



Processs-in-Process (PiP)

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# Chapter 1

## Process-in-Process (PiP) Overview

### Process-in-Process (PiP)

PiP is a user-level library to have the best of the both worlds of multi-process and multi-thread parallel execution models. PiP allows a process to create sub-processes into the same virtual address space where the parent process runs. The parent process and sub-processes share the same address space, however, each process has its own variable set. So, each process runs independently from the other process. If some or all processes agree, then data owned by a process can be accessed by the other processes. Those processes share the same address space, just like pthreads, but each process has its own variables like the process execution model. Hereinafter, the parent process is called PiP process and sub-processes are called PiP tasks.

### PiP Versions

Currently there are three PiP library versions:

- Version 1 - Deprecated
- Version 2 - Stable version
- Version 3 - Stable version supporting BLT and ULP (experimental)

Unfortunately each version has unique ABI and there is no ABI compatibility among them. The functionality of PiP-v1 is almost the same with PiP-v2, however, PiP-v2's API is a subset of the PiP-v3's API. Hereafter **NN** denotes the PiP version number.

### Bi-Level Thread (BLT, from v3)

PiP also provides new thread implementation named "Bi-Level Thread (BLT)", again, to take the best of two worlds, Kernel-Level Thread (KLT) and User-Level Thread (ULT) here. A BLT is a PiP task. When a PiP task is created it runs as a KLT. At any point the KLT can become a ULT by decoupling the associated kernel thread from the KLT. The decoupled kernel thread becomes idle. Later, the ULT can become KLT again by coupling with the kernel thread.

### User-Level Process (ULP, from v3)

As described, PiP allows PiP tasks to share the same virtual address space. This means that a PiP task can context-switch to the other PiP task at user-level. This is called User-Level Process where processes may be derived from the same program or different programs. Threads basically share most of the kernel resources, such as address space, file descriptors, a process id, and so on whilst processes do not. Every process has its own file descriptor

space, for example. When a ULP is scheduled by a KLT having PID 1000, then the `getpid()` is called by the ULP returns 1000. Further, when the ULP is migrated to be scheduled by the other KLT, then the returned PID is different. So, when implementing a ULP system, this syscall consistency must be preserved. In ULP on PiP, the consistency can be maintained by utilizing the above BLT mechanism. When a ULP tries to call a system call, it is coupled with its kernel thread which was created at the beginning as a KLT. It should be noted that Thread Local Storage (TLS) regions are also switched when switching ULP (and BLT) contexts.

## Execution Mode

There are several PiP implementation modes which can be selected at the runtime. These implementations can be categorized into two;

- Process and
- (P)Thread.

In the pthread mode, although each PiP task has its own static variables unlike thread, PiP task behaves more like PThread, having a TID, having the same file descriptor space, having the same signal delivery semantics as Pthread does, and so on. In the process mode, a PiP task behaves more like a process, having a PID, having an independent file descriptor space, having the same signal delivery semantics as Linux process does, and so on. The above mentioned ULP can only work with the process mode.

When the **PIP\_MODE** environment variable is set to "thread" then the PiP library runs in the pthread mode, and if it is set to "process" then it runs in the process mode. There are also three implementations in the process mode; "process:preload," "process:piclone" and "process:got." The "process:preload" mode must be with the **LD\_PRELOAD** environment variable setting so that the `clone()` system call wrapper can work with. The "process:piclone" mode is only effective with the PiP-patched glibc library (see below).

Several functions are made available by the PiP library to absorb the functional differences due to the execution modes.

## License

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## Installation

Basically PiP requires the following three software packages;

- **PiP** - Process in Process (this package)
- **PiP-Testsuite** - Test suite for PiP
- **PiP-glibc** - patched GNU libc for PiP
- **PiP-gdb** - patched gdb to debug PiP root and PiP tasks.

By using PiP-glibc, users can create up to 300 PiP tasks which can be debugged by using PiP-gdb. In other words, without installing PiP-glibc, users can create up to around 10 PiP tasks (the number depends on the program) and cannot debug by using PiP-gdb. Note that PiP will not run at all without PiP-glibc on CentOS/RedHat 8.

There are several ways to install the PiP packages; Yum (RPM), Docker, Spack, and building from the source code. It is strongly recommended to use the following PiP package installation program (pip-pip):

- **PiP-pip** - PiP package installing program

This is the easiest way to install PiP packages in any form. Here is the example of `pip-pip` usage:

```
$ git clone https://github.com/RIKEN-SysSoft/PiP-pip.git
$ cd PiP-pip
$ ./pip-pip --how=HOW --pip=PIP_VERSION --work=BUILD_DIR --prefix=INSTALL_DIR
```

**HOW** can be one of `yum`, `docker`, `spack` and `github`, or any combination of them. `pip-pip --help` will show you how to use the program. `yum`, `docker` and `spack` include all three packages; `PiP-glibc`, `PiP-lib`, and `PiP-gdb`.

## PiP Documents

The following PiP documents are created by using [Doxygen](#).

### Man pages

Man pages will be installed at **PIP\_INSTALL\_DIR**/share/man.

```
$ man -M PIP_INSTALL_DIR/share/man 7 libpip
```

Or, use the `pip-man` command (from v2).

```
$ PIP_INSTALL_DIR/bin/pip-man 7 libpip
```

The above two examples will show you the same document you are reading.

### PDF

[PDF documents](#) will be installed at **PIP\_INSTALL\_DIR**/share/pdf.

### HTML

[HTML documents](#) will be installed at **PIP\_INSTALL\_DIR**/share/html.

## Getting Started

### Compile and link your PiP programs

- `pipcc(1)` command (since v2)

You can use `pipcc(1)` command to compile and link your PiP programs.

```
$ pipcc -Wall -O2 -g -c pip-prog.c
$ pipcc -Wall -O2 -g pip-prog.c -o pip-prog
```

### Run your PiP programs

- `pip-exec(1)` command (`piprun(1)` in PiP v1)

Let's assume that you have a non-PiP program(s) and want to run as PiP tasks. All you have to do is to compile your program by using the above `pipcc(1)` command and to use the `pip-exec(1)` command to run your program as PiP tasks.

```
$ pipcc myprog.c -o myprog
$ pip-exec -n 8 ./myprog
$ ./myprog
```

In this case, the `pip-exec(1)` command becomes the PiP root and your program runs as 8 PiP tasks. Note that the 'myprog.c' may or may not call any PiP functions. Your program can also run as a normal program (not as a PiP task) without using the `pip-exec(1)` command. In either case, your programs must be compiled and linked by using the `pipcc(1)` command described above.

You may write your own PiP programs which includes the PiP root programming. In this case, your program can run without using the `pip-exec(1)` command.

If you get the following message when you try to run your program;

```
PiP-ERR(19673) './myprog' is not PIE
```

Then this means that the 'myprog' (having PID 19673) is not compiled by using the `pipcc(1)` command properly. You may check if your program(s) can run as a PiP root and/or PiP task by using the `pip-check(1)` command (from v2);

```
$ pip-check a.out
a.out : Root&Task
```

Above example shows that the 'a.out' program can run as a PiP root and PiP tasks.

- `pips(1)` command (from v2)

Similar to the Linux `ps` command, you can see how your PiP program(s) is (are) running by using the `pips(1)` command. `pips` can accept 'a', 'u' and 'x' options just like the `ps` command.

```
$ pips [a][u][x] [PIPS-OPTIONS] [-] [PATTERN ..]
```

List the PiP tasks via the 'ps' command;

```
$ pips -ps [ PATTERN .. ]
```

or, show the activities of PiP tasks via the 'top' command;

```
$ pips -top [ PATTERN .. ]
```

Additionally you can kill all of your PiP tasks by using the same `pips(1)` command;

```
$ pips -s KILL [ PATTERN .. ]
```

## Debugging your PiP programs by the `pip-gdb` command

The following procedure attaches all PiP tasks and PiP root which created those tasks. Each PiP task is treated as a GDB inferior in PiP-gdb. Note that PiP-glibc and PiP-gdb packages are required to do this.

```
$ pip-gdb
(pip-gdb) attach PID
```

The attached inferiors can be seen by the following GDB command:

```
(pip-gdb) info inferiors
Num  Description          Executable
  4   process 6453 (pip 2)  /somewhere/pip-task-2
  3   process 6452 (pip 1)  /somewhere/pip-task-1
  2   process 6451 (pip 0)  /somewhere/pip-task-0
* 1   process 6450 (pip root) /somewhere/pip-root
```

You can select and debug an inferior by the following GDB command:

```
(pip-gdb) inferior 2
[Switching to inferior 2 [process 6451 (pip 0)] (/somewhere/pip-task-0)]
```

