

Jinue

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Chapter 1

Data Structure Index

1.1 Data Structures

Here are the data structures with brief descriptions:

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Chapter 2

File Index

2.1 File List

Here is a list of all files with brief descriptions:

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Chapter 3

Data Structure Documentation

3.1 `boot_t` Struct Reference

```
#include <boot.h>
```

3.1.1 Detailed Description

Definition at line 26 of file `boot.h`.

Data Fields

- unsigned long **magic**
- unsigned char **setup_sects**
- unsigned short **root_flags**
- unsigned long **sysize**
- unsigned short **ram_size**
- unsigned short **vid_mode**
- unsigned short **root_dev**
- unsigned short **signature**

3.1.2 Field Documentation

3.1.2.1 unsigned long `boot_t::magic`

Definition at line 27 of file `boot.h`.

Referenced by `get__boot__data()`.

3.1.2.2 unsigned char boot__t::setup_sects

Definition at line 28 of file `boot.h`.

3.1.2.3 unsigned short boot__t::root_flags

Definition at line 29 of file `boot.h`.

3.1.2.4 unsigned long boot__t::sysize

Definition at line 30 of file `boot.h`.

3.1.2.5 unsigned short boot__t::ram_size

Definition at line 31 of file `boot.h`.

3.1.2.6 unsigned short boot__t::vid_mode

Definition at line 32 of file `boot.h`.

3.1.2.7 unsigned short boot__t::root_dev

Definition at line 33 of file `boot.h`.

3.1.2.8 unsigned short boot__t::signature

Definition at line 34 of file `boot.h`.

Referenced by `get__boot__data()`.

The documentation for this struct was generated from the following file:

- `include/boot.h`

3.2 e820__t Struct Reference

```
#include <boot.h>
```

3.2.1 Detailed Description

Definition at line 19 of file boot.h.

Data Fields

- **e820__addr__t** addr
- **e820__size__t** size
- **e820__type__t** type

3.2.2 Field Documentation

3.2.2.1 e820__addr__t e820__t::addr

Definition at line 20 of file boot.h.

3.2.2.2 e820__size__t e820__t::size

Definition at line 21 of file boot.h.

Referenced by e820__get__size().

3.2.2.3 e820__type__t e820__t::type

Definition at line 22 of file boot.h.

Referenced by e820__get__type().

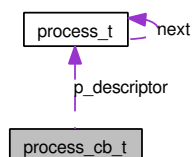
The documentation for this struct was generated from the following file:

- include/**boot.h**

3.3 process_cb_t Struct Reference

```
#include <process.h>
```

Collaboration diagram for process_cb_t:



3.3.1 Detailed Description

Definition at line 20 of file process.h.

Data Fields

- process_t * p_descriptor

3.3.2 Field Documentation

3.3.2.1 process_t* process_cb_t::p_descriptor

Definition at line 21 of file process.h.

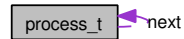
The documentation for this struct was generated from the following file:

- include/**process.h**

3.4 process_t Struct Reference

```
#include <process.h>
```

Collaboration diagram for process_t:



3.4.1 Detailed Description

Definition at line 11 of file process.h.

Data Fields

- **pid_t** pid
- **addr_t** cr3
- struct **process_t** * next
- char **name** [PROCESS_NAME_LENGTH]

3.4.2 Field Documentation

3.4.2.1 pid_t process_t::pid

Definition at line 12 of file process.h.

Referenced by kinit(), process_create(), and process_find_by_pid().

3.4.2.2 addr_t process_t::cr3

Definition at line 13 of file process.h.

Referenced by kinit().

3.4.2.3 struct process_t* process_t::next [read]

Definition at line 14 of file process.h.

Referenced by kinit(), and process_find_by_pid().

3.4.2.4 `char process_t::name[PROCESS_NAME_LENGTH]`

Definition at line 15 of file process.h.

Referenced by `kinit()`.

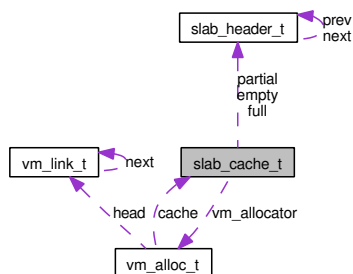
The documentation for this struct was generated from the following file:

- `include/process.h`

3.5 slab_cache_t Struct Reference

```
#include <slab.h>
```

Collaboration diagram for slab_cache_t:



3.5.1 Detailed Description

data structure describing a cache

Definition at line 24 of file slab.h.

Data Fields

- **size_t obj_size**
size of objects to allocate
- **count_t per_slab**
number of objects per slab
- **slab_header_t * empty**
head of list of empty slabs
- **slab_header_t * partial**
head of list of partial slabs
- **slab_header_t * full**
head of list of full slabs
- unsigned long **vm_flags**
flags for mapping slabs in virtual memory
- struct **vm_alloc_t * vm_allocator**

virtual address space allocator for new slabs

3.5.2 Field Documentation

3.5.2.1 `size_t slab_cache_t::obj_size`

size of objects to allocate

Definition at line 26 of file slab.h.

Referenced by `slab_create()`, and `slab_prepare()`.

3.5.2.2 `count_t slab_cache_t::per_slab`

number of objects per slab

Definition at line 29 of file slab.h.

Referenced by `slab_create()`, and `slab_prepare()`.

3.5.2.3 `slab_header_t* slab_cache_t::empty`

head of list of empty slabs

Definition at line 32 of file slab.h.

Referenced by `slab_alloc()`, `slab_create()`, and `vm_vfree_block()`.

3.5.2.4 `slab_header_t* slab_cache_t::partial`

head of list of partial slabs

Definition at line 35 of file slab.h.

Referenced by `slab_alloc()`, `slab_create()`, and `vm_vfree_block()`.

3.5.2.5 `slab_header_t* slab_cache_t::full`

head of list of full slabs

Definition at line 38 of file slab.h.

Referenced by `slab_alloc()`, and `slab_create()`.

3.5.2.6 unsigned long slab_cache_t::vm_flags

flags for mapping slabs in virtual memory

Definition at line 41 of file slab.h.

Referenced by slab_alloc(), and slab_create().

3.5.2.7 struct vm_alloc_t* slab_cache_t::vm_allocator [read]

virtual address space allocator for new slabs

Definition at line 44 of file slab.h.

Referenced by slab_alloc(), slab_create(), and vm_vfree_block().

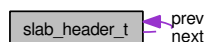
The documentation for this struct was generated from the following file:

- include/slab.h

3.6 slab_header_t Struct Reference

```
#include <slab.h>
```

Collaboration diagram for slab_header_t:



3.6.1 Detailed Description

header of a slab

Definition at line 7 of file slab.h.

Data Fields

- **count_t available**
number of available objects in free list
- **addr_t free_list**
head of the free list
- **struct slab_header_t * next**
pointer to next slab in linked list
- **struct slab_header_t * prev**
pointer to previous slab in linked list

3.6.2 Field Documentation

3.6.2.1 count_t slab_header_t::available

number of available objects in free list

Definition at line 9 of file slab.h.

Referenced by slab_alloc(), and slab_prepare().

3.6.2.2 addr_t slab_header_t::free_list

head of the free list

Definition at line 12 of file slab.h.

Referenced by slab_alloc(), and slab_prepare().

3.6.2.3 struct slab_header_t* slab_header_t::next [read]

pointer to next slab in linked list

Definition at line 15 of file slab.h.

Referenced by slab_add(), and slab_remove().

3.6.2.4 struct slab_header_t* slab_header_t::prev [read]

pointer to previous slab in linked list

Definition at line 18 of file slab.h.

Referenced by slab_add(), and slab_remove().

The documentation for this struct was generated from the following file:

- include/slab.h

3.7 thread_t Struct Reference

```
#include <process.h>
```

3.7.1 Detailed Description

Definition at line 26 of file process.h.

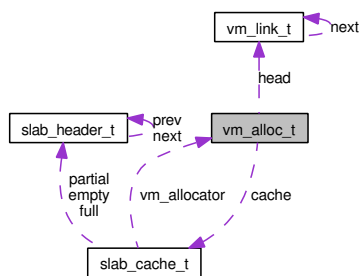
The documentation for this struct was generated from the following file:

- include/**process.h**

3.8 vm_alloc_t Struct Reference

```
#include <vm_alloc.h>
```

Collaboration diagram for vm_alloc_t:



3.8.1 Detailed Description

data structure which keep tracks of free pages in a region of virtual memory

Definition at line 23 of file `vm_alloc.h`.

