



Processs-in-Process (PiP)

3.0.0

Refernce Manual

September 29, 2020

Generated by Doxygen 1.8.5

Contents

1	Proces-in-Process (PiP) Overview	1
2	PiP Commands	11
2.1	pipcc	11
2.2	pip-check	11
2.3	pip-exec	12
2.4	pip-man	12
2.5	pip-mode	12
2.6	pips	13
2.7	printpipmode	13
3	PiP Functions	15
3.1	PiP Initialization/Finalization	15
3.1.1	Detailed Description	15
3.1.1.1	PiP Initialization/Finalization	15
3.1.2	Function Documentation	15
3.1.2.1	pip_init	15
3.1.2.2	pip_fin	17
3.2	Spawning PiP task	18
3.2.1	Detailed Description	18
3.2.1.1	PiP Spawng PiP (ULP/BLT) task	18
3.2.2	Function Documentation	18
3.2.2.1	pip_spawn_from_main	18
3.2.2.2	pip_spawn_from_func	19
3.2.2.3	pip_spawn_hook	19
3.2.2.4	pip_task_spawn	20
3.2.2.5	pip_spawn	21
3.2.2.6	pip_blt_spawn	23
3.3	Export/Import Functions	25
3.3.1	Detailed Description	25
3.3.1.1	PiP Export and Import	25
3.3.2	Function Documentation	25
3.3.2.1	pip_named_export	25
3.3.2.2	pip_named_import	26
3.3.2.3	pip_named_tryimport	27
3.3.2.4	pip_export	28
3.3.2.5	pip_import	28
3.4	Waiting for PiP task termination	29
3.4.1	Detailed Description	29
3.4.1.1	Waiting for PiP task termination	29
3.4.2	Function Documentation	29
3.4.2.1	pip_wait	29
3.4.2.2	pip_trywait	30
3.4.2.3	pip_wait_any	31
3.4.2.4	pip_trywait_any	31
3.5	PiP Query Functions	32

3.5.1	Detailed Description	33
3.5.1.1	PiP query functions	33
3.5.2	Function Documentation	33
3.5.2.1	pip_get_pipid	33
3.5.2.2	pip_is_initialized	33
3.5.2.3	pip_get_ntasks	33
3.5.2.4	pip_get_mode	34
3.5.2.5	pip_get_mode_str	34
3.5.2.6	pip_get_system_id	35
3.5.2.7	pip_isa_root	35
3.5.2.8	pip_isa_task	35
3.5.2.9	pip_is_threaded	36
3.5.2.10	pip_is_shared_fd	36
3.6	Terminating PiP Task	36
3.6.1	Detailed Description	37
3.6.1.1	Terminating PiP task	37
3.6.2	Function Documentation	37
3.6.2.1	pip_exit	37
3.6.2.2	pip_kill_all_tasks	37
3.6.2.3	pip_abort	38
3.7	PiP Signaling Functions	38
3.7.1	Detailed Description	38
3.7.1.1	PiP signaling functions	38
3.7.2	Function Documentation	38
3.7.2.1	pip_kill	38
3.7.2.2	pip_sigmask	39
3.7.2.3	pip_signal_wait	39
4	BLT/ULP Functions	41
4.1	Yielding Functionns	41
4.1.1	Detailed Description	41
4.1.1.1	Yielding functions	41
4.1.2	Function Documentation	41
4.1.2.1	pip_yield	41
4.1.2.2	pip_yield_to	42
4.2	Task Queue Operations	42
4.2.1	Detailed Description	43
4.2.1.1	Task queue operations	43
4.2.2	Function Documentation	43
4.2.2.1	pip_task_queue_init	43
4.2.2.2	pip_task_queue_trylock	43
4.2.2.3	pip_task_queue_lock	44
4.2.2.4	pip_task_queue_unlock	44
4.2.2.5	pip_task_queue_isempty	44
4.2.2.6	pip_task_queue_count	45
4.2.2.7	pip_task_queue_enqueue	45
4.2.2.8	pip_task_queue_dequeue	45
4.2.2.9	pip_task_queue_describe	46
4.2.2.10	pip_task_queue_fin	46
4.3	Suspending and Resuming BLT/ULP	46
4.3.1	Detailed Description	47
4.3.1.1	Suspending and resuming BLT/ULP	47
4.3.2	Function Documentation	47
4.3.2.1	pip_suspend_and_enqueue	47
4.3.2.2	pip_suspend_and_enqueue_nolock	48
4.3.2.3	pip_dequeue_and_resume	48
4.3.2.4	pip_dequeue_and_resume_nolock	49
4.3.2.5	pip_dequeue_and_resume_N	49