When an already-attached program calls '`pip_spawn()`' and becomes a PiP root task, the newly created PiP child tasks aren't attached automatically, but you can add empty inferiors and then attach the PiP child tasks to the inferiors. e.g.



```
.... type Control-Z to stop the root task.
^Z
Program received signal SIGTSTP, Stopped (user).

(pip-gdb) add-inferior
Added inferior 2
(pip-gdb) inferior 2
(pip-gdb) attach 1902

(pip-gdb) add-inferior
Added inferior 3
(pip-gdb) inferior 3
(pip-gdb) attach 1903

(pip-gdb) add-inferior
Added inferior 4
(pip-gdb) inferior 4
(pip-gdb) attach 1904

(pip-gdb) info inferiors
Num  Description              Executable
*  4    process 1904 (pip 2)    /somewhere/pip-task-2
   3    process 1903 (pip 1)    /somewhere/pip-task-1
   2    process 1902 (pip 0)    /somewhere/pip-task-0
   1    process 1897 (pip root) /somewhere/pip-root
```

You can attach all relevant PiP tasks by:

```
$ pip-gdb -p PID-of-your-PiP-program
```

(from v2)

If the **PIP\_GDB\_PATH** environment is set to the path pointing to PiP-gdb executable file, then PiP-gdb is automatically attached when an excetion signal (SIGSEGV and SIGHUP by default) is delivered. The exception signals can also be defined by setting the **PIP\_GDB\_SIGNALS** environment. Signal names (case insensitive) can be concatenated by the '+' or '-' symbol. 'all' is reserved to specify most of the signals. For example, 'ALL-TERM' means all signals excepting SIGTERM, another example, 'PIPE+INT' means SIGPIPE and SIGINT. If one of the specified or default signals is delivered, then PiP-gdb will be attached automatically. The PiP-gdb will show backtrace by default. If users specify **PIP\_GDB\_COMMAND**, a filename containing some GDB commands, then those GDB commands will be executed by PiP-gdb in batch mode. If the **PIP\_STOP\_ON\_START** environment is set, then the PiP library delivers SIGSTOP to a spawned PiP task which is about to start user program. If its value is a number in decimal, then the PiP task whose PiP-ID is the same with the specified number will be stopped. If the number is minus, then all PiP tasks will be stopped at the very beginning. Do not forget to compile your programs with a debug option.

## Mailing List

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## Publications

### Research papers

Atsushi Hori, Min Si, Balazs Gerofi, Masamichi Takagi, Jay Dayal, Pavan Balaji, and Yutaka Ishikawa. "Process-in-process: techniques for practical address-space sharing," In Proceedings of the 27th International Symposium on High-Performance Parallel and Distributed Computing (HPDC '18). ACM, New York, NY, USA, 131-143. DOI: <https://doi.org/10.1145/3208040.3208045>

Atsushi Hori, Balazs Gerofi, and Yuataka Ishikawa. "An Implementation of User-Level Processes using Address Space Sharing," 2020 IEEE International Parallel and Distributed Processing Symposium Workshops (IPDPSW), New Orleans, LA, USA, 2020, pp. 976-984, DOI: <https://doi.org/10.1109/IPDPSW50202.2020.00161>.

Kaiming Ouyang, Min Si, Atsushi Hori, Zizhong Chen and Pavan Balaji. "CAB-MPI: Exploring Interprocess Work Stealing toward Balanced MPI Communication," in SC'20

## Commands

- pipcc
- pip-check
- pip-exec
- pipfc
- pip-man
- pip-mode
- pips
- printpipmode

## Functions

- pip\_abort
- pip\_barrier\_fin
- pip\_barrier\_init
- pip\_barrier\_wait
- pip\_exit
- pip\_export
- pip\_fin
- pip\_get\_aux
- pip\_get\_mode
- pip\_get\_mode\_str
- pip\_get\_ntasks
- pip\_get\_pipid
- pip\_get\_system\_id
- pip\_import
- pip\_init
- pip\_isa\_root
- pip\_isa\_task
- pip\_is\_initialized
- pip\_is\_shared\_fd
- pip\_is\_threaded
- pip\_kill

- `pip_kill_all_tasks`
- `pip_named_export`
- `pip_named_import`
- `pip_named_tryimport`
- `pip_set_aux`
- `pip_sigmask`
- `pip_signal_wait`
- `pip_spawn`
- `pip_spawn_from_func`
- `pip_spawn_from_main`
- `pip_spawn_hook`
- `pip_task_spawn`
- `pip_trywait`
- `pip_trywait_any`
- `pip_wait`
- `pip_wait_any`
- `pip_yield`

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## Chapter 2

# PiP Commands

### 2.1 pipcc

C compiler driver for PiP

#### Synopsis

```
pipcc [PIP-OPTIONS] [CC-COMMAND-OPTIONS_AND_ARGS]
```

#### Parameters

<i>-piproot</i>	the compile (and link) as a PiP root
<i>-piptask</i>	the compile (and link) as a PiP task
<i>-nopip</i>	No PiP related settings will be applied

#### Note

The **-piproot** and **-piptask** options can be specified at the same time. In this case, the compiled object can be both of PiP root and PiP task. This is also the default behavior when none of them is not specified.

#### Environment

\$(CC) is used to specify a C compiler

#### See Also

pip-exec(1), pip-mode(1)

### 2.2 pip-check

PiP binary checking program if a program can run as a PiP root and/or PiP task

#### Synopsis

```
pip-check [ OPTION ] PIP-PROG [...]
```

## Parameters

<i>-r</i>	check if a.out can be PiP root
<i>-t</i>	check if a.out can be PiP task
<i>-b</i>	check if a.out can be PiP root and/or PiP task (default)
<i>-v</i>	show reason
<i>-h</i>	show this message

## See Also

pipcc

## 2.3 pip-exec

run program(s) as PiP tasks

## Synopsis

```
pip-exec [OPTIONS] <program> ... [ : ... ]
```

## Description

**Run** a program as PiP task(s). Mutiple programs can be specified by separating them with ':' to share the same virtual address space with the `pip-exec` command.

## Parameters

<i>-n N</i>	number of tasks
<i>-f FUNC</i>	function name to start
<i>-c CORE</i>	specify the CPU core number to bind core(s)
<i>-r</i>	core binding in the round-robin fashion

## See Also

pipcc(1)

## 2.4 pipfc

Fortran compiler driver for PiP

## Synopsis

```
pipfc [PIP-OPTIONS] [FC-COMMAND-OPTIONS_AND_ARGS]
```

## Parameters

<i>-piproot</i>	the compile (and link) as a PiP root
<i>-piptask</i>	the compile (and link) as a PiP task
<i>-nopip</i>	No PiP related settings will be applied

## Note

The **-piproot** and **-piptask** options can be specified at the same time. In this case, the compiled object can be both of PiP root and PiP task. This is also the default behavior when none of them is not specified.

## Environment

`$(FC)` is used to specify a Fortran compiler

**See Also**

pip-exec(1), pip-mode(1)

## 2.5 pip-man

show PiP man page

**Synopsis**

pip-man [MAN-OPT] MAN-TOPIC

**Description**

Show PiP man pages. It can also accept the man command options.

**See Also**

man(1)

## 2.6 pip-mode

Set PiP execution mode

**Synopsis**

pip-mode [OPTION] [PIP-COMMAND]

**Description**

The following options are available. If no of them specified, then the compiled output file can be used as both PiP root and PiP task.

**Parameters**

<b>-P</b>	'process' mode
<b>-L</b>	'process:preload' mode
<b>-C</b>	'process:clone' mode
<b>-G</b>	'process:got' mode
<b>-T</b>	'thread' mode
<b>-u</b>	Show usage

**See Also**

pip-exec  
printpipmode

## 2.7 pips

List or kill running PiP tasks

**Synopsis**

pips [a][u][x] [PIP-OPTIONS] [-] [PATTERN ..]

## Parameters

<code>a u x</code>	similar to the aux options of the Linux <code>ps</code> command
<code>--root</code>	List PiP root(s)
<code>--task</code>	List PiP task(s)
<code>--family</code>	List PiP root(s) and PiP task(s) in family order
<code>--kill</code>	Send SIGTERM to PiP root(s) and task(s)
<code>--signal</code>	Send a signal to PiP root(s) and task(s). This option must be followed by a signal number of name.
<code>--ps</code>	Run the <code>ps</code> Linux command. This option may have <code>ps</code> command option(s) separated by comma (,)
<code>--top</code>	Run the <code>top</code> Linux command. This option may have <code>top</code> command option(s) separated by comma (,)
<code>-</code>	Simply ignored. This option can be used to avoid the ambiguity of the options.