Data Fields

- **size_t size**
total amount of memory available
- **vm_link_t * head**
head of the free list
- **struct slab_cache_t * cache**
slab cache on which to allocate the links of the free list

3.8.2 Field Documentation

3.8.2.1 size_t vm_alloc_t::size

total amount of memory available

Definition at line 25 of file `vm_alloc.h`.

Referenced by `vm_create_pool()`.

3.8.2.2 `vm_link_t* vm_alloc_t::head`

head of the free list

Definition at line 28 of file `vm_alloc.h`.

Referenced by `vm_create_pool()`, `vm_valloc()`, and `vm_vfree_block()`.

3.8.2.3 `struct slab_cache_t* vm_alloc_t::cache` [read]

slab cache on which to allocate the links of the free list

Definition at line 31 of file `vm_alloc.h`.

Referenced by `vm_create_pool()`, `vm_valloc()`, and `vm_vfree_block()`.

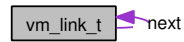
The documentation for this struct was generated from the following file:

- `include/vm_alloc.h`

3.9 vm_link_t Struct Reference

```
#include <vm_alloc.h>
```

Collaboration diagram for vm_link_t:



3.9.1 Detailed Description

links forming the linked lists of free virtual memory pages

Definition at line 8 of file vm_alloc.h.

Data Fields

- struct **vm_link_t** * **next**
next link in list
- **size_t** **size**
size of current virtual memory block
- **addr_t** **addr**
starting address of current block

3.9.2 Field Documentation

3.9.2.1 struct vm_link_t* vm_link_t::next [read]

next link in list

Definition at line 10 of file vm_alloc.h.

Referenced by vm_valloc(), and vm_vfree_block().

3.9.2.2 size_t vm_link_t::size

size of current virtual memory block

Definition at line 13 of file vm_alloc.h.

Referenced by vm_valloc(), and vm_vfree_block().

3.9.2.3 `addr_t vm_link_t::addr`

starting address of current block

Definition at line 16 of file `vm_alloc.h`.

Referenced by `vm_valloc()`, and `vm_vfree_block()`.

The documentation for this struct was generated from the following file:

- `include/vm_alloc.h`

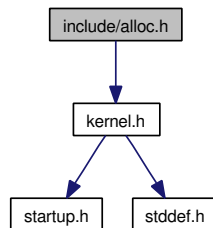
Chapter 4

File Documentation

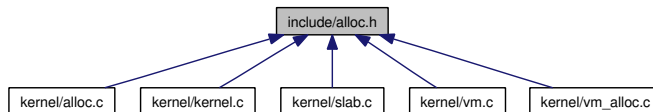
4.1 include/alloc.h File Reference

`#include <kernel.h>`

Include dependency graph for alloc.h:



This graph shows which files directly or indirectly include this file:



Functions

- void **alloc_init** (void)
- **addr_t** **alloc** (**size_t** size)
- void **free** (**addr_t** addr)

4.1.1 Function Documentation

4.1.1.1 `addr_t alloc (size_t size)`

ASSERTION: returned address should be aligned with a page boundary

Definition at line 97 of file alloc.c.

References `assert`, `PAGE_BITS`, `PAGE_MASK`, `PAGE_SIZE`, and `panic()`.

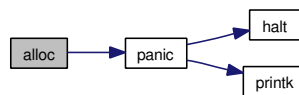
Referenced by `vm_alloc()`, `vm_map()`, and `vm_vfree_block()`.

```

97      {
98      addr_t addr;
99      size_t pages;
100
101      pages = size >> PAGE_BITS;
102
103      if( (size & PAGE_MASK) != 0 ) {
104          ++pages;
105      }
106
107      if(_alloc_size < pages) {
108          panic("out of memory.");
109      }
110
111      addr = _alloc_addr;
112      _alloc_addr += pages * PAGE_SIZE;
113      _alloc_size -= pages;
114
116      assert( ((unsigned long)addr & PAGE_MASK) == 0 );
117
118      return addr;
119 }

```

Here is the call graph for this function:



4.1.1.2 `void alloc_init (void)`

Definition at line 13 of file alloc.c.

References `e820_get_addr()`, `e820_get_size()`, `e820_get_type()`, `e820_is_available()`, `e820_is_valid()`, `kernel_region_top`, `kernel_start`, `PAGE_SIZE`, `panic()`, and `printk()`.

Referenced by `kinit()`.

```

13         {
14     unsigned int idx;
15     unsigned int remainder;
16     bool avail;
17     size_t size;
18     e820_type_t type;
19     addr_t addr, fixed_addr, best_addr;
20     size_t fixed_size, best_size;
21
22     idx = 0;
23     best_size = 0;
24
25     /*printk("Dump of the BIOS memory map:\n");
26     printk(" address size type\n");*/
27     while( e820_is_valid(idx) ) {
28         addr = e820_get_addr(idx);
29         size = e820_get_size(idx);
30         type = e820_get_type(idx);
31         avail = e820_is_available(idx);
32
33         ++idx;
34
35         /*printk("(%x) %c %x %x %s\n",
36             avail?'*':' ',
37             addr,
38             size,
39             e820_type_description(type) );*/
40
41         if( !avail ) {
42             continue;
43         }
44
45         fixed_addr = addr;
46         fixed_size = size;
47
48         /* is the region completely under the kernel ? */
49         if(addr + size > kernel_start) {
50             /* is the region completely above the kernel ? */
51             if(addr < kernel_region_top) {
52                 /* if the region touches the kernel, we take only
53                  * the part above the kernel, if there is one... */
54                 if(addr + size <= kernel_region_top) {
55                     /* ... and apparently, there is none */
56                     continue;
57                 }
58
59                 fixed_addr = kernel_region_top;
60                 fixed_size -= fixed_addr - addr;
61             }
62         }
63
64         /* we must make sure the starting address is aligned on a
65          * page boundary. The size will eventually be divided
66          * by the page size, and thus need not be aligned. */
67         remainder = (unsigned int)fixed_addr % PAGE_SIZE;
68         if(remainder != 0) {
69             remainder = PAGE_SIZE - remainder;

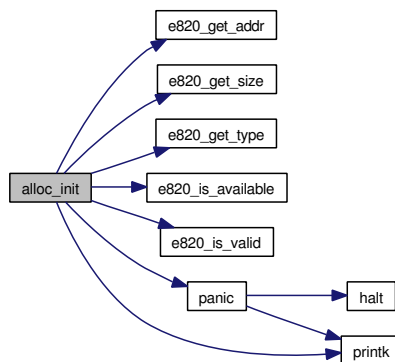
```

```

70         if(fixed_size < remainder) {
71             continue;
72         }
73
74         fixed_addr += remainder;
75         fixed_size -= remainder;
76     }
77
78     if(fixed_size > best_size) {
79         best_addr = fixed_addr;
80         best_size = fixed_size;
81     }
82 }
83
84 _alloc_addr = (addr_t)best_addr;
85 _alloc_size = best_size / PAGE_SIZE;
86
87 if(_alloc_size == 0) {
88     panic("no memory to allocate.");
89 }
90
91 printk("%u kilobytes (%u pages) available starting at %xh.\n",
92     _alloc_size * PAGE_SIZE / 1024,
93     _alloc_size,
94     _alloc_addr );
95 }

```

Here is the call graph for this function:



4.1.1.3 void free (addr__t addr)

ASSERTION: we assume starting address is aligned on a page boundary

Definition at line 121 of file alloc.c.

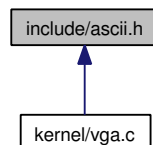
References `assert`, and `PAGE_OFFSET_OF`.

Referenced by `vm_free()`.

```
121         {  
123     assert( PAGE_OFFSET_OF(addr) == 0 );  
124 }
```

4.2 include/ascii.h File Reference

This graph shows which files directly or indirectly include this file:



Defines

- `#define CHAR_BS 0x08`
- `#define CHAR_HT 0x09`
- `#define CHAR_LF 0x0a`
- `#define CHAR_CR 0x0d`

4.2.1 Define Documentation

4.2.1.1 `#define CHAR_BS 0x08`

Definition at line 4 of file `ascii.h`.

4.2.1.2 `#define CHAR_CR 0x0d`

Definition at line 7 of file `ascii.h`.

4.2.1.3 `#define CHAR_HT 0x09`

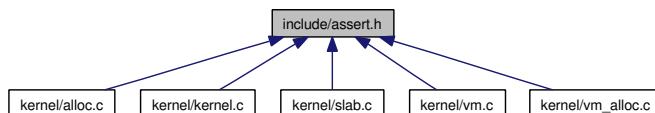
Definition at line 5 of file `ascii.h`.

4.2.1.4 `#define CHAR_LF 0x0a`

Definition at line 6 of file `ascii.h`.

