



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 a sub-process are called a PiP task.

### 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-glibc** - patched GNU libc for PiP
- **PiP** - Process in Process (this package)
- **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.

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 -o pip-prog pip-prog.c
```

### 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.

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' 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)

You can see how your PiP program is running in realtime by using the `pips(1)` command.

List the PiP tasks via the 'ps' command;

```
$ pips -l [ COMMAND ]
```

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

```
$ pips -t [ COMMAND ]
```

Here **COMMAND** is the name (not a path) of PiP program you are running.

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

```
$ pips -s KILL [ COMMAND ]
```

## 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 'processes' is treated as a GDB inferior in PiP-gdb.

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

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

```
(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:

```
(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).

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

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

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

(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 exception 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** that a filename containing some GDB commands, then those GDB commands will be executed by PiP-gdb, instead of backtrace, in batch mode. If the **PIP\_STOP\_ON\_START** environment is set (to any value), then the PiP library delivers SIGSTOP to a spawned PiP task which is about to start user program.

## 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 (to appear)

## Commands

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

## Functions

- pip\_abort
- pip\_barrier\_fin
- pip\_barrier\_init
- pip\_barrier\_wait
- pip\_blt\_spawn
- pip\_couple
- pip\_decouple
- pip\_dequeue\_and\_resume
- pip\_dequeue\_and\_resume\_N
- pip\_dequeue\_and\_resume\_N\_nolock
- pip\_dequeue\_and\_resume\_nolock
- pip\_exit
- pip\_export
- pip\_fin
- pip\_get\_aux
- pip\_get\_mode
- pip\_get\_mode\_str
- pip\_get\_ntasks
- pip\_get\_pipid
- pip\_get\_sched\_domain
- pip\_get\_system\_id
- pip\_get\_task\_by\_pipid

- `pip_get_task_pipid`
- `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_mutex_fin`
- `pip_mutex_init`
- `pip_mutex_lock`
- `pip_mutex_unlock`
- `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_suspend_and_enqueue`
- `pip_suspend_and_enqueue_nolock`
- `pip_task_queue_count`
- `pip_task_queue_dequeue`
- `pip_task_queue_describe`
- `pip_task_queue_enqueue`
- `pip_task_queue_fin`
- `pip_task_queue_init`
- `pip_task_queue_isempty`
- `pip_task_queue_lock`
- `pip_task_queue_trylock`
- `pip_task_queue_unlock`

- `pip_task_self`
- `pip_task_spawn`
- `pip_trywait`
- `pip_trywait_any`
- `pip_wait`
- `pip_wait_any`
- `pip_yield`
- `pip_yield_to`

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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

if CC environment is set then \$(CC) will be used as 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 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)

## 2.5 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**

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

**See Also**

[pip-exec](#)  
[printpipmode](#)

## 2.6 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 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

```

here, there are 3 `pip-exec` root processes running. Four `pip` tasks running program 'a' with the `pthread` 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.

## 2.7 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`, uint32\_t `opts`)  
*Initialize the PiP library.*
- int `pip_fin` (void)  
*Finalize the PiP library.*

#### 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*, uint32\_t *opts* )

#### Name

`pip_init`

#### Synopsis

```
#include <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(1)` 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 (see also `pips(1)`) 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\(PiP 1\)](#)  
[pips\(PiP 1\)](#)

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

### Name

`pip_fin`

### Synopsis

```
#include <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

<code>EPERM</code>	<code>pip_init</code> is not yet called
<code>EBUSY</code>	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 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, uint32\_t coreno, int \*pipidp, pip\_spawnhook\_t before, pip\_spawnhook\_t after, void \*hookarg)  
*spawn a PiP task (PiP v1 API and deprecated)*
- int [pip\\_blt\\_spawn](#) (pip\_spawn\_program\_t \*progp, uint32\_t coreno, uint32\_t opts, int \*pipidp, pip\_task\_t \*\*bltp, pip\_task\_queue\_t \*queue, pip\_spawn\_hook\_t \*hookp)  
*spawn a PiP BLT/ULP (Bi-Level Task / User-Level Process)*

### 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.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.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.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 <code>pip_spawn_hook_t</code> 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.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>	<b>pip_spawn_program_t</b>
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> 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\\_spawn](#)  
[pip\\_blt\\_spawn](#)

3.2.2.5 `int pip_spawn ( char * filename, char ** argv, char ** envv, uint32_t coreno, int * pipidp, pip_spawnhook_t before, pip_spawnhook_t after, void * hookarg )`