## Description

`pips` is a filter to target only PiP tasks (including PiP root) to show status like the way what the `ps` commands does and send signals to the selected PiP tasks.

Just like the `ps` command, `pips` can take the most familiar `ps` options `a`, `u`, `x`. Here is an example;

```
$ pips
PID  TID  TT      TIME      PIP COMMAND
18741 18741 pts/0    00:00:00 RT  pip-exec
18742 18742 pts/0    00:00:00 RG  pip-exec
18743 18743 pts/0    00:00:00 RL  pip-exec
18741 18744 pts/0    00:00:00 OT  a
18745 18745 pts/0    00:00:00 OG  b
18746 18746 pts/0    00:00:00 OL  c
18747 18747 pts/0    00:00:00 1L  c
18741 18748 pts/0    00:00:00 1T  a
18749 18749 pts/0    00:00:00 1G  b
18741 18750 pts/0    00:00:00 2T  a
18751 18751 pts/0    00:00:00 2G  b
18741 18752 pts/0    00:00:00 3T  a
```

here, there are 3 `pip-exec` root processes running. Four `pip` tasks running program 'a' with the `pthrad` mode, three PiP tasks running program 'b' with the `process:got` mode, and two PiP tasks running program 'c' with the `process:preload` mode.

Unlike the `ps` command, two columns 'TID' and 'PIP' are added. The 'TID' field is to identify PiP tasks in `pthread` execution mode. three PiP tasks running in the `pthread` mode. As for the 'PiP' field, if the first letter is 'R' then that `pip` task is running as a PiP root. If this letter is a number from '0' to '9' then this is a PiP task (not root). The number is the least-significant digit of the PiP ID of that PiP task. The second letter represents the PiP execution mode which is common with PiP root and task. 'L' is 'process:preload', 'C' is 'process:piplone', 'G' is 'process:got', and 'T' is 'thread'.

The last 'COMMAND' column of the `pips` output may be different from what the `ps` command shows, although it looks the same. It represents the command, not the command line consisting of a command and its argument(s). More precisely speaking, it is the first 14 letters of the command. This comes from the PiP's specificity. PiP tasks are not created by using the normal `exec` systemcall and the Linux assumes the same command line with the `pip` root process which creates the `pip` tasks.

If users want to have the other `ps` command options other than 'aux', then refer to the `--ps` option described below. But in this case, the command lines of PiP tasks (excepting PiP roots) are not correct.

- `--root (-r)` Only the PiP root tasks will be shown.

```
$ pips --root
PID  TID  TT      TIME      PIP COMMAND
18741 18741 pts/0    00:00:00 RT  pip-exec
18742 18742 pts/0    00:00:00 RG  pip-exec
18743 18743 pts/0    00:00:00 RL  pip-exec
```



- `--task (-t)` Only the PiP tasks (excluding root) will be shown. If both of `--root` and `--task` are specified, then firstly PiP roots are shown and then PiP tasks will be shown.

```
$ pips --tasks
PID   TID   TT      TIME      PIP COMMAND
18741 18744 pts/0    00:00:00 0T   a
18745 18745 pts/0    00:00:00 0G   b
18746 18746 pts/0    00:00:00 0L   c
18747 18747 pts/0    00:00:00 1L   c
18741 18748 pts/0    00:00:00 1T   a
18749 18749 pts/0    00:00:00 1G   b
18741 18750 pts/0    00:00:00 2T   a
18751 18751 pts/0    00:00:00 2G   b
18741 18752 pts/0    00:00:00 3T   a
```

- `--family (-f)` All PiP roots and tasks of the selected PiP tasks by the `PATTERN` optional argument of `pips`.

```
$ pips - a
PID   TID   TT      TIME      PIP COMMAND
18741 18744 pts/0    00:00:00 0T   a
18741 18748 pts/0    00:00:00 1T   a
18741 18750 pts/0    00:00:00 2T   a
$ pips --family a
PID   TID   TT      TIME      PIP COMMAND
18741 18741 pts/0    00:00:00 RT   pip-exec
18741 18744 pts/0    00:00:00 0T   a
18741 18748 pts/0    00:00:00 1T   a
18741 18750 pts/0    00:00:00 2T   a
```

In this example, "pips - a" (the - is needed not to confused the command name a as the `pips` option) shows the PiP tasks which is derived from the program a. The second run, "pips --family a," shows the PiP tasks of a and their PiP root (`pip-exec`, in this example).

- `--kill (-k)` Send SIGTERM signal to the selected PiP tasks.
- `--signal (-s) SIGNAL` Send the specified signal to the selected PiP tasks.
- `--ps (-P)` This option may be followed by the `ps` command options. When this option is specified, the PIDs of selected PiP tasks are passed to the `ps` command with the specified `ps` command options, if given.
- `--top (-T)` This option may be followed by the `top` command options. When this option is specified, the PIDs of selected PiP tasks are passed to the `top` command with the specified `top` command options, if given.
- `PATTERN` The last argument is the pattern(s) to select which PiP tasks to be selected and shown. This pattern can be a command name (only the first 14 characters are effective), PID, TID, or a Unix (Linux) filename matching pattern (if the `fnmatch` Python module is available).

```
$ pips - ***
PID   TID   TT      TIME      PIP COMMAND
18741 18741 pts/0    00:00:00 RT   pip-exec
18742 18742 pts/0    00:00:00 RG   pip-exec
18743 18743 pts/0    00:00:00 RL   pip-exec
```

#### Note

`pips` collects PiP tasks' status by using the Linux's `ps` command. When the `--ps` or `--top` option is specified, the `ps` or `top` command is invoked after invoking the `ps` command for information gathering. This, however, may result some PiP tasks may not appear in the invoked `ps` or `top` command when one or more PiP tasks finished after the first `ps` command invocation. The same situation may also happen with the `--kill` or `--signal` option.

## 2.8 printpipmode

Print current PiP mode

### Synopsis

```
printpipmode
```

### See Also

pip-mode

## Chapter 3

# PiP Functions

### 3.1 PiP Initialization/Finalization

#### Functions

- int [pip\\_init](#) (int \*pipidp, int \*ntasks, void \*\*root\_expp, int opts)
- int [pip\\_fin](#) (void)

#### 3.1.1 Detailed Description

##### 3.1.1.1 PiP Initialization/Finalization

#### Description

PiP initialization/finalization functions

#### 3.1.2 Function Documentation

##### 3.1.2.1 int pip\_init( int \* *pipidp*, int \* *ntasks*, void \*\* *root\_expp*, int *opts* )

#### Name

`pip_init`

#### Name

Initialize the PiP library

#### Synopsis

```
#include <pip/pip.h>
int pip_init( int *pipidp, int *ntasks, void **root_expp, uint32_t opts );
```

#### Description

This function initializes the PiP library. The PiP root process must call this. A PiP task is not required to call this function unless the PiP task calls any PiP functions.

#### Description

When this function is called by a PiP root, `ntasks`, and `root_expp` are input parameters. If this is called by a PiP task, then those parameters are output returning the same values input by the root.

### Description

A PiP task may or may not call this function. If `pip_init` is not called by a PiP task explicitly, then `pip_init` is called magically and implicitly even if the PiP task program is NOT linked with the PiP library.

### Parameters

out	<i>pipidp</i>	When this is called by the PiP root process, then this returns <code>PIP_PIPID_ROOT</code> , otherwise it returns the PiP ID of the calling PiP task.
in, out	<i>ntasks</i>	When called by the PiP root, it specifies the maximum number of PiP tasks. When called by a PiP task, then it returns the number specified by the PiP root.
in, out	<i>root_expp</i>	If the root PiP is ready to export a memory region to any PiP task(s), then this parameter is to pass the exporting address. If the PiP root is not ready to export or has nothing to export then this variable can be NULL. When called by a PiP task, it returns the exported address by the PiP root, if any.
in	<i>opts</i>	Specifying the PiP execution mode and See below.

### Execution mode option

Users may explicitly specify the PiP execution mode. This execution mode can be categorized in two; process mode and thread mode. In the process execution mode, each PiP task may have its own file descriptors, signal handlers, and so on, just like a process. Contrastingly, in the pthread execution mode, file descriptors and signal handlers are shared among PiP root and PiP tasks while maintaining the privatized variables.