4.3 include/assert.h File Reference

This graph shows which files directly or indirectly include this file:



Defines

- `#define assert(expr)`

Functions

- `void __assert_failed (const char *expr, const char *file, unsigned int line, const char *func)`

4.3.1 Define Documentation

4.3.1.1 `#define assert(expr)`

Value:

```
( \
    (expr)?(void)0:( __assert_failed(#expr, __FILE__, __LINE__, __func__) ) \
)
```

Definition at line 12 of file assert.h.

Referenced by `alloc()`, `free()`, `kinit()`, `slab_prepare()`, `vm_free()`, `vm_map()`, `vm_unmap()`, `vm_valloc()`, and `vm_vfree_block()`.

4.3.2 Function Documentation

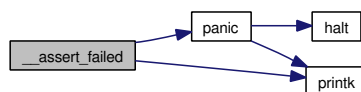
4.3.2.1 `void __assert_failed (const char * expr, const char * file, unsigned int line, const char * func)`

Definition at line 5 of file assert.c.

References `panic()`, and `printk()`.

```
9             {
10
11     printk(
12         "ASSERTION FAILED [%s]: %s at line %u in function %s.\n",
13         expr, file, line, func );
14
15     panic("Assertion failed.");
16 }
```

Here is the call graph for this function:

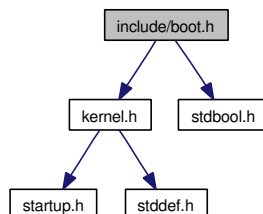


4.4 include/boot.h File Reference

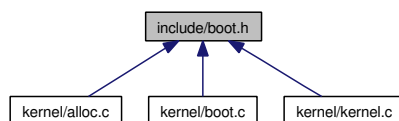
```
#include <kernel.h>
```

```
#include <stdbool.h>
```

Include dependency graph for boot.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct `e820_t`
- struct `boot_t`

Defines

- `#define BOOT_SIGNATURE 0xaa55`
- `#define BOOT_MAGIC 0xcafef00d`
- `#define SETUP_HEADER 0x53726448`
- `#define E820_RAM 1`
- `#define E820_RESERVED 2`
- `#define E820_ACPI 3`

Typedefs

- `typedef unsigned long long e820_addr_t`
- `typedef unsigned long long e820_size_t`
- `typedef unsigned long e820_type_t`

Functions

- **addr_t e820_get_addr** (unsigned int idx)
- **size_t e820_get_size** (unsigned int idx)
- **e820_type_t e820_get_type** (unsigned int idx)
- **bool e820_is_valid** (unsigned int idx)
- **bool e820_is_available** (unsigned int idx)
- **const char * e820_type_description** (e820_type_t type)
- **boot_t * get_boot_data** (void)

4.4.1 Define Documentation

4.4.1.1 **#define BOOT_MAGIC 0xcafef00d**

Definition at line 8 of file boot.h.

Referenced by `get_boot_data()`.

4.4.1.2 **#define BOOT_SIGNATURE 0xaa55**

Definition at line 7 of file boot.h.

Referenced by `get_boot_data()`.

4.4.1.3 **#define E820_ACPI 3**

Definition at line 13 of file boot.h.

Referenced by `e820_type_description()`.

4.4.1.4 **#define E820_RAM 1**

Definition at line 11 of file boot.h.

Referenced by `e820_is_available()`, and `e820_type_description()`.

4.4.1.5 **#define E820_RESERVED 2**

Definition at line 12 of file boot.h.

Referenced by `e820_type_description()`.

4.4.1.6 **#define SETUP_HEADER 0x53726448**

Definition at line 9 of file boot.h.

4.4.2 Typedef Documentation

4.4.2.1 typedef unsigned long long e820_addr_t

Definition at line 15 of file boot.h.

4.4.2.2 typedef unsigned long long e820_size_t

Definition at line 16 of file boot.h.

4.4.2.3 typedef unsigned long e820_type_t

Definition at line 17 of file boot.h.

4.4.3 Function Documentation

4.4.3.1 addr_t e820_get_addr (unsigned int *idx*)

Definition at line 8 of file boot.c.

Referenced by alloc_init().

```
8                                     {  
9     return (addr_t)(unsigned long)e820_map[idx].addr;  
10 }
```

4.4.3.2 size_t e820_get_size (unsigned int *idx*)

Definition at line 12 of file boot.c.

References e820_t::size.

Referenced by alloc_init().

```
12                                     {  
13     return (size_t)e820_map[idx].size;  
14 }
```

4.4.3.3 e820_type_t e820_get_type (unsigned int *idx*)

Definition at line 16 of file boot.c.

References e820_t::type.

Referenced by alloc_init().

```
16                                     {
17     return e820_map[idx].type;
18 }
```

4.4.3.4 bool e820__is__available (unsigned int *idx*)

Definition at line 24 of file boot.c.

References E820_RAM.

Referenced by alloc_init().

```
24                                     {
25     return (e820_map[idx].type == E820_RAM);
26 }
```

4.4.3.5 bool e820__is__valid (unsigned int *idx*)

Definition at line 20 of file boot.c.

Referenced by alloc_init().

```
20                                     {
21     return (e820_map[idx].size != 0);
22 }
```

4.4.3.6 const char* e820__type__description (e820__type__t *type*)

Definition at line 28 of file boot.c.

References E820_ACPI, E820_RAM, and E820_RESERVED.

```
28                                     {
29     switch(type) {
30
31     case E820_RAM:
32         return "available";
33
34     case E820_RESERVED:
35         return "unavailable/reserved";
36
37     case E820_ACPI:
38         return "unavailable/acpi";
39
40     default:
41         return "unavailable/other";
42     }
43 }
```

4.4.3.7 boot_t* get_boot_data (void)

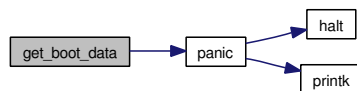
Definition at line 45 of file boot.c.

References `boot_data`, `BOOT_MAGIC`, `BOOT_SIGNATURE`, `boot_t::magic`, `panic()`, and `boot_t::signature`.

Referenced by `kinit()`.

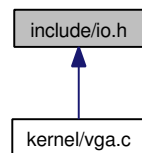
```
45         {
46     boot_t *boot;
47
48     boot = (boot_t *)boot_data;
49
50     if(boot->signature != BOOT_SIGNATURE) {
51         panic("bad boot sector signature.");
52     }
53
54     if(boot->magic != BOOT_MAGIC) {
55         panic("bad boot sector magic.");
56     }
57
58     return boot;
59 }
```

Here is the call graph for this function:



4.5 include/io.h File Reference

This graph shows which files directly or indirectly include this file:



Functions

- unsigned char **inb** (unsigned short int *port*)
- unsigned short int **inw** (unsigned short int *port*)
- unsigned int **inl** (unsigned short int *port*)
- void **outb** (unsigned short int *port*, unsigned char *value*)
- void **outw** (unsigned short int *port*, unsigned short int *value*)
- void **outl** (unsigned short int *port*, unsigned int *value*)

4.5.1 Function Documentation

4.5.1.1 unsigned char inb (unsigned short int *port*)

Referenced by vga_get_cursor_pos(), and vga_init().

4.5.1.2 unsigned int inl (unsigned short int *port*)

4.5.1.3 unsigned short int inw (unsigned short int *port*)

4.5.1.4 void outb (unsigned short int *port*, unsigned char *value*)

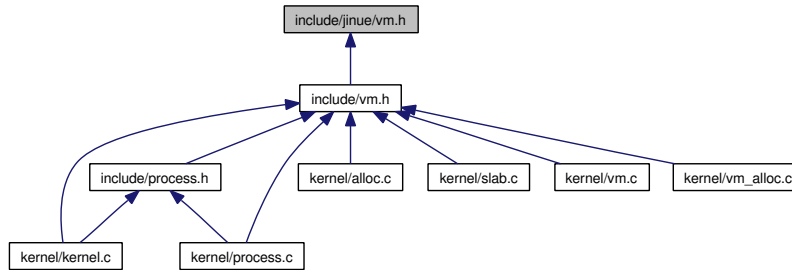
Referenced by vga_get_cursor_pos(), vga_init(), and vga_set_cursor_pos().