#### Name

`pip_spawn`

#### Synopsis

```
#include <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, <i>coreno</i> 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, <i>coreno</i> 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>	<i>progp</i> is NULL
<i>EINVAL</i>	<i>opts</i> is invalid and/or unacceptable
<i>EINVAL</i>	the value off <i>pipidp</i> is invalid

<i>EINVAL</i>	the coreno 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

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

3.2.2.6 `int pip_blt_spawn ( pip_spawn_program_t * progp, uint32_t coreno, uint32_t opts, int * pipidp, pip_task_t ** bltp, pip_task_queue_t * queue, pip_spawn_hook_t * hookp )`

### Name

`pip_blt_spawn`

### Synopsis

```
#include <pip.h>
int pip_blt_spawn( pip_spawn_program_t *progp, uint32_t coreno, uint32_t opts, int *pipidp, pip_task_t **bltp,
pip_task_queue_t *queue, pip_spawn_hook_t *hookp );
```

### Description

This function spawns a BLT (PiP task) specified by `progp`. The created and returned BLT is another form of a PiP task. It is an opaque object, essentially a double-linked list. Thus created BLT can be enqueued or dequeued to/from a `pip_task_queue_t`.

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>	<b>pip_spawn_program_t</b>
in	<i>coreno</i>	CPU core number for the PiP task to be bound to. By default, <i>coreno</i> 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, <i>coreno</i> 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. If <code>PIP_TASK_INACTIVE</code> is set, the created BLT is suspended and enqueued to the specified <i>queue</i> . Otherwise the BLT will schedules the BLTs in <i>queue</i> .
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. The PiP execution mode can also be specified (see below).
in, out	<i>bltp</i>	returns created BLT
in	<i>queue</i>	PiP task queue. See the above <i>opts</i> description.
in	<i>hookp</i>	Hook information to be invoked before and after the program invocation.

## 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>	<i>progp</i> is NULL
<i>EINVAL</i>	<i>opts</i> is invalid and/or unacceptable
<i>EINVAL</i>	the value off <i>pipidp</i> is invalid
<i>EBUSY</i>	specified PiP ID is already occupied
<i>ENOMEM</i>	not enough memory
<i>ENXIO</i>	<i>dlopen</i> failss

## 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()** syscall. 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.

## Note

In theory, there is no reason to restrict for a PiP task to spawn another PiP task. However, the current implementation fails to do so. If the root process is multithreaded, only the main thread can call this function.

## Environment

- **PIP\_MODE** Specifying the PiP execution mode. The value can be one of; 'process', 'process:preload', 'process:got' and 'thread' (or 'pthread').

- **PIP\_STACKSZ** Sepcifying the stack size (in bytes). The **KMP\_STACKSIZE** and **OMP\_STACKSIZE** can also be specified. The 't', 'g', 'm', 'k' and 'b' postfix character can be used.
- **PIP\_STOP\_ON\_START** Specifying the PIP ID to stop on start PiP task program to debug from the beginning. If the before hook is specified, then the PiP task will be stopped just before calling the before hook.
- **PIP\_STACKSZ** Sepcifying the stack size (in bytes). The **KMP\_STACKSIZE** and **OMP\_STACKSIZE** can also be specified. The 't', 'g', 'm', 'k' and 'b' postfix character can be used.

#### 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](#)  
[pip\\_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 \*\*expp, const char \*format,...) `__attribute__((format(printf, 2, 3)))`  
*import the named exported address*
- int int int [pip\\_named\\_tryimport](#) (int pipid, void \*\*expp, const char \*format,...) `__attribute__((format(printf, 2, 3)))`  
*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.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 <code>NULL</code> , then the name is assumed to be "".

##### Returns

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

##### Return values

<i>EPERM</i>	<code>pip_init</code> 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](#)

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

##### Name

`pip_named_import`

##### Synopsis

```
#include <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. The



## 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 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 <code>pipid</code> is invalid
<i>ENOMEM</i>	Not enough memory
<i>ECANCELED</i>	The target task is terminated
<i>EDEADLK</i>	<code>pipid</code> 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.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> .