To spawn a PiP task in the process mode, the PiP library modifies the `clone()` flag so that the created PiP task can exhibit the almost same way with that of normal Linux process. There are three ways implemented; using `LD_PRELOAD`, modifying Glibc, and modifying `GIOT` entry of the `clone()` systemcall. One of the option flag values; **PIP\_MODE\_PTHREAD**, **PIP\_MODE\_PROCESS**, **PIP\_MODE\_PROCESS\_PRELOAD**, **PIP\_MODE\_PROCESS\_PIPCLONE**, or **PIP\_MODE\_PROCESS\_GOT** can be specified as the option flag. Or, users may specify the execution mode by the **PIP\_MODE** environment described below.

### Returns

Zero is returned if this function succeeds. Otherwise an error number is returned.

### Return values

<i>EINVAL</i>	<i>ntasks</i> is negative
<i>EBUSY</i>	PiP root called this function twice or more without calling <a href="#">pip_fin</a> .
<i>EPERM</i>	<i>opts</i> is invalid or unacceptable
<i>EOVERFLOW</i>	<i>ntasks</i> is too large
<i>ELIBSCN</i>	version miss-match between PiP root and PiP task

### Environment

- **PIP\_MODE** Specifying the PiP execution mode. Its value can be either `thread`, `pthread`, `process`, `process:preload`, `process:pipclone`, or `process:got`.
- **LD\_PRELOAD** This is required to set appropriately to hold the path to the `pip_preload.so` file, if the PiP execution mode is `PIP_MODE_PROCESS_PRELOAD` (the *opts* in `pip_init`) and/or the **PIP\_MODE** environment is set to `process:preload`. See also the `pip-mode` command to set the environment variable appropriately and easily.
- **PIP\_STACKSZ** Specifying the stack size (in bytes). The **KMP\_STACKSIZE** and **OMP\_STACKSIZE** are also effective. The 't', 'g', 'm', 'k' and 'b' postfix character can be used.
- **PIP\_STOP\_ON\_START** Specifying the PIP ID to stop on start to debug the specified PiP task from the beginning. If the before hook is specified, then the PiP task will be stopped just before calling the before hook.

- **PIP\_GDB\_PATH** If this environment is set to the path pointing to the PiP-gdb executable file, then PiP-gdb is automatically attached when an execution signal (SIGSEGV and SIGHUP by default) is delivered. The signals which triggers the PiP-gdb invocation can be specified the `PIP_GDB_SIGNALS` environment described below.
- **PIP\_GDB\_COMMAND** If this `PIP_GDB_COMMAND` is set to a filename containing some GDB commands, then those GDB commands will be executed by the GDB in batch mode, instead of backtrace.
- **PIP\_GDB\_SIGNALS** Specifying the signal(s) resulting automatic PiP-gdb attach. Signal names (case insensitive) can be concatenated by the '+' or '-' symbol. 'all' is reserved to specify most of the signals. For example, 'ALL-TERM' means all signals excepting `SIGTERM`, another example, 'PIPE+INT' means `SIGPIPE` and `SIGINT`. Some signals such as `SIGKILL` and `SIGCONT` cannot be specified.
- **PIP\_SHOW\_MAPS** If the value is 'on' and one of the above execution signals is delivered, then the memory map will be shown.
- **PIP\_SHOW\_PIPS** If the value is 'on' and one of the above execution signals is delivered, then the process status by using the `pips` command will be shown.

### Bugs

It is NOT guaranteed that users can spawn tasks up to the number specified by the `ntasks` argument. There are some limitations come from outside of the PiP library (from GLIBC).

### See Also

[pip\\_named\\_export](#)  
[pip\\_export](#)  
[pip\\_fin](#)  
[pip-mode](#)  
[pips](#)

#### 3.1.2.2 int pip\_fin ( void )

##### Name

`pip_fin`

##### Name

Finalize the PiP library

##### Synopsis

```
#include <pip/pip.h>
int pip_fin( void );
```

##### Description

This function finalizes the PiP library. After calling this, most of the PiP functions will return the error code `EPERM`.

##### Returns

zero is returned if this function succeeds. On error, error number is returned.

## Return values

<i>EPERM</i>	<code>pip_init</code> is not yet called
<i>EBUSY</i>	one or more PiP tasks are not yet terminated

## Notes

The behavior of calling `pip_init` after calling this `pip_fin` is not defined and recommended not to do so.

## See Also

`pip_init`

## 3.2 Spawning PiP task

### Functions

- void `pip_spawn_from_main` (`pip_spawn_program_t` \*progp, char \*prog, char \*\*argv, char \*\*envv, void \*exp, void \*aux)  
*Setting information to invoke a PiP task starting from the main function.*
- void `pip_spawn_from_func` (`pip_spawn_program_t` \*progp, char \*prog, char \*funcname, void \*arg, char \*\*envv, void \*exp, void \*aux)  
*Setting information to invoke a PiP task starting from a function defined in a program.*
- void `pip_spawn_hook` (`pip_spawn_hook_t` \*hook, `pip_spawnhook_t` before, `pip_spawnhook_t` after, void \*hookarg)  
*Setting invocation hook information.*
- int `pip_task_spawn` (`pip_spawn_program_t` \*progp, `uint32_t` coreno, `uint32_t` opts, int \*pipidp, `pip_spawn_hook_t` \*hookp)  
*Spawning a PiP task.*
- int `pip_spawn` (char \*filename, char \*\*argv, char \*\*envv, int coreno, int \*pipidp, `pip_spawnhook_t` before, `pip_spawnhook_t` after, void \*hookarg)  
*spawn a PiP task (PiP v1 API and deprecated)*

### 3.2.1 Detailed Description

#### 3.2.1.1 PiP Spawng PiP (ULP/BLT) task

## Description

Spawning PiP task or ULP/BLT task

### 3.2.2 Function Documentation

- 3.2.2.1 void `pip_spawn_from_main` ( `pip_spawn_program_t` \* *progp*, char \* *prog*, char \*\* *argv*, char \*\* *envv*, void \* *exp*, void \* *aux* )

## Name

`pip_spawn_from_main`

## Synopsis

```
#include <pip/pip.h>
void pip_spawn_from_main( pip_spawn_program_t *progp, char *prog, char **argv, char **envv, void *exp, void *aux )
```

**Description**

This function sets up the `pip_spawn_program_t` structure for spawning a PiP task, starting from the `mmain` function.

**Parameters**

out	<i>progp</i>	Pointer to the <code>pip_spawn_program_t</code> structure in which the program invocation information will be set
in	<i>prog</i>	Path to the executable file.
in	<i>argv</i>	Argument vector.
in	<i>envv</i>	Environment variables. If this is <code>NULL</code> , then the <code>environ</code> variable is used for the spawning PiP task.
in	<i>exp</i>	Export value to the spawning PiP task
in	<i>aux</i>	Auxiliary data to be associated with the created PiP task

**See Also**

[pip\\_task\\_spawn](#)  
[pip\\_spawn\\_from\\_func](#)

**3.2.2.2** `void pip_spawn_from_func ( pip_spawn_program_t *progp, char *prog, char *funcname, void *arg, char **envv, void *exp, void *aux )`

**Name**

`pip_spawn_from_func`

**Synopsis**

```
#include <pip/pip.h>
pip_spawn_from_func( pip_spawn_program_t *progp, char *prog, char *funcname, void *arg, char **envv,
void *exp, void *aux );
```

**Description**

This function sets the required information to invoke a program, starting from the `main()` function. The function should have the function prototype as shown below;

```
int start_func( void *arg )
```

This start function must be globally defined in the program.. The returned integer of the start function will be treated in the same way as the `main` function. This implies that the `pip_wait` function family called from the PiP root can retrieve the return code.

**Parameters**

out	<i>progp</i>	Pointer to the <code>pip_spawn_program_t</code> structure in which the program invocation information will be set
in	<i>prog</i>	Path to the executable file.
in	<i>funcname</i>	Function name to be started
in	<i>arg</i>	Argument which will be passed to the start function
in	<i>envv</i>	Environment variables. If this is <code>NULL</code> , then the <code>environ</code> variable is used for the spawning PiP task.

in	<i>exp</i>	Export value to the spawning PiP task
in	<i>aux</i>	Auxiliary data to be associated with the created PiP task

#### See Also

[pip\\_task\\_spawn](#)  
[pip\\_spawn\\_from\\_main](#)

3.2.2.3 void pip\_spawn\_hook( pip\_spawn\_hook\_t \* *hook*, pip\_spawnhook\_t *before*, pip\_spawnhook\_t *after*, void \* *hookarg* )

#### Name

pip\_spawn\_hook

#### Synopsis

```
#include <pip/pip.h>
void pip_spawn_hook( pip_spawn_hook_t *hook, pip_spawnhook_t before, pip_spawnhook_t after, void
*hookarg );
```

#### Description

The *before* and *after* functions are introduced to follow the programming model of the *fork* and *exec*. *before* function does the prologue found between the *fork* and *exec*. *after* function is to free the argument if it is *malloc()*ed, for example.