4.5.1.5 void outl (unsigned short int *port*, unsigned int *value*)

4.5.1.6 void outw (unsigned short int *port*, unsigned short int *value*)

4.6 include/jinue/vm.h File Reference

This graph shows which files directly or indirectly include this file:



Defines

- **#define PAGE_BITS 12**
number of bits in virtual address for offset inside page
- **#define PAGE_SIZE (1<<PAGE_BITS)**
size of page
- **#define PAGE_TABLE_BITS 10**
number of bits in virtual address for page table entry
- **#define PAGE_TABLE_ENTRIES (1<<PAGE_TABLE_BITS)**
number of entries in page table
- **#define PAGE_TABLE_SIZE PAGE_SIZE**
size of a page table
- **#define PTE_SIZE 4**
size of a page table entry, in bytes
- **#define KLIMIT (1<<24)**
Virtual address range 0 to KLIMIT is reserved by kernel to store global data structures.
- **#define PLIMIT (KLIMIT + (1<<24))**
Virtual address range KLIMIT to PLIMIT is reserved by kernel to store data structures specific to the current process.

- `#define PAGE_TABLES_ADDR KLIMIT`

This is where the page tables are mapped in every address space.

- `#define PAGE_DIRECTORY_ADDR (KLIMIT + PAGE_TABLE_ENTRIES * PAGE_TABLE_SIZE)`

This is where the page directory is mapped in every address space.

4.6.1 Define Documentation

4.6.1.1 `#define KLIMIT (1<<24)`

Virtual address range 0 to KLIMIT is reserved by kernel to store global data structures.

Kernel image must be completely inside this region. This region has the same mapping in the address space of all processes. Size must be a multiple of the size described by a single page directory entry (PTE_SIZE * PAGE_SIZE).

Definition at line 28 of file vm.h.

Referenced by kinit().

4.6.1.2 `#define PAGE_BITS 12`

number of bits in virtual address for offset inside page

Definition at line 5 of file vm.h.

Referenced by alloc().

4.6.1.3 `#define PAGE_DIRECTORY_ADDR (KLIMIT + PAGE_TABLE_ENTRIES * PAGE_TABLE_SIZE)`

This is where the page directory is mapped in every address space.

It must reside in region spanning from KLIMIT to PLIMIT.

Definition at line 46 of file vm.h.

Referenced by kinit().

4.6.1.4 `#define PAGE_SIZE (1<<PAGE_BITS)`

size of page

Definition at line 8 of file vm.h.

Referenced by `alloc()`, `alloc_init()`, `kinit()`, `slab_create()`, `vm_alloc()`, `vm_map()`, `vm_valloc()`, `vm_vfree()`, and `vm_vfree_block()`.

4.6.1.5 `#define PAGE_TABLE_BITS 10`

number of bits in virtual address for page table entry

Definition at line 11 of file `vm.h`.

4.6.1.6 `#define PAGE_TABLE_ENTRIES (1<<PAGE_TABLE_BITS)`

number of entries in page table

Definition at line 14 of file `vm.h`.

Referenced by `kinit()`, and `vm_map()`.

4.6.1.7 `#define PAGE_TABLE_SIZE PAGE_SIZE`

size of a page table

Definition at line 17 of file `vm.h`.

4.6.1.8 `#define PAGE_TABLES_ADDR KLIMIT`

This is where the page tables are mapped in every address space.

This requires a virtual memory region of size 4M, which must reside completely inside region spanning from `KLIMIT` to `PLIMIT`. Must be aligned on a 4M boundary

Definition at line 42 of file `vm.h`.

Referenced by `kinit()`.

4.6.1.9 `#define PLIMIT (KLIMIT + (1<<24))`

Virtual address range `KLIMIT` to `PLIMIT` is reserved by kernel to store data structures specific to the current process.

The mapping of this region changes from one address space to the next. Size must be a multiple of the size described by a single page directory entry (`PTE_SIZE * PAGE_SIZE`).

Definition at line 36 of file `vm.h`.

4.6.1.10 `#define PTE_SIZE 4`

size of a page table entry, in bytes

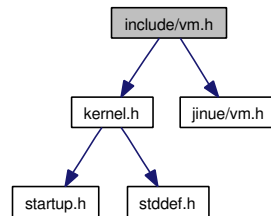
Definition at line 20 of file vm.h.

4.7 include/vm.h File Reference

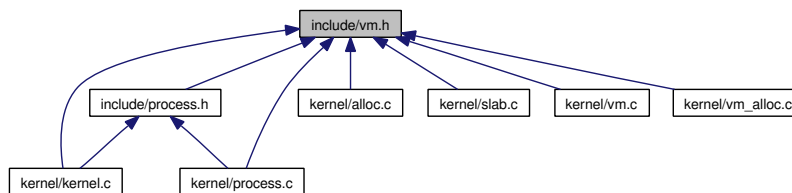
```
#include <kernel.h>
```

```
#include <jinue/vm.h>
```

Include dependency graph for vm.h:



This graph shows which files directly or indirectly include this file:



Defines

- #define **PAGE_MASK** (PAGE_SIZE - 1)
bit mask for offset in page
- #define **PAGE_OFFSET_OF**(x) ((unsigned long)(x) & PAGE_MASK)
offset in page of virtual address
- #define **PAGE_TABLE_MASK** (PAGE_TABLE_ENTRIES - 1)
bit mask for page table entry
- #define **PAGE_TABLE_OFFSET_OF**(x) (((unsigned long)(x) >> PAGE_BITS) & PAGE_TABLE_MASK)
page table entry offset of virtual (linear) address

- **#define PAGE_DIRECTORY_OFFSET_OF(x)** ((unsigned long)(x) >> (PAGE_BITS + PAGE_TABLE_BITS))
page directory entry offset of virtual (linear address)
- **#define PMAPPING_START** (PAGE_DIRECTORY_ADDR + PAGE_TABLE_SIZE)
low limit of region spanning from KLIMIT to PLIMIT actually available for mappings
- **#define PMAPPING_END** PLIMIT
high limit of region spanning from KLIMIT to PLIMIT actually available for mappings
- **#define PAGE_DIRECTORY** ((pte_t *)PAGE_DIRECTORY_ADDR)
page directory in virtual memory
- **#define PAGE_TABLES** ((page_table_t *)PAGE_TABLES_ADDR)
page tables in virtual memory
- **#define PAGE_TABLE_OF(x)** (PAGE_TABLES[PAGE_DIRECTORY_OFFSET_OF(x)])
page table in virtual memory
- **#define PDE_OF(x)** (&PAGE_DIRECTORY[PAGE_DIRECTORY_OFFSET_OF(x)])
address of page directory entry in virtual memory
- **#define PTE_OF(x)** (&PAGE_TABLE_OF(x)[PAGE_TABLE_OFFSET_OF(x)])
address of page table entry in virtual memory
- **#define PAGE_TABLES_TABLE** (PAGE_TABLE_OF(PAGE_TABLES_ADDR))
page table which maps all page tables in memory
- **#define PAGE_TABLE_PTE_OF(x)** (&PAGE_TABLES_TABLE[PAGE_DIRECTORY_OFFSET_OF(x)])
address of page entry in PAGE_OF_PAGE_TABLES
- **#define VM_FLAG_PRESENT** (1<< 0)
page is present in memory

- #define **VM_FLAG_READ_ONLY** 0
page is read only
- #define **VM_FLAG_READ_WRITE** (1<< 1)
page is read/write accessible
- #define **VM_FLAG_KERNEL** 0
kernel mode page (default)
- #define **VM_FLAG_USER** (1<< 2)
user mode page
- #define **VM_FLAG_WRITE_THROUGH** (1<< 3)
write-through cache policy for page
- #define **VM_FLAG_CACHE_DISABLE** (1<< 4)
uncached page
- #define **VM_FLAG_ACCESSED** (1<< 5)
page was accessed (read)
- #define **VM_FLAG_DIRTY** (1<< 6)
page was written to
- #define **VM_FLAG_BIG_PAGE** (1<< 7)
page directory entry describes a 4M page
- #define **VM_FLAG_GLOBAL** (1<< 8)
page is global (mapped in every address space)
- #define **VM_FLAGS_PAGE_TABLE** (VM_FLAG_USER | VM_FLAG_READ_ONLY)
set of flags for a page table (or page directory)

Typedefs

- typedef unsigned long **pte_t**
type of a page table (or page directory) entry
- typedef **pte_t** **page_table_t** [PAGE_TABLE_ENTRIES]
type of a page table

Functions

- void **vm_map** (**addr_t** vaddr, **addr_t** paddr, unsigned long flags)
Map a page frame (physical page) to a virtual memory page.
- void **vm_unmap** (**addr_t** addr)
Unmap a page from virtual memory.

4.7.1 Define Documentation

4.7.1.1 `#define PAGE_DIRECTORY ((pte_t *)PAGE_DIRECTORY_ADDR)`

page directory in virtual memory

Definition at line 49 of file vm.h.

4.7.1.2 `#define PAGE_DIRECTORY_OFFSET - OF(x) ((unsigned long)(x) >> (PAGE_BITS + PAGE_TABLE_BITS))`

page directory entry offset of virtual (linear address)

Definition at line 29 of file vm.h.

