean}

For any positive integer $n$, and vector $\x$ of
length $n$,
the Euclidean ($l^2$) norm $\| \x \|$ is
%
\begin{equation}
\| \x \| = \sqrt{ \sum_{k=1}^n |x_k|^2 },
\end{equation}
%
where $x_1$,~$x_2$, \dots, $x_{n-1}$,~$x_n$ are
the entries of $\x$.
```

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\subsection{Spectral norm}
\label{spectral}

For any positive integers $m$ and $n$, and $m
\times n$ matrix $A$,
the spectral ($l^2$ operator) norm $\| A \|$ is
%
\begin{equation}
\| A_{m \times n} \|
= \max \frac{\| A_{m \times n} \, \x_{n \times
1} \|}
            {\| \x_{n \times 1} \|},
\end{equation}
%
where the $\max$ is taken over all $n \times 1$
column vectors $\x$
such that $\| \x \| \ne 0$.


\subsection{Singular value decomposition (SVD)}

For any positive real number $\epsilon$,
positive integers $k$, $m$, and $n$ with $k \le
m$ and $k \le n$,
and any $m \times n$ matrix $A$,
a rank-$k$ approximation to $A$ in the form of
an SVD
(to precision $\epsilon$) consists of an $m
\times k$ matrix $U$
whose columns are orthonormal, an $n \times k$
matrix $V$
whose columns are orthonormal, and a diagonal $k
\times k$ matrix
$\Sigma$ with diagonal entries
$\Sigma_{1,1} \ge \Sigma_{2,2} \ge \dots \ge
\Sigma_{n-1,n-1}
                                         \ge
\Sigma_{n,n} \ge 0$,
such that
%
\begin{equation}
\| A_{m \times n} - U_{m \times k} \, \Sigma_{k
\times k}
                 \, (V^*)_{k \times n} \| \le
\epsilon.
\end{equation}
%
The product $U \, \Sigma \, V^*$ is known as an
SVD.
The columns of $U$ are known as left singular
vectors;
the columns of $V$ are known as right singular
vectors.
```

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```
The diagonal entries of $\Sigma$ are known as
singular values.

When $k = m$ or $k = n$, and $A = U \, \Sigma \,
V^*$,
then $U \, \Sigma \, V^*$ is known as the SVD
of $A$; the columns of $U$ are the left singular
vectors of $A$,
the columns of $V$ are the right singular
vectors of $A$,
and the diagonal entries of $\Sigma$ are the
singular values of $A$.
For any positive integer $k$ with $k < m$ and $k
< n$,
there exists a rank-$k$ approximation to $A$ in
the form of an SVD,
to precision $\sigma_{k+1}$, where $
\sigma_{k+1}$ is the $(k+1)^\st$
greatest singular value of $A$.


\subsection{Interpolative decomposition (ID)}

For any positive real number $\epsilon$,
positive integers $k$, $m$, and $n$ with $k \le
m$ and $k \le n$,
and any $m \times n$ matrix $A$,
a rank-$k$ approximation to $A$ in the form of
an ID
(to precision $\epsilon$) consists of a $k
\times n$ matrix $P$,
and an $m \times k$ matrix $B$ whose columns
constitute a subset
of the columns of $A$, such that
%
\begin{enumerate}
\item $\| A_{m \times n} - B_{m \times k} \,
P_{k \times n} \|
      \le \epsilon$,
\item some subset of the columns of $P$ makes up
the $k \times k$
      identity matrix, and
\item every entry of $P$ has an absolute value
less than or equal
      to a reasonably small positive real
number, say 2.
\end{enumerate}
%
The product $B \, P$ is known as an ID.
The matrix $P$ is known as the projection or
interpolation matrix
of the ID. Property~1 above approximates each
column of $A$
via a linear combination of the columns of $B$
(which are themselves columns of $A$), with the
```

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coefficients
in the linear combination given by the entries
of $P$.

The interpolative decomposition is
``interpolative''
due to Property~2 above. The ID is numerically
stable
due to Property~3 above.
It follows from Property~2 that the least
($k^\th$ greatest) singular value
of $P$ is at least 1. Combining Properties~2
and~3 yields that
%
\begin{equation}
\| P_{k \times n} \| \le \sqrt{4k(n-k)+1}.
\end{equation}

When $k = m$ or $k = n$, and $A = B \, P$,
then $B \, P$ is known as the ID of $A$.
For any positive integer $k$ with $k < m$ and $k
< n$,
there exists a rank-$k$ approximation to $A$ in
the form of an ID,
to precision $\sqrt{k(n-k)+1} \; \sigma_{k+1}$,
where $\sigma_{k+1}$ is the $(k+1)^\st$ greatest
singular value of $A$
(in fact, there exists an ID in which every entry
of the projection matrix $P$ has an absolute
value less than or equal
to 1).



\section{Bug reports, feedback, and support}

Please let us know about errors in the software
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History and License
*******************


History of the software
=======================

Python was created in the early 1990s by Guido
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Mathematisch Centrum (CWI, see https://
www.cwi.nl/) in the Netherlands as a
successor of a language called ABC.  Guido
remains Python's principal author,
although it includes many contributions from
others.

In 1995, Guido continued his work on Python at
the Corporation for National
Research Initiatives (CNRI, see https://
www.cnri.reston.va.us/) in Reston,
Virginia where he released several versions of
the software.

In May 2000, Guido and the Python core
development team moved to BeOpen.com to
form the BeOpen PythonLabs team.  In October of
the same year, the PythonLabs
team moved to Digital Creations (now Zope
Corporation; see
https://www.zope.org/).  In 2001, the Python
Software Foundation (PSF, see
https://www.python.org/psf/) was formed, a non-
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All Python releases are Open Source (see https://
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Source Definition). Historically, most, but not
all, Python releases have also
been GPL-compatible; the table below summarizes
the various releases.

+----------------+--------------+------------
+------------+-----------------+
| Release        | Derived from | Year       |
Owner      | GPL compatible? |
+================+==============+============+===
=========+=================+
| 0.9.0 thru 1.2 | n/a          | 1991-1995  |
CWI        | yes             |
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| 1.6            | 1.5.2        | 2000       |
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+------------+-----------------+
| 2.0            | 1.6          | 2000       |
BeOpen.com | no              |
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| 1.6.1          | 1.6          | 2001       |
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+------------+-----------------+
| 2.1            | 2.0+1.6.1    | 2001       |
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+------------+-----------------+
| 2.0.1          | 2.0+1.6.1    | 2001       |
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http://www.math.sci.hiroshima-u.ac.jp/~m-mat/MT/
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the verbatim comments from the original code::

   A C-program for MT19937, with initialization
improved 2002/1/26.
   Coded by Takuji Nishimura and Makoto
Matsumoto.

   Before using, initialize the state by using
init_genrand(seed)
   or init_by_array(init_key, key_length).

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Sockets
-------

The :mod:`socket` module uses the functions, :c:func:`!getaddrinfo`, and
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Asynchronous socket services
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UUencode and UUdecode functions
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   Modified by Jack Jansen, CWI, July 1995:
   - Use binascii module to do the actual line-
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     between ascii and binary. This results in a
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   - Arguments more compliant with Python
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XML Remote Procedure Calls
--------------------------


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test_epoll
----------

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---------

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  Original location:
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  Solution inspired by code from:
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---------------

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----

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-------

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