#### Precondition

It should be noted that the *before* and *after* functions are called in the *context* of PiP root, although they are running as a part of PiP task (i.e., having PID of the spawning PiP task). Conversely speaking, those functions cannot access the variables defined in the spawning PiP task.

The *before* and *after* hook functions should have the function prototype as shown below;

```
int hook_func( void *hookarg )
```

#### Parameters

out	<i>hook</i>	Pointer to the <i>pip_spawn_hook_t</i> structure in which the invocation hook information will be set
in	<i>before</i>	Just before the executing of the spawned PiP task, this function is called so that file descriptors inherited from the PiP root, for example, can deal with. This is only effective with the PiP process mode. This function is called with the argument <i>hookarg</i> described below.
in	<i>after</i>	This function is called when the PiP task terminates for the cleanup purpose. This function is called with the argument <i>hookarg</i> described below.
in	<i>hookarg</i>	The argument for the <i>before</i> and <i>after</i> function call.

#### Note

Note that the file descriptors and signal handlers are shared between PiP root and PiP tasks in the pthread execution mode.

#### See Also

[pip\\_task\\_spawn](#)



3.2.2.4 `int pip_task_spawn ( pip_spawn_program_t * progp, uint32_t coreno, uint32_t opts, int * pipidp, pip_spawn_hook_t * hookp )`

#### Name

`pip_task_spawn`

#### Synopsis

```
#include <pip/pip.h>
int pip_task_spawn( pip_spawn_program_t *progp, uint32_t coreno, uint32_t opts, int *pipidp, pip_spawn_hook_t *hookp );
```

#### Description

This function spawns a PiP task specified by `progp`.

In the process execution mode, the file descriptors having the `FD_CLOEXEC` flag is closed and will not be passed to the spawned PiP task. This simulated close-on-exec will not take place in the pthread execution mode.

#### Parameters

out	<i>progp</i>	Pointer to the <code>pip_spawn_hook_t</code> structure in which the invocation hook information is set
in	<i>coreno</i>	CPU core number for the PiP task to be bound to. By default, <code>coreno</code> is set to zero, for example, then the calling task will be bound to the first core available. This is in mind that the available core numbers are not contiguous. To specify an absolute core number, <code>coreno</code> must be bitwise-ORed with <code>PIP_CPUCORE_ABS</code> . If <code>PIP_CPUCORE_ASIS</code> is specified, then the core binding will not take place.
in	<i>opts</i>	option flags
in, out	<i>pipidp</i>	Specify PiP ID of the spawned PiP task. If <code>PIP_PIPID_ANY</code> is specified, then the PiP ID of the spawned PiP task is up to the PiP library and the assigned PiP ID will be returned.
in	<i>hookp</i>	Hook information to be invoked before and after the program invocation.

#### Returns

Zero is returned if this function succeeds. On error, an error number is returned.

#### Return values

<i>EPERM</i>	PiP library is not yet initialized
<i>EPERM</i>	PiP task tries to spawn child task
<i>EINVAL</i>	<code>progp</code> is NULL
<i>EINVAL</i>	<code>opts</code> is invalid and/or unacceptable
<i>EINVAL</i>	the value of <code>pipidp</code> is invalid
<i>EINVAL</i>	the <code>coreno</code> is larger than or equal to <code>PIP_CPUCORE_CORENO_MAX</code>
<i>EBUSY</i>	specified PiP ID is already occupied
<i>ENOMEM</i>	not enough memory
<i>ENXIO</i>	<code>dlopen</code> failss

#### Note

In the process execution mode, each PiP task may have its own file descriptors, signal handlers, and so on, just like a process. Contrastingly, in the pthread execution mode, file descriptors and signal handlers are shared among PiP root and PiP tasks while maintaining the privatized variables.

## Environment

- **PIP\_STOP\_ON\_START** Specifying the PiP ID to stop on start to debug the specified PiP task from the beginning. If the before hook is specified, then the PiP task will be stopped just before calling the before hook.

## Bugs

In theory, there is no reason to restrict for a PiP task to spawn another PiP task. However, the current glibc implementation does not allow to do so.

If the root process is multithreaded, only the main thread can call this function.

## See Also

[pip\\_task\\_spawn](#)  
[pip\\_spawn\\_from\\_main](#)  
[pip\\_spawn\\_from\\_func](#)  
[pip\\_spawn\\_hook](#)  
[pip\\_spawn](#)

3.2.2.5 `int pip_spawn ( char * filename, char ** argv, char ** envv, int coreno, int * pipidp, pip_spawnhook_t before, pip_spawnhook_t after, void * hookarg )`

## Name

`pip_spawn`

## Synopsis

```
#include <pip/pip.h>
int pip_spawn( char *filename, char **argv, char **envv, uint32_t coreno, int *pipidp, pip_spawnhook_t before,
pip_spawnhook_t after, void *hookarg);
```

## Description

This function spawns a PiP task.

In the process execution mode, the file descriptors having the `FD_CLOEXEC` flag is closed and will not be passed to the spawned PiP task. This simulated close-on-exec will not take place in the pthread execution mode.

## Parameters

in	<i>filename</i>	The executable to run as a PiP task
in	<i>argv</i>	Argument(s) for the spawned PiP task
in	<i>envv</i>	Environment variables for the spawned PiP task
in	<i>coreno</i>	CPU core number for the PiP task to be bound to. By default, <code>coreno</code> is set to zero, for example, then the calling task will be bound to the first core available. This is in mind that the available core numbers are not contiguous. To specify an absolute core number, <code>coreno</code> must be bitwise-ORed with <code>PIP_CPUCORE_ABS</code> . If <code>PIP_CPUCORE_ASIS</code> is specified, then the core binding will not take place.

in, out	<i>pipidp</i>	Specify PiP ID of the spawned PiP task. If <code>PIP_PIPID_ANY</code> is specified, then the PiP ID of the spawned PiP task is up to the PiP library and the assigned PiP ID will be returned.
in	<i>before</i>	Just before the executing of the spawned PiP task, this function is called so that file descriptors inherited from the PiP root, for example, can deal with. This is only effective with the PiP process mode. This function is called with the argument <i>hookarg</i> described below.
in	<i>after</i>	This function is called when the PiP task terminates for the cleanup purpose. This function is called with the argument <i>hookarg</i> described below.
in	<i>hookarg</i>	The argument for the <i>before</i> and <i>after</i> function call.

#### Returns

Return 0 on success. Return an error code on error.

#### Return values

<i>EPERM</i>	PiP library is not yet initialized
<i>EPERM</i>	PiP task tries to spawn child task
<i>EINVAL</i>	<code>progp</code> is NULL
<i>EINVAL</i>	<code>opts</code> is invalid and/or unacceptable
<i>EINVAL</i>	the value of <code>pipidp</code> is invalid
<i>EINVAL</i>	the <code>coreno</code> is larger than or equal to <code>PIP_CPUCORE_CORENO_MAX</code>
<i>EBUSY</i>	specified PiP ID is already occupied
<i>ENOMEM</i>	not enough memory
<i>ENXIO</i>	<code>dlmopen</code> fails

#### Bugs

In theory, there is no reason to restrict for a PiP task to spawn another PiP task. However, the current glibc implementation does not allow to do so.

If the root process is multithreaded, only the main thread can call this function.

#### See Also

[pip\\_task\\_spawn](#)  
[pip\\_spawn\\_from\\_main](#)  
[pip\\_spawn\\_from\\_func](#)  
[pip\\_spawn\\_hook](#)  
[pip\\_task\\_spawn](#)

## 3.3 Export/Import Functions

#### Functions

- int [pip\\_named\\_export](#) (void \*exp, const char \*format,...) `__attribute__((format(printf, 2, 3)))`  
export an address of the calling PiP root or a PiP task to the others.
- int int [pip\\_named\\_import](#) (int pipid, void \*\*exp, const char \*format,...) `__attribute__((format(printf, 3, 4)))`  
import the named exported address
- int int int [pip\\_named\\_tryimport](#) (int pipid, void \*\*exp, const char \*format,...) `__attribute__((format(printf, 3, 4)))`  
import the named exported address (non-blocking)
- int int int int [pip\\_export](#) (void \*exp)  
export an address

- int [pip\\_import](#) (int pipid, void \*\*expp)  
*import exported address of a PiP task*
- int [pip\\_set\\_aux](#) (void \*aux)  
*Associate user data with a PiP task.*
- int [pip\\_get\\_aux](#) (void \*\*auxp)  
*Retrieve the user data associated with a PiP task.*

### 3.3.1 Detailed Description

#### 3.3.1.1 PiP Export and Import

##### Description

Export and import functions to exchange addresses among tasks

### 3.3.2 Function Documentation

#### 3.3.2.1 int [pip\\_named\\_export](#) ( void \* *exp*, const char \* *format*, ... )

##### Name

[pip\\_named\\_export](#)

##### Synopsis

```
#include <pip/pip.h>
int pip\_named\_export( void *exp, const char *format, ... )
```

##### Description

Pass an address of a memory region to the other PiP task. Unlike the simple [pip\\_export](#) and [pip\\_import](#) functions which can only export one address per task, [pip\\_named\\_export](#) and [pip\\_named\\_import](#) can associate a name with an address so that PiP root or PiP task can exchange arbitrary number of addresses.