Referenced by kinit().

4.7.1.3 `#define PAGE_MASK (PAGE_SIZE - 1)`

bit mask for offset in page

Definition at line 11 of file vm.h.

Referenced by alloc(), kinit(), slab_prepare(), and vm_free().

4.7.1.4 `#define PAGE_OFFSET_OF(x) ((unsigned long)(x) & PAGE_MASK)`

offset in page of virtual address

Definition at line 14 of file vm.h.

Referenced by free(), kinit(), slab_prepare(), vm_map(), vm_unmap(), vm_valloc(), and vm_vfree_block().

4.7.1.5 `#define PAGE_TABLE_MASK (PAGE_TABLE_ENTRIES - 1)`

bit mask for page table entry

Definition at line 23 of file vm.h.

4.7.1.6 `#define PAGE_TABLE_OF(x) (PAGE_TABLES[PAGE_DIRECTORY_OFFSET_OF(x)])`

page table in virtual memory

Definition at line 55 of file vm.h.

Referenced by vm_map().

4.7.1.7 `#define PAGE_TABLE_OFFSET_OF(x) (((unsigned long)(x) >> PAGE_BITS) & PAGE_TABLE_MASK)`

page table entry offset of virtual (linear) address

Definition at line 26 of file vm.h.

Referenced by kinit().

4.7.1.8 `#define PAGE_TABLE_PTE_OF(x) (&PAGE_TABLES_TABLE[PAGE_DIRECTORY_OFFSET_OF(x)])`

address of page entry in PAGE_OF_PAGE_TABLES

Definition at line 67 of file vm.h.

Referenced by vm_map().

4.7.1.9 `#define PAGE_TABLES ((page_table_t *)PAGE_TABLES_ADDR)`

page tables in virtual memory

Definition at line 52 of file vm.h.

4.7.1.10 `#define PAGE_TABLES_TABLE (PAGE_TABLE_OF(PAGE_TABLES_ADDR))`

page table which maps all page tables in memory

Definition at line 64 of file vm.h.

4.7.1.11 `#define PDE_OF(x) (&PAGE_DIRECTORY[
PAGE_DIRECTORY_OFFSET_OF(x)])`

address of page directory entry in virtual memory

Definition at line 58 of file vm.h.

Referenced by slab_prepare(), and vm_map().

4.7.1.12 `#define PMAPPING_END PLIMIT`

high limit of region spanning from KLIMIT to PLIMIT actually available for mappings

Definition at line 43 of file vm.h.

4.7.1.13 `#define PMAPPING_START (PAGE_DIRECTORY_
ADDR + PAGE_TABLE_SIZE)`

low limit of region spanning from KLIMIT to PLIMIT actually available for mappings

Definition at line 39 of file vm.h.

4.7.1.14 `#define PTE_OF(x) (&PAGE_TABLE_OF(x)[
PAGE_TABLE_OFFSET_OF(x)])`

address of page table entry in virtual memory

Definition at line 61 of file vm.h.

Referenced by slab_prepare(), vm_free(), vm_map(), and vm_unmap().

4.7.1.15 `#define VM_FLAG_ACCESSED (1<< 5)`

page was accessed (read)

Definition at line 94 of file vm.h.

4.7.1.16 `#define VM_FLAG_BIG_PAGE (1<< 7)`

page directory entry describes a 4M page

Definition at line 100 of file vm.h.

4.7.1.17 #define VM_FLAG_CACHE_DISABLE (1<< 4)

uncached page

Definition at line 91 of file vm.h.

4.7.1.18 #define VM_FLAG_DIRTY (1<< 6)

page was written to

Definition at line 97 of file vm.h.

4.7.1.19 #define VM_FLAG_GLOBAL (1<< 8)

page is global (mapped in every address space)

Definition at line 103 of file vm.h.

4.7.1.20 #define VM_FLAG_KERNEL 0

kernel mode page (default)

Definition at line 82 of file vm.h.

Referenced by kinit(), and vm_vfree_block().

4.7.1.21 #define VM_FLAG_PRESENT (1<< 0)

page is present in memory

Definition at line 73 of file vm.h.

Referenced by kinit(), slab_prepare(), and vm_map().

4.7.1.22 #define VM_FLAG_READ_ONLY 0

page is read only

Definition at line 76 of file vm.h.

4.7.1.23 #define VM_FLAG_READ_WRITE (1<< 1)

page is read/write accessible

Definition at line 79 of file vm.h.

Referenced by kinit(), and vm_map().

4.7.1.24 `#define VM_FLAG_USER (1<< 2)`

user mode page

Definition at line 85 of file vm.h.

Referenced by kinit(), and vm_map().

4.7.1.25 `#define VM_FLAG_WRITE_THROUGH (1<< 3)`

write-through cache policy for page

Definition at line 88 of file vm.h.

4.7.1.26 `#define VM_FLAGS_PAGE_TABLE (VM_FLAG_USER | VM_FLAG_READ_ONLY)`

set of flags for a page table (or page directory)

Definition at line 106 of file vm.h.

Referenced by kinit(), and vm_map().

4.7.2 Typedef Documentation**4.7.2.1** `typedef pte_t page_table_t[PAGE_TABLE_ENTRIES]`

type of a page table

Definition at line 32 of file vm.h.

4.7.2.2 `typedef unsigned long pte_t`

type of a page table (or page directory) entry

Definition at line 20 of file vm.h.

4.7.3 Function Documentation**4.7.3.1** `void vm_map(addr_t vaddr, addr_t paddr, unsigned long flags)`

Map a page frame (physical page) to a virtual memory page.

Parameters:

vaddr virtual address of mapping

paddr address of page frame

flags flags used for mapping (see VM_FLAG_x constants in vm.h)

ASSERTION: we assume vaddr is aligned on a page boundary

ASSERTION: we assume paddr is aligned on a page boundary

Definition at line 14 of file vm.c.

References `alloc()`, `assert`, `invalidate_tlb()`, `PAGE_OFFSET_OF`, `PAGE_SIZE`, `PAGE_TABLE_ENTRIES`, `PAGE_TABLE_OF`, `PAGE_TABLE_PTE_OF`, `PDE_OF`, `PTE_OF`, `VM_FLAG_PRESENT`, `VM_FLAG_READ_WRITE`, `VM_FLAG_USER`, and `VM_FLAGS_PAGE_TABLE`.

Referenced by `vm_alloc()`, and `vm_vfree_block()`.

```

14                                     {
15     pte_t *pte, *pde;
16     addr_t page_table;
17     int idx;
18
19
20     assert( PAGE_OFFSET_OF(vaddr) == 0 );
21
22     assert( PAGE_OFFSET_OF(paddr) == 0 );
23
24
25     /* get page directory entry */
26     pde = PDE_OF(vaddr);
27
28     /* check if page table must be created */
29     if( !(*pde & VM_FLAG_PRESENT) ) {
30         /* allocate a new page table */
31         page_table = alloc(PAGE_SIZE);
32
33         /* map page table in the region of memory reserved for that purpose */
34         pte = PAGE_TABLE_PTE_OF(vaddr);
35         *pte = (pte_t)page_table | VM_FLAGS_PAGE_TABLE | VM_FLAG_PRESENT;
36
37         /* obtain virtual address of new page table */
38         pte = PAGE_TABLE_OF(vaddr);
39
40         /* invalidate TLB entry for new page table */
41         invalidate_tlb( (addr_t)pte );
42
43         /* zero content of page table */
44         for(idx = 0; idx < PAGE_TABLE_ENTRIES; ++idx) {
45             pte[idx] = 0;
46         }
47
48         /* link to page table from page directory */
49         *pde = (pte_t)page_table | VM_FLAG_USER | VM_FLAG_READ_WRITE | VM_FLAG_PRESENT;
50     }
51
52     /* perform the actual mapping */
53     pte = PTE_OF(vaddr);
54     *pte = (pte_t)paddr | flags | VM_FLAG_PRESENT;

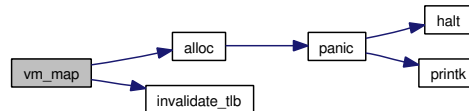
```

```

55
56  /* invalidate TLB entry for newly mapped page */
57  invalidate_tlb(vaddr);
58 }

```

Here is the call graph for this function:



4.7.3.2 void vm_unmap (addr_t addr)

Unmap a page from virtual memory.

Parameters:

addr address of page to unmap

ASSERTION: we assume addr is aligned on a page boundary

Definition at line 64 of file vm.c.

References assert, invalidate_tlb(), NULL, PAGE_OFFSET_OF, and PTE_OF.