4.3.2.6	pip_dequeue_and_resume_N_nolock	50
4.4	BLT/ULP Miscellaneous Function	51
4.4.1	Detailed Description	51
4.4.1.1	BLT/ULP miscellaneous function	51
4.4.2	Function Documentation	51
4.4.2.1	pip_task_self	51
4.4.2.2	pip_get_task_pipid	52
4.4.2.3	pip_get_task_by_pipid	52
4.4.2.4	pip_set_aux	52
4.4.2.5	pip_get_aux	53
4.4.2.6	pip_get_sched_domain	53
4.5	BLT/ULP Barrier Functions	54
4.5.1	Detailed Description	54
4.5.1.1	BLT/ULP barrier synchronization functions	54
4.5.2	Function Documentation	54
4.5.2.1	pip_barrier_init	54
4.5.2.2	pip_barrier_wait	55
4.5.2.3	pip_barrier_fin	55
4.6	BLT/ULP Mutex Functions	56
4.6.1	Detailed Description	56
4.6.2	Function Documentation	56
4.6.2.1	pip_mutex_init	56
4.6.2.2	pip_mutex_lock	57
4.6.2.3	pip_mutex_unlock	57
4.6.2.4	pip_mutex_fin	58
4.7	BLT/ULP Coupling/Decoupling Functions	58
4.7.1	Detailed Description	58
4.7.1.1	BLT/ULP coupling/decoupling functions	58
4.7.2	Function Documentation	59
4.7.2.1	pip_couple	59
4.7.2.2	pip_decouple	59

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

In this document, **N** 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 ULT 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 ULT 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 `"(p)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:pipeclone"` 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:pipeclone"` 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

This package is licensed under the 2-clause simplified BSD License - see the LICENSE file for details.

Installation

There are several ways to install PiP; Docker, Spack, RPM, and building from the source code.

Docker image

Download and run the PiP Docker image.

```
$ docker pull rikenpip/pip-vN
$ sudo docker run -it rikenpip/pip-vN /bin/bash
```

Spack

Download spack and do the following;

```
$ git clone https://github.com/spack/spack.git
$ cd spack/bin
$ spack install process-in-process
```


Installation from RPMs

RPM packages and their yum repository are also available for CentOS 7 / RHEL7.

```
$ sudo rpm -Uvh https://git.sys.r-ccs.riken.jp/PiP/package/el/7/noarch/pip-1/pip-release-N-0.noarch.rpm
$ sudo yum install pip-glibc
$ sudo yum install pip pip-debuginfo
$ sudo yum install pip-gdb
```

If PiP packages are installed by the above RPMs, **PIP_INSTALL_DIR** will be `"/usr."`

Source Code

The installation of PiP related packages must follow the order below;

1. Build PiP-glibc (optional)
2. Build PiP
3. Build PiP-gdb (optional)

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. Above Docker image and Spack include PiP-glibc and PiP-gdb.

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

Before installing PiP, we strongly recommend you to install PiP-glibc.

After installing PiP, PiP-gdb can be installed too.

Installation from the source code.

1. Building PiP-glibc (optional)

Fetch source tree (CentOS7 or RHEL7):

```
$ git clone -b pip-centos7 git@git.sys.aics.riken.jp:software/PIP-glibc
```

Fetch source tree (CentOS8 or RHEL8):

```
$ git clone -b pip-centos8 git@git.sys.aics.riken.jp:software/PIP-glibc
```

Build PiP-glibc

```
$ mkdir GLIBC_BUILD_DIR $ cd GLIBC_BUILD_DIR $ GLIBC_SRC_DIR/build.sh --prefix=GLIBC_INSTALL_DIR
```