##### Parameters

in	<i>exp</i>	an address to be passed to the other PiP task
in	<i>format</i>	a <code>printf</code> format to give the exported address a name. If this is NULL, then the name is assumed to be "".

##### Returns

Return 0 on success. Return an error code on error.

##### Return values

<i>EPERM</i>	<a href="#">pip_init</a> is not yet called.
<i>EBUSY</i>	The name is already registered.
<i>ENOMEM</i>	Not enough memory

##### Note

The addresses exported by [pip\\_named\\_export](#) cannot be imported by calling [pip\\_import](#), and vice versa.

## See Also

[pip\\_named\\_import](#)  
[pip\\_named\\_tryimport](#)  
[pip\\_export](#)  
[pip\\_import](#)

3.3.2.2 `int pip_named_import( int pipid, void **expp, const char *format, ... )`

## Name

`pip_named_import`

## Synopsis

```
#include <pip/pip.h>
int pip_named_import( int pipid, void **expp, const char *format, ... )
```

## Description

Import an address exported by the specified PiP task and having the specified name. If it is not exported yet, the calling task will be blocked.

## Parameters

in	<i>pipid</i>	The PiP ID to import the exposed address
out	<i>expp</i>	The starting address of the exposed region of the PiP task specified by the <i>pipid</i> .
in	<i>format</i>	a <code>printf</code> format to give the exported address a name

## Note

There is a possibility of deadlock when two or more tasks are mutually waiting for exported addresses.

The addresses exported by [pip\\_export](#) cannot be imported by calling [pip\\_named\\_import](#), and vice versa.

## Returns

zero is returned if this function succeeds. On error, an error number is returned.

## Return values

<i>EPERM</i>	<code>pip_init</code> is not yet called.
<i>EINVAL</i>	The specified <i>pipid</i> is invalid
<i>ENOMEM</i>	Not enough memory
<i>ECANCELED</i>	The target task is terminated
<i>EDEADLK</i>	<i>pipid</i> is the calling task and tries to block itself

## See Also

[pip\\_named\\_export](#)  
[pip\\_named\\_tryimport](#)  
[pip\\_export](#)  
[pip\\_import](#)

### 3.3.2.3 int int int pip\_named\_tryimport ( int *pipid*, void \*\* *expp*, const char \* *format*, ... )

#### Name

pip\_named\_tryimport

#### Synopsis

```
#include <pip/pip.h>
int pip_named_tryimport( int pipid, void **expp, const char *format, ... )
```

#### Description

Import an address exported by the specified PiP task and having the specified name. If it is not exported yet, this returns `EAGAIN`.

#### Parameters

in	<i>pipid</i>	The PiP ID to import the exposed address
out	<i>expp</i>	The starting address of the exposed region of the PiP task specified by the <i>pipid</i> .
in	<i>format</i>	a <code>printf</code> format to give the exported address a name

#### Note

The addresses exported by [pip\\_export](#) cannot be imported by calling [pip\\_named\\_import](#), and vice versa.

#### Returns

Zero is returned if this function succeeds. On error, an error number is returned.

#### Return values

<i>EPERM</i>	<code>pip_init</code> is not yet called.
<i>EINVAL</i>	The specified <code>pipid</code> is invalid
<i>ENOMEM</i>	Not enough memory
<i>ECANCELED</i>	The target task is terminated
<i>EAGAIN</i>	Target is not exported yet

#### See Also

[pip\\_named\\_export](#)  
[pip\\_named\\_import](#)  
[pip\\_export](#)  
[pip\\_import](#)

### 3.3.2.4 int int int int pip\_export ( void \* *exp* )

#### Name

pip\_export

#### Synopsis

```
#include <pip/pip.h>
int pip_export( void *exp );
```

#### Description

Pass an address of a memory region to the other PiP task. This is a very naive implementation in PiP v1 and deprecated. Once a task export an address, there is no way to change the exported address or undo export.

## Parameters

<i>in</i>	<i>exp</i>	An addresss
-----------	------------	-------------

## Returns

Return 0 on success. Return an error code on error.

## Return values

<i>EPERM</i>	PiP library is not initialized yet
--------------	------------------------------------

## See Also

[pip\\_import](#)  
[pip\\_named\\_export](#)  
[pip\\_named\\_import](#)  
[pip\\_named\\_tryimport](#)

3.3.2.5 `int pip_import ( int pipid, void ** expp )`

## Name

`pip_import`

## Synopsis

```
#include <pip/pip.h>
int pip_export( void **expp );
```

## Description

Get an address exported by the specified PiP task. This is a very naive implementation in PiP v1 and deprecated. If the address is not yet exported at the time of calling this function, then `NULL` is returned.

## Parameters

<i>in</i>	<i>pipid</i>	The PiP ID to import the exportedaddress
<i>out</i>	<i>expp</i>	The exported address

## Returns

Return 0 on success. Return an error code on error.

## Return values

<i>EPERM</i>	PiP library is not initialized yet
--------------	------------------------------------

## See Also

[pip\\_export](#)  
[pip\\_named\\_export](#)  
[pip\\_named\\_import](#)  
[pip\\_named\\_tryimport](#)

### 3.3.2.6 int pip\_set\_aux ( void \* aux )

#### Name

pip\_set\_aux

#### Synopsis

```
#include <pip/pip.h>
int pip_set_aux( void *aux );
```

#### Parameters

in	aux	Pointer to the user data to associate with the calling PiP task
----	-----	---

#### Returns

Return 0 on success. Return an error code on error.

#### Return values

EPERM	PiP library is not yet initialized or already finalized
-------	---

#### See Also

[pip\\_get\\_aux](#)

### 3.3.2.7 int pip\_get\_aux ( void \*\* auxp )

#### Name

pip\_get\_aux

#### Synopsis

```
#include <pip/pip.h>
int pip_get_aux( void **auxp );
```

#### Parameters

out	auxp	Returned user data
-----	------	--------------------

#### Returns

Return 0 on success. Return an error code on error.

#### Return values

EINVAL	domainp is NULL or auxp is NULL
EPERM	PiP library is not yet initialized or already finalized

#### See Also

[pip\\_set\\_aux](#)

## 3.4 Waiting for PiP task termination

#### Functions

- int [pip\\_wait](#) (int pipid, int \*status)



- wait for the termination of a PiP task*
- int [pip\\_trywait](#) (int pipid, int \*status)  
*wait for the termination of a PiP task in a non-blocking way*
- int [pip\\_wait\\_any](#) (int \*pipid, int \*status)  
*Wait for the termination of any PiP task.*
- int [pip\\_trywait\\_any](#) (int \*pipid, int \*status)  
*non-blocking version of pip\_wait\_any*

### 3.4.1 Detailed Description

#### 3.4.1.1 Waiting for PiP task termination

##### Description

Functions to wait for PiP task termination. All functions listed here must only be called from PiP root.

### 3.4.2 Function Documentation

#### 3.4.2.1 int pip\_wait ( int pipid, int \* status )

##### Name

`pip_wait`

##### Synopsis

```
#include <pip/pip.h>
int pip_wait( int pipid, int *status );
```

##### Description

This function can be used regardless to the PiP execution mode. This function blocks until the specified PiP task terminates. The macros such as `WIFEXITED` and so on defined in `Glibc` can be applied to the returned `status` value.

##### Parameters

in	<i>pipid</i>	PiP ID to wait for.
out	<i>status</i>	Status value of the terminated PiP task

##### Returns

Return 0 on success. Return an error code on error.