Referenced by vm_free().

```

64  {
65      pte_t *pte;
66
67      assert( PAGE_OFFSET_OF(addr) == 0 );
68
69      pte = PTE_OF(addr);
70      *pte = NULL;
71
72      /* TODO: is this really necessary? */
73      invalidate_tlb(addr);
74  }

```

Here is the call graph for this function:

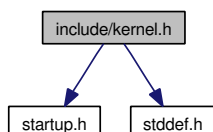


4.8 include/kernel.h File Reference

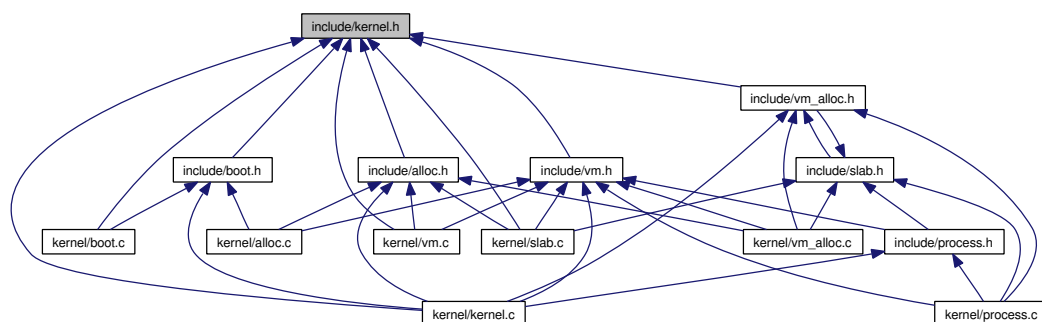
```
#include <startup.h>
```

```
#include <stddef.h>
```

Include dependency graph for kernel.h:



This graph shows which files directly or indirectly include this file:



Defines

- `#define kernel_start ((addr_t)start)`

Typedefs

- `typedef void * addr_t`
- `typedef unsigned long count_t`

Functions

- `void kernel (void)`
- `void kinit (void)`
- `void idle (void)`

Variables

- **addr_t kernel_top**
address of top of kernel image (`kernel_start + kernel_size`)
- **addr_t kernel_region_top**
top of region of memory mapped 1:1 (kernel image plus some pages for data structures allocated during initialization)
- **size_t kernel_size**
size of the kernel image

4.8.1 Define Documentation

4.8.1.1 `#define kernel_start ((addr_t)start)`

Definition at line 10 of file `kernel.h`.

Referenced by `alloc_init()`, and `kinit()`.

4.8.2 Typedef Documentation

4.8.2.1 `typedef void* addr_t`

Definition at line 7 of file `kernel.h`.

4.8.2.2 `typedef unsigned long count_t`

Definition at line 8 of file `kernel.h`.

4.8.3 Function Documentation

4.8.3.1 `void idle (void)`

Definition at line 252 of file `kernel.c`.

Referenced by `kernel()`.

```
252         {  
253     while(1) {}  
254 }
```

4.8.3.2 void kernel (void)

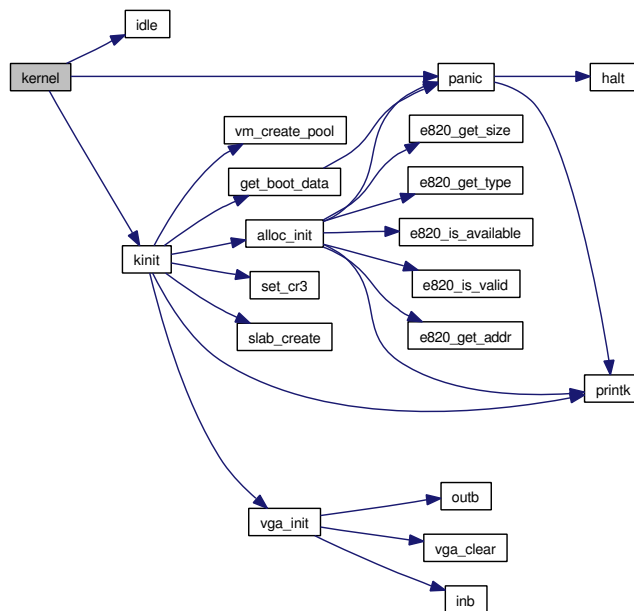
Definition at line 28 of file kernel.c.

References `idle()`, `kinit()`, and `panic()`.

```

28         {
29     kinit();
30     idle();
31
32     panic("idle() returned.");
33 }
```

Here is the call graph for this function:



4.8.3.3 void kinit (void)

ASSERTION: we assume the kernel starts on a page boundary

ASSERTION: we assume kernel_start is aligned with a page directory entry boundary

ASSERTION: we assume kernel_start is aligned with a page directory entry boundary

TODO: remove

TODO: remove

TODO: /remove

Definition at line 35 of file kernel.c.

References `alloc_init()`, `assert`, `process_t::cr3`, `first_process`, `get_boot_data()`, `global_pool`, `global_pool_cache`, `kernel_region_top`, `kernel_size`, `kernel_start`, `KLIMIT`, `process_t::name`, `process_t::next`, `next_pid`, `NULL`, `PAGE_DIRECTORY_ADDR`, `PAGE_DIRECTORY_OFFSET_OF`, `page_directory_template`, `PAGE_MASK`, `PAGE_OFFSET_OF`, `PAGE_SIZE`, `PAGE_TABLE_ENTRIES`, `PAGE_TABLE_OFFSET_OF`, `PAGE_TABLES_ADDR`, `process_t::pid`, `printk()`, `PROCESS_NAME_LENGTH`, `process_slab_cache`, `set_cr3()`, `slab_create()`, `vga_init()`, `vm_create_pool()`, `VM_FLAG_KERNEL`, `VM_FLAG_PRESENT`, `VM_FLAG_READ_WRITE`, `VM_FLAG_USER`, and `VM_FLAGS_PAGE_TABLE`.

Referenced by `kernel()`.

```

35         {
36     pte_t *page_table1, *page_table2, *page_directory;
37     pte_t *pte;
38     addr_t addr;
39     unsigned long idx, idy;
40     unsigned long temp;
41
42     /* say hello */
43     vga_init();
44     printk("Kernel started.\n");
45
46     assert( PAGE_OFFSET_OF( (unsigned int)kernel_start ) == 0 );
47
48     assert( PAGE_TABLE_OFFSET_OF(PAGE_TABLES_ADDR) == 0 );
49     assert( PAGE_OFFSET_OF(PAGE_TABLES_ADDR) == 0 );
50
51     assert( PAGE_TABLE_OFFSET_OF(PAGE_DIRECTORY_ADDR) == 0 );
52     assert( PAGE_OFFSET_OF(PAGE_DIRECTORY_ADDR) == 0 );
53
54     printk("Kernel size is %u bytes.\n", kernel_size);
55
56     printk("kernel_region_top on entry: 0x%x\n", (unsigned long)kernel_region_top );
57
58     /* initialize data structures for caches and the global virtual page allocator */
59     slab_create(
60         &global_pool_cache,
61         &global_pool,
62         sizeof(vm_link_t),
63         VM_FLAG_KERNEL);
64
65     vm_create_pool(&global_pool, &global_pool_cache);
66
67     slab_create(&process_slab_cache, &global_pool,
68         sizeof(process_t), VM_FLAG_KERNEL);
69
70     /* allocate one page for page directory template just after the