2. Build PiP library

The same source code can be used for CentOS7 and CentOS8 (RHEL7 and RHEL8).

```
$ git clone -b pip-N git@git.sys.aics.riken.jp:software/PiP $ cd PIP_SRC_DIR $ ./configure --prefix=PIP_INSTALL_DIR [ --with-glibc-libdir=GLIBC_INSTALL_DIR/lib ] $ make install doc
```

If you want to make sure if the PiP library is correctly installed, then do the following;

```
$ cd PIP_SRC_DIR $ make check-installed
```

3. Build PiP-gdb (optional)

Fetch source tree; CentOS7 or RHEL7

```
$ git clone -b pip-centos7 git@git.sys.aics.riken.jp:software/PIP-gdb
```

CentOS8 or RHEL8

```
$ git clone -b pip-centos8 git@git.sys.aics.riken.jp:software/PIP-gdb
```

Build PiP-gdb

```
$ cd GDB_SRC_DIR $ ./build.sh --prefix=GDB_INSTALL_DIR --with-pip=PIP_INSTALL_DIR
```

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

pip@ml.riken.jp

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`

Author

Atsushi Hori

Riken Center for Computational Science (R-CCS)

Japan

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

```
pipcheck [ 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
<i>-v</i>	show reason
<i>-h</i>	show this message

See Also

pipcc(1)

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(1)

2.6 pips

List or kill running PiP tasks

Synopsis

```
pips [ OPTION ] [ PIP-PROG-NAME ...]
```

Description

The following options are available.

Parameters

<code>-s SIGNAL</code>	Send the specified signal to the specified PiP tasks
<code>-k</code>	Same as 'pips -s TERM'
<code>-l</code>	List (ps command) running PiP tasks specified. This is the default action.
<code>--list</code>	Same as 'pips -l'
<code>-t</code>	Show running PiP tasks specified by using the top command.
<code>-v</code>	Verbose mode
<code>--top</code>	Same as 'pip -t'

See Also

ps(1), top(1)

2.7 printpipmode

Print current PiP mode

Synopsis

```
printpipmode
```

See Also

pip-mode(1)

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 pip_fin .
<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)
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)
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*)

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 )
```

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

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)`

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 );
```

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

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>	pip_spawn_program_t
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
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>	<i>progp</i> is NULL
<i>EINVAL</i>	<i>opts</i> is invalid and/or unacceptable
<i>EINVAL</i>	the value of <i>pipidp</i> is invalid
<i>EINVAL</i>	the <i>coreno</i> 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>	dlopen 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_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 of <i>pipidp</i> is invalid
<i>EINVAL</i>	the <i>coreno</i> 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>	<i>dlmopen</i> 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](#)
[pip_bltp_spawn](#)

```
3.2.2.6 int pip_bltp_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_bltp_spawn