##### Return values

<i>EPERM</i>	PiP library is not initialized yet
<i>EPERM</i>	This function is called other than PiP root
<i>EDEADLK</i>	The specified <code>pipid</code> is the one of PiP root
<i>ECHILD</i>	The target PiP task does not exist or it was already terminated and waited for

##### See Also

[pip\\_exit](#)  
[pip\\_trywait](#)  
[pip\\_wait\\_any](#)  
[pip\\_trywait\\_any](#)  
[wait\(Linux 2\)](#)

### 3.4.2.2 `int pip_trywait ( int pipid, int * status )`

#### Name

`pip_trywait`

#### Synopsis

```
#include <pip/pip.h>
int pip_trywait( int pipid, int *status );
```

#### Description

This function can be used regardless to the PiP execution mode. This function behaves like the `wait` function of glibc and the macros such as `WIFEXITED` and so on can be applied to the returned `status` value.

#### Synopsis

```
#include <pip/pip.h>
int pip_trywait( int pipid, int *status );
```

#### Parameters

in	<i>pipid</i>	PiP ID to wait for.
out	<i>status</i>	Status value of the terminated PiP task

#### Note

This function can be used regardless to the PiP execution mode.

#### Returns

Return 0 on success. Return an error code on error.

#### Return values

<i>EPERM</i>	The PiP library is not initialized yet
<i>EPERM</i>	This function is called other than PiP root
<i>EDEADLK</i>	The specified <i>pipid</i> is the one of PiP root
<i>ECHILD</i>	The target PiP task does not exist or it was already terminated and waited for

#### See Also

[pip\\_exit](#)  
[pip\\_wait](#)  
[pip\\_wait\\_any](#)  
[pip\\_trywait\\_any](#)  
[wait\(Linux 2\)](#)

### 3.4.2.3 `int pip_wait_any ( int * pipid, int * status )`

#### Name

`pip_wait_any`

#### Synopsis

```
#include <pip/pip.h>
int pip_wait_any( int *pipid, int *status );
```

**Description**

This function can be used regardless to the PiP execution mode. This function blocks until any of PiP tasks terminates. The macros such as `WIFEXITED` and so on defined in Glibc can be applied to the returned `status` value.

**Parameters**

out	<i>pipid</i>	PiP ID of terminated PiP task.
out	<i>status</i>	Exit status of the terminated PiP task

**Returns**

Return 0 on success. Return an error code on error.

**Return values**

<i>EPERM</i>	The PiP library is not initialized yet
<i>EPERM</i>	This function is called other than PiP root
<i>ECHILD</i>	The target PiP task does not exist or it was already terminated and waited for

**See Also**

[pip\\_exit](#)  
[pip\\_wait](#)  
[pip\\_trywait](#)  
[pip\\_trywait\\_any](#)  
[wait\(Linux 2\)](#)

**3.4.2.4 int pip\_trywait\_any ( int \* pipid, int \* status )****Name**

`pip_trywait_any`

**Synopsis**

```
#include <pip/pip.h>
int pip_trywait_any( int *pipid, int *status );
```

**Description**

This function can be used regardless to the PiP execution mode. This function blocks until any of PiP tasks terminates. The macros such as `WIFEXITED` and so on defined in Glibc can be applied to the returned `status` value.

**Parameters**

out	<i>pipid</i>	PiP ID of terminated PiP task.
out	<i>status</i>	Exit status of the terminated PiP task

**Returns**

Return 0 on success. Return an error code on error.

## Return values

<i>EPERM</i>	The PiP library is not initialized yet
<i>EPERM</i>	This function is called other than PiP root
<i>ECHILD</i>	There is no PiP task to wait for

## See Also

[pip\\_exit](#)  
[pip\\_wait](#)  
[pip\\_trywait](#)  
[pip\\_wait\\_any](#)  
[wait\(Linux 2\)](#)

## 3.5 PiP Query Functions

### Functions

- int [pip\\_get\\_pipid](#) (int \*pipidp)  
*get PiP ID of the calling task*
- int [pip\\_is\\_initialized](#) (void)  
*Query is PiP library is already initialized.*
- int [pip\\_get\\_ntasks](#) (int \*ntasksp)  
*get the maximum number of the PiP tasks*
- int [pip\\_get\\_mode](#) (int \*modep)  
*get the PiP execution mode*
- const char \* [pip\\_get\\_mode\\_str](#) (void)  
*get a character string of the current execution mode*
- int [pip\\_get\\_system\\_id](#) (int pipid, pip\_id\_t \*idp)  
*deliver a process or thread ID defined by the system*
- int [pip\\_isa\\_root](#) (void)  
*check if calling PiP task is a PiP root or not*
- int [pip\\_isa\\_task](#) (void)  
*check if calling PiP task is a PiP task or not*
- int [pip\\_is\\_threaded](#) (int \*flagp)  
*check if PiP execution mode is pthread or not*
- int [pip\\_is\\_shared\\_fd](#) (int \*flagp)  
*check if file descriptors are shared or not. This is equivalent with the [pip\\_is\\_threaded](#) function.*

### 3.5.1 Detailed Description

#### 3.5.1.1 PiP Query functions

##### Description

Query functions for PiP task

### 3.5.2 Function Documentation

#### 3.5.2.1 int pip\_get\_pipid ( int \* pipidp )

##### Name

[pip\\_get\\_pipid](#)

**Synopsis**

```
#include <pip/pip.h>
int pip_get_pipid( int *pipidp );
```

**Parameters**

out	<i>pipidp</i>	This parameter points to the variable which will be set to the PiP ID of the calling task
-----	---------------	---

**Returns**

Return 0 on success. Return an error code on error.

**Return values**

<i>EPERM</i>	PiP library is not initialized yet
--------------	------------------------------------

**See Also**

[pip\\_init](#)

**3.5.2.2 int pip\_is\_initialized ( void )****Name**

pip\_is\_initialized

**Synopsis**

```
#include <pip/pip.h>
int pip_is_initialized( void );
```

**Returns**

Return a non-zero value if PiP is already initialized. Otherwise this returns zero.

**See Also**

[pip\\_init](#)

**3.5.2.3 int pip\_get\_ntasks ( int \* ntasksp )****Name**

pip\_get\_ntasks

**Synopsis**

```
#include <pip/pip.h>
int pip_get_ntasks( int *ntasksp );
```

## Parameters

out	<i>ntasksp</i>	Maximum number of PiP tasks is returned
-----	----------------	---

## Returns

Return 0 on success. Return an error code on error.

## Return values

<i>EPERM</i>	PiP library is not yet initialized
--------------	------------------------------------

## See Also

[pip\\_init](#)

## 3.5.2.4 int pip\_get\_mode ( int \* modep )

## Name

pip\_get\_mode

## Synopsis

```
#include <pip/pip.h>
int pip_get_mode( int *modep );
```

## Parameters

out	<i>modep</i>	Returned PiP execution mode
-----	--------------	-----------------------------

## Returns

Return 0 on success. Return an error code on error.

## Return values

<i>EPERM</i>	PiP library is not yet initialized
--------------	------------------------------------

## See Also

[pip\\_get\\_mode\\_str](#)

## 3.5.2.5 const char\* pip\_get\_mode\_str ( void )

## Name

pip\_get\_mode\_str

## Synopsis

```
#include <pip/pip.h>
char *pip_get_mode_str( void );
```

## Returns

Return the name string of the current execution mode. If PiP library is not initialized yet, then this returns NULL.

## See Also

[pip\\_get\\_mode](#)

3.5.2.6 `int pip_get_system_id ( int pipid, pip_id_t * idp )`

## Name

`pip_get_system_id`

## Synopsis

```
#include <pip/pip.h>
int pip_get_system_id( int *pipid, uintptr_t *idp );
```

## Description

The returned object depends on the PiP execution mode. In the process mode it returns TID (Thread ID, not PID) and in the thread mode it returns thread (`pthread_t`) associated with the PiP task. This function can be used regardless of the PiP execution mode.

## Parameters

out	<i>pipid</i>	PiP ID of a target PiP task
out	<i>idp</i>	a pointer to store the ID value

## Returns

Return 0 on success. Return an error code on error.

## Return values

<i>EPERM</i>	The PiP library is not initialized yet
--------------	--

## See Also

`getpid`(Linux 2)  
`pthread_self`(Linux 3)

3.5.2.7 `int pip_isa_root ( void )`

## Name

`pip_isa_root`

## Synopsis

```
#include <pip/pip.h>
int pip_isa_root( void );
```

## Returns

Return a non-zero value if the caller is the PiP root. Otherwise this returns zero.

## See Also

`pip_init`

3.5.2.8 `int pip_isa_task ( void )`

## Name

`pip_isa_task`

## Synopsis

```
#include <pip/pip.h>
int pip_isa_task( void );
```

## Returns

Return a non-zero value if the caller is the PiP task. Otherwise this returns zero.