<i>in</i>	<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.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.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

in	<i>pipid</i>	The PiP ID to import the exported address
out	<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.h>
int pip_set_aux( void *aux );
```

#### Parameters

in	<i>aux</i>	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

<i>EPERM</i>	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.h>
int pip_get_aux( void **auxp );
```

## Parameters

out	<i>auxp</i>	Returned user data
-----	-------------	--------------------

## Returns

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

## Return values

<i>EINAVL</i>	domainp is NULL or auxp is NULL
<i>EPERM</i>	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.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](#)

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

##### Name

`pip_trywait`

##### Synopsis

```
#include <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.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](#)

**3.4.2.3 int pip\_wait\_any ( int \* *pipid*, int \* *status* )****Name**

`pip_wait_any`

**Synopsis**

```
#include <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 value 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](#)

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

## Name

pip\_trywait\_any

## Synopsis

```
#include <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 value 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](#)

## 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.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
--------------	------------------------------------

3.5.2.2 `int pip_is_initialized ( void )`

## Name

`pip_is_initialized`

## Synopsis

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

## Returns

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

3.5.2.3 `int pip_get_ntasks ( int * ntasksp )`

## Name

`pip_get_ntasks`

## Synopsis

```
#include <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
--------------	------------------------------------

3.5.2.4 `int pip_get_mode ( int * modep )`

## Name

`pip_get_mode`

## Synopsis

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

## Parameters

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

## Returns

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

## Return values

<code>EPERM</code>	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.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.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
--------------	--

## 3.5.2.7 int pip\_isa\_root ( void )

## Name

pip\_isa\_root

## Synopsis

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

## Returns

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

## 3.5.2.8 int pip\_isa\_task ( void )

## Name

pip\_isa\_task

## Synopsis

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

## Returns

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

## 3.5.2.9 int pip\_is\_threaded ( int \* flagp )

## Name

pip\_is\_threaded

## Synopsis

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

## Parameters

out	flagp	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

EPERM	The PiP library is not initialized yet
-------	--

## 3.5.2.10 int pip\_is\_shared\_fd ( int \* flagp )

## Name

pip\_is\_shared\_fd

## Synopsis

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

## Parameters

out	flagp	set to a non-zero value if FDs are shared
-----	-------	---

## Returns

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

## Return values

EPERM	The PiP library is not initialized yet
-------	--

## 3.6 Terminating PiP Task

## 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.*

### 3.6.1 Detailed Description

#### 3.6.1.1 Terminating PiP task

## Description

Function to terminate PiP task normally or abnormally (abort).

### 3.6.2 Function Documentation

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

**Name**

pip\_exit

**Synopsis**

```
#include <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**

<i>in</i>	<i>status</i>	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](#)

#### 3.6.2.2 int pip\_kill\_all\_tasks ( void )

**Name**

pip\_kill\_all\_tasks

**Synopsis**

```
#include <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

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

## 3.6.2.3 void pip\_abort ( void )

## Name

pip\_abort

## Synopsis

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

## 3.7 PiP Signaling Functions

## Functions

- int [pip\\_kill](#) (int pipid, int signal)  
*deliver a signal to PiP task*
- 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

Signal manipulating functions. All functions listed here are agnostic to the PiP execution mode.

## 3.7.2 Function Documentation

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

## Name

pip\_kill

## Description

This function is agnostic to the PiP execution mode.

## Synopsis

```
#include <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(Linux 2)

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

## Name

pip\_sigmask

## Synopsis

```
#include <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 2)

3.7.2.3 int pip\_signal\_wait ( int *signal* )

## Name

pip\_signal\_wait

**Synopsis**

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

**Description**

This function is agnostic to the PiP execution mode.

**Parameters**

<i>in</i>	<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 2)  
sigsuspend(Linux 2)



# Chapter 4

## BLT/ULP Functions

### 4.1 Yielding Functionns

#### Functions

- int [pip\\_yield](#) (int flag)  
*Yield.*
- int [pip\\_yield\\_to](#) (pip\_task\_t \*task)  
*Yield to the specified PiP task.*

#### 4.1.1 Detailed Description

##### 4.1.1.1 Yielding functions

#### Description

Yielding execution of the calling BLT/ULP

#### 4.1.2 Function Documentation

##### 4.1.2.1 int [pip\\_yield](#) ( int *flag* )

#### Name

[pip\\_yield](#)

#### Synopsis

```
#include <pip.h>
int pip\_yield( int flag );
```

#### Parameters

<i>in</i>	<i>flag</i>	to specify the behavior of yielding. See below.
-----------	-------------	---

#### Returns

No context-switch takes place during the call, then this returns zero. If the context-switch to the other BLT happens, then this returns `EINTR`.