Synopsis

```
#include <pip.h>
int pip_bltp_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>	pip_spawn_program_t
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. If <code>PIP_TASK_INACTIVE</code> is set, the created BLT is suspended and enqueued to the specified <code>queue</code> . Otherwise the BLT will schedules the BLTs in <code>queue</code> .
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 <code>opts</code> 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>	progp is NULL
<i>EINVAL</i>	opts is invalid and/or unacceptable
<i>EINVAL</i>	the value off pipidp is invalid
<i>EBUSY</i>	specified PiP ID is already occupied
<i>ENOMEM</i>	not enough memory
<i>ENXIO</i>	dlopen 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 GOT entry of the **clone()** syscall. One of the option flag values; **PIP_MODE_PTHREAD**, **PIP_MODE_PROCESS**, **PIP_MODE_PROCESS_PRELOAD**, **PIP_MODE_PROCESS_PICLONE**, or b **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, 3, 4)))`
import the named exported address
- int int int `pip_named_tryimport` (int pipid, void **expp, 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

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 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>	<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 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> .
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 <i>pipid</i> 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

in	exp	An addresss
----	-----	-------------

Returns

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

Return values

EPERM	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 ** exp)

Name

pip_import

Synopsis

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

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	pipid	The PiP ID to import the exportedaddress
out	exp	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](#)

3.4 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 <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_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 <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_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 *pipid)
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

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.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 to 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	<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
--------------	--

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

Returns

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

Return values

<i>EPERM</i>	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

in	<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 sigprocmask or pthread_sigmask
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 PIP_YIELD_USER , the calling task is scheduling PiP task(s) then the calling task switch to the next eligible-to-run BLT. If PIP_YIELD_SYSTEM , regardless if the calling task is active or inactive, it calls <code>sched_yield</code> . If PIP_YIELD_DEFAULT or zero, then both PIP_YIELD_USER and PIP_YIELD_SYSTEM 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_ismpty](#) (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_set_aux` (pip_task_t *task, void *aux)
Associate user data with a PiP task.
- `int pip_get_aux` (pip_task_t *task, void **auxp)
Retrieve the user data associated with a PiP task.
- `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>	task 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_set_aux (pip_task_t * task, void * aux)

Name

pip_set_aux

Synopsis

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

Parameters

in	<i>task</i>	PiP task. If NULL, then the data is associated with the current PiP task
in	<i>aux</i>	Pointer to the user dat to associate with

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](#)

4.4.2.5 int pip_get_aux (pip_task_t * task, void ** auxp)

Name

pip_get_aux

Synopsis

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

Parameters

in	<i>task</i>	PiP task. If NULL, then the data is associated with the current PiP task