```



```

75     kernel image. Since paging is not yet activated, virtual and
76     physical address are the same. */
77     page_directory_template = (pte_t *)kernel_region_top;
78     kernel_region_top += PAGE_SIZE;
79
80     /* allocate page tables for kernel data/code region (0..KLIMIT) and add
81     relevant entries to page directory template */
82     for(idx = 0; idx < PAGE_DIRECTORY_OFFSET_OF(KLIMIT); ++idx) {
83         page_table1 = kernel_region_top;
84         kernel_region_top += PAGE_SIZE;
85
86         page_directory_template[idx] = (pte_t)page_table1 | VM_FLAG_PRESENT | VM_FLAG_KERNEL;
87
88         for(idy = 0; idy < PAGE_TABLE_ENTRIES; ++idy) {
89             page_table1[idy] = 0;
90         }
91     }
92
93     while(idx < PAGE_TABLE_ENTRIES) {
94         page_directory_template[idx] = 0;
95         ++idx;
96     }
97
98     /* allocate and fill content of a page directory and two page tables
99     for the creation of the address space of the first process (idle) */
100    page_directory = kernel_region_top;
101    kernel_region_top += PAGE_SIZE;
102
103    page_table1 = kernel_region_top;
104    kernel_region_top += PAGE_SIZE;
105
106    page_table2 = kernel_region_top;
107    kernel_region_top += PAGE_SIZE;
108
109    for(idx = 0; idx < PAGE_TABLE_ENTRIES; ++idx) {
110        temp = page_directory_template[idx];
111        page_directory[idx] = temp;
112        page_table1[idx] = temp;
113    }
114
115    page_directory[PAGE_DIRECTORY_OFFSET_OF(PAGE_TABLES_ADDR)] =
116        (pte_t)page_table1 | VM_FLAG_PRESENT | VM_FLAG_USER | VM_FLAG_READ_WRITE;
117
118    page_directory[PAGE_DIRECTORY_OFFSET_OF(PAGE_DIRECTORY_ADDR)] =
119        (pte_t)page_table2 | VM_FLAG_PRESENT | VM_FLAG_USER | VM_FLAG_READ_WRITE;
120
121    page_table1[PAGE_DIRECTORY_OFFSET_OF(PAGE_TABLES_ADDR)] =
122        (pte_t)page_table1 | VM_FLAG_PRESENT | VM_FLAGS_PAGE_TABLE;
123
124    page_table1[PAGE_DIRECTORY_OFFSET_OF(PAGE_DIRECTORY_ADDR)] =
125        (pte_t)page_table2 | VM_FLAG_PRESENT | VM_FLAGS_PAGE_TABLE;
126
127    page_table2[0] = (pte_t)page_directory | VM_FLAG_PRESENT | VM_FLAGS_PAGE_TABLE;
128    for(idx = 1; idx < PAGE_TABLE_ENTRIES; ++idx) {
129        page_table2[idx] = 0;
130    }
131

```

```

132  /* create process descriptor for first process */
133  idle_process.pid = 0;
134  next_pid = 1;
135
136  idle_process.next = NULL;
137  first_process = &idle_process;
138
139  idle_process.cr3 = (addr_t)page_directory;
140
141  idle_process.name[0] = 'i';
142  idle_process.name[1] = 'd';
143  idle_process.name[2] = 'l';
144  idle_process.name[3] = 'e';
145  for(idx = 4; idx < PROCESS_NAME_LENGTH; ++idx) {
146      idle_process.name[idx] = 0;
147  }
148
149  /* perform 1:1 mapping of kernel image and data
150
151      note: page tables for memory region (0..KLIMIT) are contiguous
152      in memory */
153  page_table1 =
154      (pte_t *)page_directory[ PAGE_DIRECTORY_OFFSET_OF(kernel_start) ];
155  page_table1 = (pte_t *) ( (unsigned int)page_table1 & ~PAGE_MASK );
156
157  pte =
158      (pte_t *)&page_table1[ PAGE_TABLE_OFFSET_OF(kernel_start) ];
159
160  for(addr = kernel_start; addr < kernel_region_top; addr += PAGE_SIZE) {
161      *pte = (pte_t)addr | VM_FLAG_PRESENT | VM_FLAG_KERNEL;
162      ++pte;
163  }
164
165  printk("boot data: 0x%x\n", (unsigned long)get_boot_data() );
166
167  printk("page directory (0x%x):\n", (unsigned long)page_directory);
168  printk(" 0x%x 0x%x 0x%x 0x%x 0x%x 0x%x 0x%x\n",
169      (unsigned long)page_directory[0],
170      (unsigned long)page_directory[1],
171      (unsigned long)page_directory[2],
172      (unsigned long)page_directory[3],
173      (unsigned long)page_directory[4],
174      (unsigned long)page_directory[5],
175      (unsigned long)page_directory[6]
176  );
177
178
179  if(PAGE_DIRECTORY_OFFSET_OF(kernel_start) != 0) {
180      printk("OOPS: PAGE_DIRECTORY_OFFSET_OF(kernel_start) != 0 (%u)\n",
181          PAGE_DIRECTORY_OFFSET_OF(kernel_start));
182  }
183
184  if(PAGE_TABLE_OFFSET_OF(kernel_start) != 256) {
185      printk("PAGE_TABLE_OFFSET_OF(kernel_start) != 256 (%u)\n",
186          PAGE_TABLE_OFFSET_OF(kernel_start));
187  }
188
189  page_table1 =

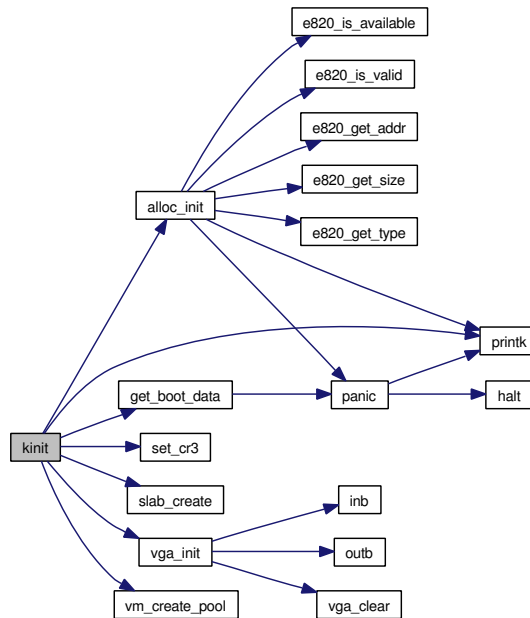
```

```

190     (pte_t *)page_directory[0];
191     page_table1 = (pte_t *) ( (unsigned int)page_table1 & ~PAGE_MASK );
192     pte = (pte_t *)&page_table1[250];
193     printk("Page table 0 (0x%x) offset 250 (0x%x):\n", (unsigned long)page_table1, (unsigned long) pte);
194
195     for(idx = 0; idx < 42; ++idx) {
196         if(idx % 7 == 0) {
197             printk(" 0x%x ", (unsigned long)pte[idx]);
198         }
199         else if(idx % 7 == 6) {
200             printk("0x%x\n", (unsigned long)pte[idx]);
201         }
202         else {
203             printk("0x%x ", (unsigned long)pte[idx]);
204         }
205     }
206
207     page_table1 =
208         (pte_t *)page_directory[4];
209     page_table1 = (pte_t *) ( (unsigned int)page_table1 & ~PAGE_MASK );
210     printk("page table 4 (0x%x):\n", (unsigned long)page_table1);
211     printk(" 0x%x 0x%x 0x%x 0x%x 0x%x 0x%x 0x%x 0x%x\n",
212         (unsigned long)page_table1[0],
213         (unsigned long)page_table1[1],
214         (unsigned long)page_table1[2],
215         (unsigned long)page_table1[3],
216         (unsigned long)page_table1[4],
217         (unsigned long)page_table1[5],
218         (unsigned long)page_table1[6]
219     );
220
221     page_table1 =
222         (pte_t *)page_directory[5];
223     page_table1 = (pte_t *) ( (unsigned int)page_table1 & ~PAGE_MASK );
224     printk("page table 5 (0x%x):\n", (unsigned long)page_table1);
225     printk(" 0x%x 0x%x 0x%x 0x%x 0x%x 0x%x 0x%x 0x%x\n",
226         (unsigned long)page_table1[0],
227         (unsigned long)page_table1[1],
228         (unsigned long)page_table1[2],
229         (unsigned long)page_table1[3],
230         (unsigned long)page_table1[4],
231         (unsigned long)page_table1[5],
232         (unsigned long)page_table1[6]
233     );
234
235     /* activate paging */
236     set_cr3( (unsigned long)page_directory );
237
238     /*temp = get_cr0();
239     temp |= (1 << X86_FLAG_PG);
240     set_cr0(temp);*/
241
242     /* initialize page frame allocator */
243     alloc_init();
244 }

```

Here is the call graph for this function:



4.8.4 Variable Documentation

4.8.4.1 `addr_t kernel_region_top`

top of region of memory mapped 1:1 (kernel image plus some pages for data structures allocated during initialization)

Definition at line 22 of file kernel.c.

Referenced by `alloc_init()`, and `kinit()`.

4.8.4.2 `size_t kernel_size`

size of the kernel image

Definition at line 15 of file kernel.c.

Referenced by `kinit()`.

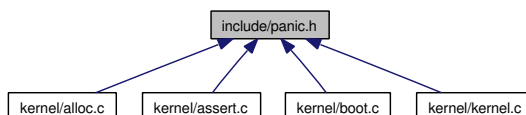
4.8.4.3 `addr_t kernel_top`

address of top of kernel image (`kernel_start + kernel_size`)

Definition at line 18 of file kernel.c.