## Parameters

<i>flag</i>	If <b>PIP_YIELD_USER</b> , the calling task is scheduling PiP task(s) then the calling task switch to the next eligible-to-run BLT. If <b>PIP_YIELD_SYSTEM</b> , regardless if the calling task is active or inactive, it calls <code>sched_yield</code> . If <b>PIP_YIELD_DEFAULT</b> or zero, then both <b>PIP_YIELD_USER</b> and <b>PIP_YIELD_SYSTEM</b> will be effective.
-------------	--

## See Also

[pip\\_yield\\_to](#)

## 4.1.2.2 int pip\_yield\_to ( pip\_task\_t \* task )

## Name

pip\_yield\_to

## Synopsis

```
#include <pip.h>
int pip_yield( pip_task_t *task );
```

## Description

Context-switch to the specified PiP task. If `task` is `NULL`, then this works the same as what `pip_yield(3)` does with `PIP_YIELD_DEFAULT`.

## Parameters

<i>in</i>	<i>task</i>	Target PiP task to switch.
-----------	-------------	----------------------------

## Returns

Return `Zero` or `EINTR` on success. Return an error code on error.

## Return values

<i>EPERM</i>	PiP library is not yet initialized or already
<i>EPERM</i>	The specified task belongs to the other scheduling domain.

## See Also

[pip\\_yield](#)

## 4.2 Task Queue Operations

## Functions

- int [pip\\_task\\_queue\\_init](#) (pip\_task\_queue\_t \*queue, pip\_task\_queue\_methods\_t \*methods)  
*Initialize task queue.*
- int [pip\\_task\\_queue\\_trylock](#) (pip\_task\_queue\_t \*queue)  
*Try locking task queue.*
- void [pip\\_task\\_queue\\_lock](#) (pip\_task\_queue\_t \*queue)  
*Lock task queue.*
- void [pip\\_task\\_queue\\_unlock](#) (pip\_task\_queue\_t \*queue)  
*Unlock task queue.*

- int [pip\\_task\\_queue\\_isempty](#) (pip\_task\_queue\_t \*queue)  
*Query function if the current task has some tasks to be scheduled with.*
- int [pip\\_task\\_queue\\_count](#) (pip\_task\_queue\_t \*queue, int \*np)  
*Count the length of task queue.*
- void [pip\\_task\\_queue\\_enqueue](#) (pip\_task\_queue\_t \*queue, pip\_task\_t \*task)  
*Enqueue a BLT.*
- pip\_task\_t \* [pip\\_task\\_queue\\_dequeue](#) (pip\_task\_queue\_t \*queue)  
*Dequeue a task from a task queue.*
- void [pip\\_task\\_queue\\_describe](#) (pip\_task\_queue\_t \*queue, FILE \*fp)  
*Describe queue.*
- int [pip\\_task\\_queue\\_fin](#) (pip\_task\_queue\_t \*queue)  
*Finalize a task queue.*

## 4.2.1 Detailed Description

### 4.2.1.1 Task queue operations

#### Description

Manipulating ULP/BLT task queue functions

## 4.2.2 Function Documentation

### 4.2.2.1 int pip\_task\_queue\_init ( pip\_task\_queue\_t \* *queue*, pip\_task\_queue\_methods\_t \* *methods* )

#### Name

pip\_task\_queue\_init

#### Synopsis

```
#include <pip.h>
int pip_task_queue_init( pip_task_queue_t *queue, pip_task_queue_methods_t *methods );
```

#### Parameters

in	<i>queue</i>	A task queue
in	<i>methods</i>	Must be set to NULL. Researved for future use.

#### Returns

Always return 0.

### 4.2.2.2 int pip\_task\_queue\_trylock ( pip\_task\_queue\_t \* *queue* )

#### Name

pip\_task\_queue\_trylock

#### Synopsis

```
#include <pip.h>
int pip_task_queue_trylock( pip_task_queue_t *queue );
```

**Parameters**

<i>in</i>	<i>queue</i>	A task queue
-----------	--------------	--------------

**Returns**

Returns a non-zero value if lock succeeds.

**4.2.2.3 void pip\_task\_queue\_lock ( pip\_task\_queue\_t \* *queue* )****Name**

pip\_task\_queue\_lock

**Synopsis**

```
#include <pip.h>
int pip_task_queue_lock( pip_task_queue_t *queue );
```

**Parameters**

<i>in</i>	<i>queue</i>	A task queue
-----------	--------------	--------------

**Returns**

This function returns no error

**4.2.2.4 void pip\_task\_queue\_unlock ( pip\_task\_queue\_t \* *queue* )****Name**

pip\_task\_queue\_unlock

**Synopsis**

```
#include <pip.h>
int pip_task_queue_unlock( pip_task_queue_t *queue );
```

**Parameters**

<i>in</i>	<i>queue</i>	A task queue
-----------	--------------	--------------

**Returns**

This function returns no error

**4.2.2.5 int pip\_task\_queue\_isempty ( pip\_task\_queue\_t \* *queue* )****Name**

pip\_task\_queue\_isempty

**Synopsis**

```
#include <pip.h>
int pip_task_queue_isempty( pip_task_queue_t *queue );
```

## Parameters

in	<i>queue</i>	A task queue
----	--------------	--------------

## Returns

Returns a non-zero value if the queue is empty

4.2.2.6 int pip\_task\_queue\_count( pip\_task\_queue\_t \* *queue*, int \* *np* )