## See Also

[pip\\_init](#)

3.5.2.9 `int pip_is_threaded ( int * flagp )`

## Name

`pip_is_threaded`

## Synopsis

```
#include <pip/pip.h>
int pip_is_threaded( int *flagp );
```

## Parameters

out	<i>flagp</i>	set to a non-zero value if PiP execution mode is Pthread
-----	--------------	--

## Returns

Return 0 on success. Return an error code on error.

## Return values

<i>EPERM</i>	The PiP library is not initialized yet
--------------	--

## See Also

[pip\\_init](#)

3.5.2.10 `int pip_is_shared_fd ( int * flagp )`

## Name

`pip_is_shared_fd`

## Synopsis

```
#include <pip/pip.h>
int pip_is_shared_fd( int *flagp );
```



## Parameters

<code>out</code>	<code>flagp</code>	set to a non-zero value if FDs are shared
------------------	--------------------	---

## Returns

Return 0 on success. Return an error code on error.

## Return values

<code>EPERM</code>	The PiP library is not initialized yet
--------------------	--

## See Also

[pip\\_init](#)

## 3.6 PiP task termination

### Functions

- void [pip\\_exit](#) (int status)  
*terminate the calling PiP task*
- int [pip\\_kill\\_all\\_tasks](#) (void)  
*kill all PiP tasks*
- void [pip\\_abort](#) (void)  
*Kill all PiP tasks and then kill PiP root.*
- int [pip\\_kill](#) (int pipid, int signal)  
*deliver a signal to PiP task*

### 3.6.1 Detailed Description

#### 3.6.1.1 Terminating PiP task

##### Description

Terminating PiP task(s)

### 3.6.2 Function Documentation

#### 3.6.2.1 void [pip\\_exit](#) ( int *status* )

##### Name

[pip\\_exit](#)

##### Synopsis

```
#include <pip/pip.h>
void pip\_exit( int status );
```

##### Description

When the main function or the start function of a PiP task returns with an integer value, then it has the same effect of calling [pip\\_exit](#) with the returned value.

## Parameters

<code>in</code>	<code>status</code>	This status is returned to PiP root.
-----------------	---------------------	--------------------------------------

## Note

This function can be used regardless to the PiP execution mode. `exit(3)` is called in the process mode and `pthread_exit(3)` is called in the pthread mode.

## See Also

[pip\\_wait](#)  
[pip\\_trywait](#)  
[pip\\_wait\\_any](#)  
[pip\\_trywait\\_any](#)  
[exit\(Linux 3\)](#)  
[pthread\\_exit\(Linux 3\)](#)

3.6.2.2 `int pip_kill_all_tasks( void )`

## Name

`pip_kill_all_tasks`

## Synopsis

```
#include <pip/pip.h>
int pip_kill_all_tasks( void );
```

## Note

This function must be called from PiP root.

## Returns

Return 0 on success. Return an error code on error.

## Return values

<code>EPERM</code>	The PiP library is not initialized yet
<code>EPERM</code>	Not called from root

3.6.2.3 `void pip_abort( void )`

## Name

`pip_abort`

## Synopsis

```
#include <pip/pip.h>
void pip_abort( void );
```

3.6.2.4 int pip\_kill ( int *pipid*, int *signal* )

## Name

pip\_kill

## Synopsis

```
#include <pip/pip.h>
int pip_kill( int pipid, int signal );
```

## Parameters

out	<i>pipid</i>	PiP ID of a target PiP task to deliver the signal
out	<i>signal</i>	signal number to be delivered

## Returns

Return 0 on success. Return an error code on error.

## Return values

<i>EPERM</i>	PiP library is not yet initialized
<i>EINVAL</i>	An invalid signal number or invalid PiP ID is specified

## See Also

tkill(Luinux 2)

## 3.7 PiP Siganling Functions

### Functions

- int [pip\\_sigmask](#) (int *how*, const sigset\_t \**sigmask*, sigset\_t \**oldmask*)  
*set signal mask of the current PiP task*
- int [pip\\_signal\\_wait](#) (int *signal*)  
*wait for a signal*

### 3.7.1 Detailed Description

#### 3.7.1.1 PiP signaling functions

## Description

Signaling functions for PiP task

### 3.7.2 Function Documentation

3.7.2.1 int pip\_sigmask ( int *how*, const sigset\_t \* *sigmask*, sigset\_t \* *oldmask* )

## Name

pip\_sigmask

## Synopsis

```
#include <pip/pip.h>
int pip_sigmask( int how, const sigset_t *sigmask, sigset_t *oldmask );
```

**Description**

This function is agnostic to the PiP execution mode.

**Parameters**

in	<i>how</i>	see <b>sigprocmask</b> or <b>pthread_sigmask</b>
in	<i>sigmask</i>	signal mask
out	<i>oldmask</i>	old signal mask

**Returns**

Return 0 on success. Return an error code on error.

**Return values**

<i>EPERM</i>	PiP library is not yet initialized
<i>EINVAL</i>	An invalid signal number or invalid PiP ID is specified

**See Also**

sigprocmask(Linux 2)  
pthread\_sigmask(Linux 3)

**3.7.2.2 int pip\_signal\_wait ( int *signal* )****Name**

pip\_signal\_wait

**Synopsis**

```
#include <pip/pip.h>
int pip_signal_wait( int signal );
```

**Description**

This function is agnostic to the PiP execution mode.

**Parameters**

in	<i>signal</i>	signal to wait
----	---------------	----------------

**Returns**

Return 0 on success. Return an error code on error.

**Note**

This function does NOT return the `EINTR` error. This case is treated as normal return;

**See Also**

sigwait(Linux 3)  
sigsuspend(Linux 2)

## 3.8 PiP Synchronization Functions

### Functions

- int `pip_yield` (int flag)  
*Yield.*
- int `pip_barrier_init` (pip\_barrier\_t \*barrp, int n)  
*initialize barrier synchronization structure*
- int `pip_barrier_wait` (pip\_barrier\_t \*barrp)  
*wait on barrier synchronization in a busy-wait way*
- int `pip_barrier_fin` (pip\_barrier\_t \*barrp)  
*finalize barrier synchronization structure*

### 3.8.1 Detailed Description

#### 3.8.1.1 PiP synchronization functions

##### Description

Synchronization functions for PiP tasks

### 3.8.2 Function Documentation

#### 3.8.2.1 int `pip_yield` ( int flag )

##### Name

`pip_yield`

##### Synopsis

```
#include <pip/pip.h>
int pip_yield( int flag );
```

##### Parameters

in	flag	to specify the behavior of yielding. Unused and reserved for BLT/ULP (in PiP-v3)
----	------	--

##### Returns

This function always succeeds and returns zero.

##### See Also

`sched_yield`(Linux 2)  
`pthread_yield`(Linux 3)

#### 3.8.2.2 int `pip_barrier_init` ( pip\_barrier\_t \* barrp, int n )

##### Name

`pip_barrier_init`

##### Synopsis

```
#include <pip/pip.h>
int pip_barrier_init( pip_barrier_t *barrp, int n );
```

## Parameters

in	<i>barrp</i>	pointer to a PiP barrier structure
in	<i>n</i>	number of participants of this barrier synchronization

## Returns

Return 0 on success. Return an error code on error.

## Return values

<i>EPERM</i>	PiP library is not yet initialized or already finalized
<i>EINAVL</i>	<i>n</i> is invalid

## See Also

[pip\\_barrier\\_wait](#)  
[pip\\_barrier\\_fin](#)

3.8.2.3 int pip\_barrier\_wait ( pip\_barrier\_t \* *barrp* )

## Name

pip\_barrier\_wait

## Synopsis

```
#include <pip/pip.h>
int pip_barrier_wait( pip_barrier_t *barrp );
```

## Parameters

in	<i>barrp</i>	pointer to a PiP barrier structure
----	--------------	------------------------------------

## Returns

Return 0 on success. Return an error code on error.

## Return values

<i>EPERM</i>	PiP library is not yet initialized or already finalized
--------------	---

## See Also

[pip\\_barrier\\_init](#)  
[pip\\_barrier\\_fin](#)

3.8.2.4 int pip\_barrier\_fin ( pip\_barrier\_t \* *barrp* )

## Name

pip\_barrier\_fin

## Synopsis

```
#include <pip/pip.h>
int pip_barrier_fin( pip_barrier_t *barrp );
```

## Parameters

<code>in</code>	<code>barrp</code>	pointer to a PiP barrier structure
-----------------	--------------------	------------------------------------

## Returns

Return 0 on success. Return an error code on error.

## Return values

<code>EPERM</code>	PiP library is not yet initialized or already finalized
<code>EBUSY</code>	there are some tasks waiting for barrier synchronization

## See Also

[pip\\_barrier\\_init](#)  
[pip\\_barrier\\_wait](#)

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