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](#)

4.4.2.6 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	domainp	Returned scheduling domain of the current task
-----	---------	--

Returns

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

Return values

EPERM	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	barrp	pointer to a PiP barrier structure
----	-------	------------------------------------

<code>in</code>	<code>n</code>	number of participants of this barrier synchronization
-----------------	----------------	--

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>EINAVL</code>	<code>n</code> 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

<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
--------------------	---

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

Index

BLT/ULP Barrier Functions, 54

- pip_barrier_fin, 55
- pip_barrier_init, 54
- pip_barrier_wait, 55

BLT/ULP Coupling/Decoupling Functions, 58

- pip_couple, 59
- pip_decouple, 59

BLT/ULP Miscellaneous Function, 51

- pip_get_aux, 53
- pip_get_sched_domain, 53
- pip_get_task_by_pipid, 52
- pip_get_task_pipid, 51
- pip_set_aux, 52
- pip_task_self, 51

BLT/ULP Mutex Functions, 56

- pip_mutex_fin, 58
- pip_mutex_init, 56
- pip_mutex_lock, 57
- pip_mutex_unlock, 57

Export/Import Functions, 25

- pip_export, 27
- pip_import, 28
- pip_named_export, 25
- pip_named_import, 26
- pip_named_tryimport, 27

PiP Initialization/Finalization, 15

- pip_fin, 17
- pip_init, 15

PiP Query Functions, 32

- pip_get_mode, 34
- pip_get_mode_str, 34
- pip_get_ntasks, 33
- pip_get_pipid, 33
- pip_get_system_id, 34
- pip_is_initialized, 33
- pip_is_shared_fd, 36
- pip_is_threaded, 35
- pip_isa_root, 35
- pip_isa_task, 35

PiP Signaling Functions, 38

- pip_kill, 38
- pip_sigmask, 39
- pip_signal_wait, 39

pip_abort

- Terminating PiP Task, 38

pip_barrier_fin

- BLT/ULP Barrier Functions, 55

pip_barrier_init

BLT/ULP Barrier Functions, 54

pip_barrier_wait

- BLT/ULP Barrier Functions, 55

pip_blt_spawn

- Spawning PiP task, 23

pip_couple

- BLT/ULP Coupling/Decoupling Functions, 59

pip_decouple

- BLT/ULP Coupling/Decoupling Functions, 59

pip_dequeue_and_resume

- Suspending and Resuming BLT/ULP, 48

pip_dequeue_and_resume_N

- Suspending and Resuming BLT/ULP, 49

pip_dequeue_and_resume_N_nolock

- Suspending and Resuming BLT/ULP, 50

pip_dequeue_and_resume_nolock

- Suspending and Resuming BLT/ULP, 49

pip_exit

- Terminating PiP Task, 37

pip_export

- Export/Import Functions, 27

pip_fin

- PiP Initialization/Finalization, 17

pip_get_aux

- BLT/ULP Miscellaneous Function, 53

pip_get_mode

- PiP Query Functions, 34

pip_get_mode_str

- PiP Query Functions, 34

pip_get_ntasks

- PiP Query Functions, 33

pip_get_pipid

- PiP Query Functions, 33

pip_get_sched_domain

- BLT/ULP Miscellaneous Function, 53

pip_get_system_id

- PiP Query Functions, 34

pip_get_task_by_pipid

- BLT/ULP Miscellaneous Function, 52

pip_get_task_pipid

- BLT/ULP Miscellaneous Function, 51

pip_import

- Export/Import Functions, 28

pip_init

- PiP Initialization/Finalization, 15

pip_is_initialized

- PiP Query Functions, 33

pip_is_shared_fd

- PiP Query Functions, 36

- pip_is_threaded
 - PiP Query Functions, [35](#)
- pip_isa_root
 - PiP Query Functions, [35](#)
- pip_isa_task
 - PiP Query Functions, [35](#)
- pip_kill
 - PiP Signaling Functions, [38](#)
- pip_kill_all_tasks
 - Terminating PiP Task, [37](#)
- pip_mutex_fin
 - BLT/ULP Mutex Functions, [58](#)
- pip_mutex_init
 - BLT/ULP Mutex Functions, [56](#)
- pip_mutex_lock
 - BLT/ULP Mutex Functions, [57](#)
- pip_mutex_unlock
 - BLT/ULP Mutex Functions, [57](#)
- pip_named_export
 - Export/Import Functions, [25](#)
- pip_named_import
 - Export/Import Functions, [26](#)
- pip_named_tryimport
 - Export/Import Functions, [27](#)
- pip_set_aux
 - BLT/ULP Miscellaneous Function, [52](#)
- pip_sigmask
 - PiP Signaling Functions, [39](#)
- pip_signal_wait
 - PiP Signaling Functions, [39](#)
- pip_spawn
 - Spawning PiP task, [21](#)
- pip_spawn_from_func
 - Spawning PiP task, [19](#)
- pip_spawn_from_main
 - Spawning PiP task, [18](#)
- pip_spawn_hook
 - Spawning PiP task, [19](#)