## Name

pip\_task\_queue\_count

## Synopsis

```
#include <pip.h>
int pip_task_queue_count( pip_task_queue_t *queue, int *np );
```

## Parameters

in	<i>queue</i>	A task queue
out	<i>np</i>	the queue length returned

## Returns

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

## Return values

<i>EINVAL</i>	queue is NULL
<i>EINVAL</i>	np is NULL

4.2.2.7 void pip\_task\_queue\_enqueue( pip\_task\_queue\_t \* *queue*, pip\_task\_t \* *task* )

## Name

pip\_task\_queue\_enqueue

## Synopsis

```
#include <pip.h>
void pip_task_queue_enqueue( pip_task_queue_t *queue, pip_task_t *task );
```

## Parameters

in	<i>queue</i>	A task queue
in	<i>task</i>	A task to be enqueued

## Note

It is the user responsibility to lock (and unlock) the queue.

4.2.2.8 pip\_task\_t\* pip\_task\_queue\_dequeue( pip\_task\_queue\_t \* *queue* )

## Name

pip\_task\_queue\_dequeue

**Synopsis**

```
#include <pip.h>
pip_task_t* pip_task_queue_dequeue( pip_task_queue_t *queue );
```

**Parameters**

in	<i>queue</i>	A task queue
----	--------------	--------------

**Returns**

Dequeued task is returned. If the queue is empty then `NULL` is returned.

**Note**

It is the user responsibility to lock (and unlock) the queue.

4.2.2.9 void pip\_task\_queue\_describe ( pip\_task\_queue\_t \* *queue*, FILE \* *fp* )

**Name**

pip\_task\_queue\_describe

**Synopsis**

```
#include <pip.h>
void pip_task_queue_describe( pip_task_queue_t *queue, FILE *fp );
```

**Parameters**

in	<i>queue</i>	A task queue
in	<i>fp</i>	a File pointer

4.2.2.10 int pip\_task\_queue\_fin ( pip\_task\_queue\_t \* *queue* )

**Name**

pip\_task\_queue\_fin

**Synopsis**

```
#include <pip.h>
int pip_task_queue_fin( pip_task_queue_t *queue );
```

**Parameters**

in	<i>queue</i>	A task queue
----	--------------	--------------

**Returns**

Zero is returned always

## 4.3 Suspending and Resuming BLT/ULP

**Functions**

- int [pip\\_suspend\\_and\\_enqueue](#) (pip\_task\_queue\_t \*queue, pip\_enqueue\_callback\_t callback, void \*cbarg)

- suspend the current task and enqueue it with lock*
- int [pip\\_suspend\\_and\\_enqueue\\_nolock](#) (pip\_task\_queue\_t \*queue, pip\_enqueue\_callback\_t callback, void \*cbarg)
- suspend the current task and enqueue it without locking the queue*
- int [pip\\_dequeue\\_and\\_resume](#) (pip\_task\_queue\_t \*queue, pip\_task\_t \*sched)
- dequeue a task and make it runnable*
- int [pip\\_dequeue\\_and\\_resume\\_nolock](#) (pip\_task\_queue\_t \*queue, pip\_task\_t \*sched)
- dequeue a task and make it runnable*
- int [pip\\_dequeue\\_and\\_resume\\_N](#) (pip\_task\_queue\_t \*queue, pip\_task\_t \*sched, int \*np)
- dequeue multiple tasks and resume the execution of them*
- int [pip\\_dequeue\\_and\\_resume\\_N\\_nolock](#) (pip\_task\_queue\_t \*queue, pip\_task\_t \*sched, int \*np)
- dequeue tasks and resume the execution of them*

### 4.3.1 Detailed Description

#### 4.3.1.1 Suspending and resuming BLT/ULP

##### Description

Suspending and resuming BLT/ULP

### 4.3.2 Function Documentation

#### 4.3.2.1 int pip\_suspend\_and\_enqueue ( pip\_task\_queue\_t \* queue, pip\_enqueue\_callback\_t callback, void \* cbarg )

##### Name

pip\_suspend\_and\_enqueue

##### Synopsis

```
#include <pip.h>
int pip_suspend_and_enqueue( pip_task_queue_t *queue, pip_enqueue_callback_t callback, void *cbarg );
```

##### Description

The **queue** is locked just before the calling task is enqueued and unlocked after the calling task is enqueued. After then the **callback** function is called.

As the result of this suspension, a context-switch takes place if there is at least one eligible-to-run task in the scheduling queue (this is hidden from users). If there is no other task to schedule then the kernel thread of the current task will be blocked.

##### Parameters

in	<i>queue</i>	A task queue
in	<i>callback</i>	A callback function which is called immediately after the task is enqueued
in	<i>cbarg</i>	An argument given to the callback function

##### Returns

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

## Return values

<i>EPERM</i>	PiP library is not initialized yet
<i>EINVAL</i>	queue is NULL

## See Also

[pip\\_enqueue\\_and\\_suspend\\_nolock](#)  
[pip\\_dequeue\\_and\\_resume](#)

4.3.2.2 `int pip_suspend_and_enqueue_nolock ( pip_task_queue_t * queue, pip_enqueue_callback_t callback, void * cbarg )`

## Name

`pip_suspend_and_enqueue_nolock`

## Synopsis

```
#include <pip.h>
int pip_suspend_and_enqueue_nolock( pip_task_queue_t *queue, pip_enqueue_callback_t callback, void
*cbarg );
```

## Description

Unlike `pip_suspend_and_enqueue`, this function never locks the queue. It is the user's responsibility to lock the queue before calling this function and unlock the queue after calling this function. The **callback** function can be used for unlocking.

As the result of this suspension, a context-switch takes place if there is at least one eligible-to-run task in the scheduling queue (this is hidden from users). If there is no other task to schedule then the kernel thread of the current task will be blocked.

## Parameters

in	<i>queue</i>	A task queue
in	<i>callback</i>	A callback function which is called when enqueued
in	<i>cbarg</i>	An argument given to the callback function

## Returns

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

## Return values

<i>EPERM</i>	PiP library is not initialized yet
<i>EINVAL</i>	queue is NULL

4.3.2.3 `int pip_dequeue_and_resume ( pip_task_queue_t * queue, pip_task_t * sched )`

## Name

`pip_dequeue_and_resume`

## Description

The **queue** is locked and then unlocked when to dequeued a task.

## Synopsis

```
#include <pip.h>
int pip_dequeue_and_resume( pip_task_queue_t *queue, pip_task_t *sched );
```



## Parameters

in	<i>queue</i>	A task queue
in	<i>sched</i>	A task to specify a scheduling domain

## Returns

If succeedss, 0 is returned. Otherwise an error code is returned.

## Return values

<i>EPERM</i>	PiP library is not initialized yet
<i>EINVAL</i>	queue is NULL
<i>ENOENT</i>	queue is empty.

## 4.3.2.4 int pip\_dequeue\_and\_resume\_nolock ( pip\_task\_queue\_t \* queue, pip\_task\_t \* sched )

## Name

pip\_dequeue\_and\_resume\_nolock

## Synopsis

```
#include <pip.h>
int pip_dequeue_and_resume( pip_task_queue_t *queue, pip_task_t *sched );
```

## Description

Task in the queue is dequeued and scheduled by the specified *sched*. If *sched* is NULL, then the task is enqueued into the scheduling queue of calling task.

It is the user's responsibility to lock the queue beofre calling this function and unlock the queue after calling this function.

## Parameters

in	<i>queue</i>	A task queue
in	<i>sched</i>	A task to specify a scheduling domain

## Returns

This function returns no error

## Return values

<i>EPERM</i>	PiP library is not initialized yet
<i>EINVAL</i>	queue is NULL
<i>ENOENT</i>	queue is empty.

## 4.3.2.5 int pip\_dequeue\_and\_resume\_N ( pip\_task\_queue\_t \* queue, pip\_task\_t \* sched, int \* np )

## Name

pip\_dequeue\_and\_resume\_N

## Synopsis

```
#include <pip.h>
int pip_dequeue_and_resume_N( pip_task_queue_t *queue, pip_task_t *sched, int *np );
```

**Description**

The specified number of tasks are dequeued and scheduled by the specified *sched*. If *sched* is NULL, then the task is enqueued into the scheduling queue of calling task.

The **queue** is locked and unlocked when dequeued.

**Parameters**

in	<i>queue</i>	A task queue
in	<i>sched</i>	A task to specify a scheduling domain
in, out	<i>np</i>	A pointer to an interger which spcifies the number of tasks dequeued and actual number of tasks dequeued is returned. When PIP_TASK_ALL is specified, then all tasks in the queue will be resumed.