- pip_suspend_and_enqueue
 - Suspending and Resuming BLT/ULP, [47](#)
- pip_suspend_and_enqueue_nolock
 - Suspending and Resuming BLT/ULP, [48](#)
- pip_task_queue_count
 - Task Queue Operations, [45](#)
- pip_task_queue_dequeue
 - Task Queue Operations, [45](#)
- pip_task_queue_describe
 - Task Queue Operations, [46](#)
- pip_task_queue_enqueue
 - Task Queue Operations, [45](#)
- pip_task_queue_fin
 - Task Queue Operations, [46](#)
- pip_task_queue_init
 - Task Queue Operations, [43](#)
- pip_task_queue_isempty
 - Task Queue Operations, [44](#)
- pip_task_queue_lock
 - Task Queue Operations, [44](#)
- pip_task_queue_trylock
 - Task Queue Operations, [43](#)
- pip_task_queue_unlock
 - Task Queue Operations, [44](#)
- pip_task_self
 - BLT/ULP Miscellaneous Function, [51](#)
- pip_task_spawn
 - Spawning PiP task, [20](#)
- pip_trywait
 - Waiting for PiP task termination, [30](#)
- pip_trywait_any
 - Waiting for PiP task termination, [31](#)
- pip_wait
 - Waiting for PiP task termination, [29](#)
- pip_wait_any
 - Waiting for PiP task termination, [31](#)
- pip_yield
 - Yielding Functionns, [41](#)
- pip_yield_to
 - Yielding Functionns, [42](#)
- pip_abort, [38](#)
- pip_barrier_fin, [55](#)
- pip_barrier_init, [54](#)
- pip_barrier_wait, [55](#)
- pip_blt_spawn, [23](#)
- pip_couple, [59](#)
- pip_decouple, [59](#)
- pip_dequeue_and_resume, [48](#)
- pip_dequeue_and_resume_N, [49](#)
- pip_dequeue_and_resume_N_nolock, [50](#)
- pip_dequeue_and_resume_nolock, [49](#)
- pip_exit, [37](#)
- pip_export, [28](#)
- pip_fin, [17](#)
- pip_get_aux, [53](#)
- pip_get_mode, [34](#)
- pip_get_mode_str, [34](#)
- pip_get_ntasks, [33](#)
- pip_get_pipid, [33](#)
- pip_get_sched_domain, [53](#)
- pip_get_system_id, [35](#)
- pip_get_task_by_pipid, [52](#)
- pip_get_task_pipid, [52](#)
- pip_import, [28](#)
- pip_init, [15](#)
- pip_is_initialized, [33](#)
- pip_is_shared_fd, [36](#)
- pip_is_threaded, [36](#)
- pip_isa_root, [35](#)
- pip_isa_task, [35](#)
- pip_kill, [38](#)
- pip_kill_all_tasks, [37](#)
- pip_mutex_fin, [58](#)
- pip_mutex_init, [56](#)
- pip_mutex_lock, [57](#)
- pip_mutex_unlock, [57](#)
- pip_named_export, [25](#)
- pip_named_import, [26](#)

- [pip_named_tryimport, 27](#)
 - [pip_set_aux, 52](#)
 - [pip_sigmask, 39](#)
 - [pip_signal_wait, 39](#)
 - [pip_spawn, 21](#)
 - [pip_spawn_from_func, 19](#)
 - [pip_spawn_from_main, 18](#)
 - [pip_spawn_hook, 19](#)
 - [pip_suspend_and_enqueue, 47](#)
 - [pip_suspend_and_enqueue_nolock, 48](#)
 - [pip_task_queue_count, 45](#)
 - [pip_task_queue_dequeue, 45](#)
 - [pip_task_queue_describe, 46](#)
 - [pip_task_queue_enqueue, 45](#)
 - [pip_task_queue_fin, 46](#)
 - [pip_task_queue_init, 43](#)
 - [pip_task_queue_isempty, 44](#)
 - [pip_task_queue_lock, 44](#)
 - [pip_task_queue_trylock, 43](#)
 - [pip_task_queue_unlock, 44](#)
 - [pip_task_self, 51](#)
 - [pip_task_spawn, 20](#)
 - [pip_trywait, 30](#)
 - [pip_trywait_any, 31](#)
 - [pip_wait, 29](#)
 - [pip_wait_any, 31](#)
 - [pip_yield, 41](#)
 - [pip_yield_to, 42](#)
- Spawning PiP task, [18](#)
 - [pip_blt_spawn, 23](#)
 - [pip_spawn, 21](#)
 - [pip_spawn_from_func, 19](#)
 - [pip_spawn_from_main, 18](#)
 - [pip_spawn_hook, 19](#)
 - [pip_task_spawn, 20](#)
- Suspending and Resuming BLT/ULP, [46](#)
 - [pip_dequeue_and_resume, 48](#)
 - [pip_dequeue_and_resume_N, 49](#)
 - [pip_dequeue_and_resume_N_nolock, 50](#)
 - [pip_dequeue_and_resume_nolock, 49](#)
 - [pip_suspend_and_enqueue, 47](#)
 - [pip_suspend_and_enqueue_nolock, 48](#)
- Task Queue Operations, [42](#)
 - [pip_task_queue_count, 45](#)
 - [pip_task_queue_dequeue, 45](#)
 - [pip_task_queue_describe, 46](#)
 - [pip_task_queue_enqueue, 45](#)
 - [pip_task_queue_fin, 46](#)
 - [pip_task_queue_init, 43](#)
 - [pip_task_queue_isempty, 44](#)
 - [pip_task_queue_lock, 44](#)
 - [pip_task_queue_trylock, 43](#)
 - [pip_task_queue_unlock, 44](#)
- Terminating PiP Task, [36](#)
 - [pip_abort, 38](#)
 - [pip_exit, 37](#)
 - [pip_kill_all_tasks, 37](#)
- Waiting for PiP task termination, [29](#)
 - [pip_trywait, 30](#)
 - [pip_trywait_any, 31](#)
 - [pip_wait, 29](#)
 - [pip_wait_any, 31](#)
- Yielding Functionns, [41](#)
 - [pip_yield, 41](#)
 - [pip_yield_to, 42](#)