**Returns**

This function returns no error

**Return values**

<i>EPERM</i>	PiP library is not initialized yet
<i>EINVAL</i>	<i>queue</i> is NULL
<i>EINVAL</i>	the specified number of tasks is invalid
<i>ENOENT</i>	<i>queue</i> is empty.

It is the user's responsibility to lock the queue beofre calling this function and unlock the queue after calling this function.

4.3.2.6 `int pip_dequeue_and_resume_N_nolock ( pip_task_queue_t * queue, pip_task_t * sched, int * np )`

**Name**

`pip_dequeue_and_resume_N_nolock`

**Synopsis**

```
#include <pip.h>
int pip_dequeue_and_resume_N_nolock( pip_task_queue_t *queue, pip_task_t *sched, int *np );
```

**Description**

The specified number of tasks are dequeued and scheduled by the specified *sched*. If *sched* is NULL, then the task is enqueued into the scheduling queue of calling task.

It is the user's responsibility to lock the queue beofre calling this function and unlock the queue after calling this function.

**Parameters**

in	<i>queue</i>	A task queue
in	<i>sched</i>	A task to specify a scheduling domain
in, out	<i>np</i>	A pointer to an interger which spcifies the number of tasks dequeued and actual number of tasks dequeued is returned. When PIP_TASK_ALL is specified, then all tasks in the queue will be resumed.

**Returns**

This function returns no error

## Return values

<i>EPERM</i>	PiP library is not initialized yet
<i>EINVAL</i>	queue is NULL
<i>EINVAL</i>	the specified number of tasks is invalid
<i>ENOENT</i>	queue is empty.

## 4.4 BLT/ULP Miscellaneous Function

### Functions

- `pip_task_t * pip_task_self (void)`  
*Return the current task.*
- `int pip_get_task_pipid (pip_task_t *task, int *pipidp)`  
*Return PIPID of a PiP task.*
- `int pip_get_task_by_pipid (int pipid, pip_task_t **taskp)`  
*get PiP task from PiP ID*
- `int pip_get_sched_domain (pip_task_t **domainp)`  
*Return the task representing the scheduling domain.*

### 4.4.1 Detailed Description

#### 4.4.1.1 BLT/ULP miscellaneous function

##### Description

BLT/ULP miscellaneous function

### 4.4.2 Function Documentation

#### 4.4.2.1 `pip_task_t* pip_task_self ( void )`

##### Name

`pip_task_self`

##### Synopsis

```
#include <pip.h>
pip_task_t *pip_task_self( void );
```

##### Returns

Return the current task.

#### 4.4.2.2 `int pip_get_task_pipid ( pip_task_t * task, int * pipidp )`

##### Name

`pip_get_task_pipid`

##### Synopsis

```
#include <pip.h>
int pip_get_task_pipid( pip_task_t *task, int *pipidp );
```

**Parameters**

in	<i>task</i>	a PiP task
out	<i>pipidp</i>	PiP ID of the specified task

**Returns**

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

**Return values**

<i>EINAVL</i>	<i>task</i> is NULL
<i>EPERM</i>	PiP library is not yet initialized or already finalized

#### 4.4.2.3 int pip\_get\_task\_by\_pipid ( int *pipid*, pip\_task\_t \*\* *taskp* )

**Name**

pip\_get\_task\_by\_pipid

**Synopsis**

```
#include <pip.h>
int pip_get_task_by_pipid( int pipid, pip_task_t **taskp );
```

**Parameters**

in	<i>pipid</i>	PiP ID
out	<i>taskp</i>	returning PiP task of the specified PiP ID

**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>ENOENT</i>	No such PiP task
<i>ERANGE</i>	The specified <i>pipid</i> is out of range

#### 4.4.2.4 int pip\_get\_sched\_domain ( pip\_task\_t \*\* *domainp* )

**Name**

pip\_get\_sched\_domain

**Synopsis**

```
#include <pip.h>
int pip_get_sched_domain( pip_task_t **domainp );
```

**Parameters**

out	<i>domainp</i>	Returned scheduling domain of the current task
-----	----------------	--

**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
--------------	---

## 4.5 BLT/ULP Barrier Functions

### Functions

- 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\\_wait](#)( pip\_barrier\_t \*barrp );*
- int [pip\\_barrier\\_fin](#) (pip\_barrier\_t \*barrp)  
*finalize barrier synchronization structure*

### 4.5.1 Detailed Description

#### 4.5.1.1 BLT/ULP barrier synchronization functions

##### Description

BLT/ULP barrier synchronization functions

##### Description

BLT/ULP mutex functions

### 4.5.2 Function Documentation

#### 4.5.2.1 int pip\_barrier\_init ( pip\_barrier\_t \* barrp, int n )

##### Name

pip\_barrier\_init

##### Synopsis

```
#include <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

**Note**

This barrier works on PiP tasks only.

**See Also**

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

**4.5.2.2 int pip\_barrier\_wait ( pip\_barrier\_t \* barrp )****Name**

pip\_barrier\_wait

**Synopsis**

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

**Parameters**

<i>in</i>	<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](#)

**4.5.2.3 int pip\_barrier\_fin ( pip\_barrier\_t \* barrp )****Name**

pip\_barrier\_fin

**Synopsis**

```
#include <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](#)

## 4.6 BLT/ULP Mutex Functions

**Functions**

- int [pip\\_mutex\\_init](#) (pip\_mutex\_t \*mutex)  
*Initialize PiP mutex.*
- int [pip\\_mutex\\_lock](#) (pip\_mutex\_t \*mutex)  
*Lock PiP mutex.*
- int [pip\\_mutex\\_unlock](#) (pip\_mutex\_t \*mutex)  
*Unlock PiP mutex.*
- int [pip\\_mutex\\_fin](#) (pip\_mutex\_t \*mutex)  
*Finalize PiP mutex.*

### 4.6.1 Detailed Description

### 4.6.2 Function Documentation

#### 4.6.2.1 int pip\_mutex\_init ( pip\_mutex\_t \* mutex )

**Name**

`pip_mutex_init`

**Synopsis**

```
#include <pip.h>
int pip_mutex_init( pip_mutex_t *mutex );
```

**Parameters**

<code>in, out</code>	<code>mutex</code>	pointer to the PiP task mutex
----------------------	--------------------	-------------------------------

**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\\_mutex\\_lock](#)  
[pip\\_mutex\\_unlock](#)  
[pip\\_mutex\\_fin](#)

## 4.6.2.2 int pip\_mutex\_lock ( pip\_mutex\_t \* mutex )

## Name

pip\_mutex\_lock

## Synopsis

```
#include <pip.h>
int pip_mutex_lock( pip_mutex_t *mutex );
```

## Parameters

in	<i>mutex</i>	pointer to the PiP task mutex
----	--------------	-------------------------------

## 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\\_mutex\\_init](#)  
[pip\\_mutex\\_unlock](#)  
[pip\\_mutex\\_fin](#)

## 4.6.2.3 int pip\_mutex\_unlock ( pip\_mutex\_t \* mutex )

## Name

pip\_mutex\_unlock

## Synopsis

```
#include <pip.h>
int pip_mutex_unlock( pip_mutex_t *mutex );
```

## Parameters

in	<i>mutex</i>	pointer to the PiP task mutex
----	--------------	-------------------------------

## 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\\_mutex\\_init](#)  
[pip\\_mutex\\_lock](#)  
[pip\\_mutex\\_fin](#)

## 4.6.2.4 int pip\_mutex\_fin ( pip\_mutex\_t \* mutex )

## Name

pip\_mutex\_fin

## Synopsis

```
#include <pip.h>
int pip_mutex_fin( pip_mutex_t *mutex );
```

## Parameters

<i>in, out</i>	<i>mutex</i>	pointer to the PiP task mutex
----------------	--------------	-------------------------------

## 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>EBUSY</i>	There is one or more waiting PiP task

## See Also

[pip\\_mutex\\_lock](#)  
[pip\\_mutex\\_unlock](#)

## 4.7 BLT/ULP Coupling/Decoupling Functions

### Functions

- int [pip\\_couple](#) (void)  
*Couple the curren task with the original kernel thread.*
- int [pip\\_decouple](#) (pip\_task\_t \*task)  
*Decouple the curren task from the kernel thread.*

### 4.7.1 Detailed Description

#### 4.7.1.1 BLT/ULP coupling/decoupling functions

## Description

BLT/ULP coupling/decoupling functions

## 4.7.2 Function Documentation

### 4.7.2.1 int pip\_couple ( void )

#### Name

pip\_couple

#### Synopsis

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

#### 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>EBUSY</i>	the current task is already coupled with a kernel thread

### 4.7.2.2 int pip\_decouple ( pip\_task\_t \* task )

#### Name

pip\_decouple

#### Synopsis

```
#include <pip.h>
int pip_decouple( pip_task_t *sched )
```

#### Parameters

in	task	specify the scheduling task to schedule the decoupled task (calling this function). If <code>NULL</code> , then the previously coupled pip_task takes place.
----	------	--

#### 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>EBUSY</i>	the current task is already decoupled from a kernel thread

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