4.9 include/panic.h File Reference

This graph shows which files directly or indirectly include this file:



Functions

- void **panic** (const char *message)

4.9.1 Function Documentation

4.9.1.1 void panic (const char * *message*)

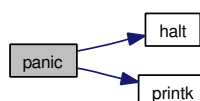
Definition at line 4 of file `panic.c`.

References `halt()`, and `printk()`.

Referenced by `__assert_failed()`, `alloc()`, `alloc_init()`, `get_boot_data()`, and `kernel()`.

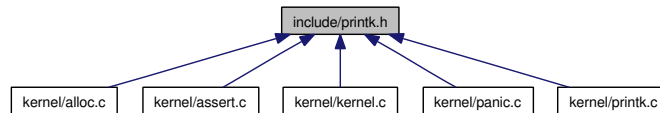
```
4      {  
5  printk("KERNEL PANIC: %s\n", message);  
6  halt();  
7 }
```

Here is the call graph for this function:



4.10 include/printk.h File Reference

This graph shows which files directly or indirectly include this file:



Functions

- void **printk** (const char *format,...)
- void **print_unsigned_int** (unsigned int n)
- void **print_hex_nibble** (unsigned char byte)
- void **print_hex_b** (unsigned char byte)
- void **print_hex_w** (unsigned short word)
- void **print_hex_l** (unsigned long dword)
- void **print_hex_q** (unsigned long long qword)

4.10.1 Function Documentation

4.10.1.1 void print_hex_b (unsigned char *byte*)

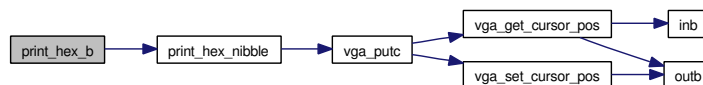
Definition at line 107 of file printk.c.

References `print_hex_nibble()`.

```

107                                     {
108     print_hex_nibble( (char)byte );
109     print_hex_nibble( (char)(byte>>4) );
110 }
```

Here is the call graph for this function:



4.10.1.2 void print_hex_l (unsigned long *dword*)

Definition at line 120 of file printk.c.

References `print_hex_nibble()`.

```

120                                     {
121     int off;
122
123     for(off=32-4; off>=0; off-=4) {
124         print_hex_nibble( (char)(dword>>off) );
125     }
126 }

```

Here is the call graph for this function:



4.10.1.3 void print_hex_nibble (unsigned char *byte*)

Definition at line 93 of file printk.c.

References vga_putc().

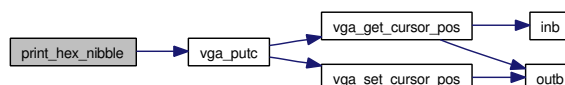
Referenced by print_hex_b(), print_hex_l(), print_hex_q(), and print_hex_w().

```

93                                     {
94     char c;
95
96     c = byte & 0xf;
97     if(c < 10) {
98         c += '0';
99     }
100     else {
101         c += ('a' - 10);
102     }
103
104     vga_putc(c);
105 }

```

Here is the call graph for this function:



4.10.1.4 void print_hex_q (unsigned long long *qword*)

Definition at line 128 of file printk.c.

References `print_hex_nibble()`.

```

128                                     {
129     int off;
130
131     for(off=64-4; off>=0; off-=4) {
132         print_hex_nibble( (char)(qword>>off) );
133     }
134 }
```

Here is the call graph for this function:



4.10.1.5 void `print_hex_w` (unsigned short *word*)

Definition at line 112 of file `printk.c`.

References `print_hex_nibble()`.

```

112                                     {
113     int off;
114
115     for(off=16-4; off>=0; off-=4) {
116         print_hex_nibble( (char)(word>>off) );
117     }
118 }
```

Here is the call graph for this function:



4.10.1.6 void `print_unsigned_int` (unsigned int *n*)

Definition at line 69 of file `printk.c`.

References `vga_putc()`.

```

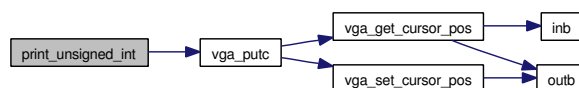
69                                     {
70     unsigned int flag = 0;
```

```

71     unsigned int pwr;
72     unsigned int digit;
73     char c;
74
75     if(n == 0) {
76         vga_putc('0');
77         return;
78     }
79
80     for(pwr = 1000 * 1000 * 1000; pwr > 0; pwr /= 10) {
81         digit = n / pwr;
82
83         if(digit != 0 || flag) {
84             c = (char)digit + '0';
85             vga_putc(c);
86
87             flag = 1;
88             n -= digit * pwr;
89         }
90     }
91 }

```

Here is the call graph for this function:



4.10.1.7 void printk (const char * *format*, ...)

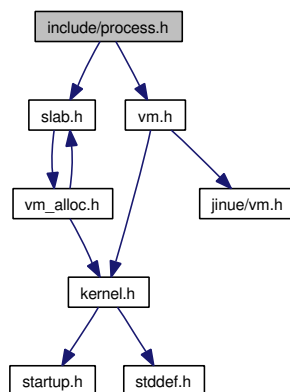
Referenced by `__assert_failed()`, `alloc_init()`, `kinit()`, and `panic()`.

4.11 include/process.h File Reference

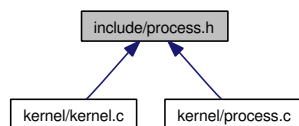
```
#include <slab.h>
```

```
#include <vm.h>
```

Include dependency graph for process.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct `process_t`
- struct `process_cb_t`
- struct `thread_t`

Defines

- `#define PROCESS_NAME_LENGTH 16`

Typedefs

- typedef unsigned long `pid_t`

- typedef struct **process_t** process_t
- typedef struct **process_cb_t** process_cb_t
- typedef struct **thread_t** thread_t

Functions

- **process_t * process_create** (void)
- void **process_destroy** (process_t *p)
- void **process_destroy_by_pid** (pid_t pid)
- **process_t * process_find_by_pid** (pid_t pid)

Variables

- **pid_t next_pid**
PID for next process creation.
- **process_t * first_process**
head of process descriptors linked list
- **slab_cache_t process_slab_cache**
slab cache for allocation of process descriptors
- **pte_t * page_directory_template**
template for the creation of a new page directory

4.11.1 Define Documentation

4.11.1.1 #define PROCESS_NAME_LENGTH 16

Definition at line 7 of file process.h.

Referenced by kinit().

4.11.2 Typedef Documentation

4.11.2.1 typedef unsigned long pid_t

Definition at line 9 of file process.h.

4.11.2.2 typedef struct process_cb_t process_cb_t

Definition at line 24 of file process.h.

4.11.2.3 typedef struct process_t process_t

Definition at line 18 of file process.h.

4.11.2.4 typedef struct thread_t thread_t

Definition at line 29 of file process.h.

4.11.3 Function Documentation**4.11.3.1 process_t* process_create (void)**

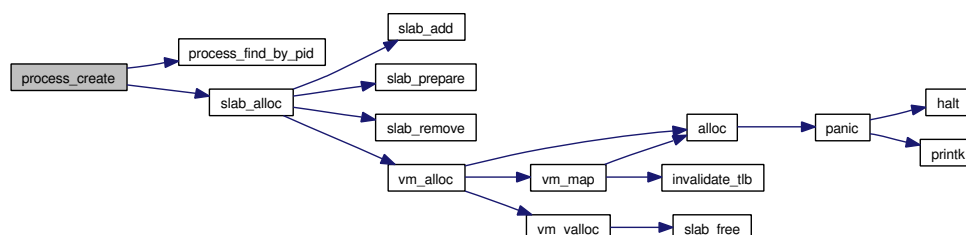
Definition at line 20 of file process.c.

References `next_pid`, `NULL`, `process_t::pid`, `process_find_by_pid()`, and `slab_alloc()`.

```

20         {
21     process_t *p = slab_alloc(&process_slab_cache);
22
23     while( process_find_by_pid(next_pid) != NULL ) {
24         ++next_pid;
25     }
26
27     p->pid = next_pid++;
28
29     /* TODO: actual implementation */
30     return p;
31 }
```

Here is the call graph for this function:



4.11.3.2 void process__destroy (process__t * p)

Definition at line 33 of file process.c.

Referenced by process__destroy__by__pid().

```

33                                     {
34     /* TODO: actual implementation */
35 }
```

4.11.3.3 void process__destroy__by__pid (pid__t pid)

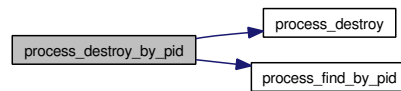
Definition at line 37 of file process.c.

References process__destroy(), and process__find__by__pid().

```

37                                     {
38     process__destroy( process__find__by__pid(pid) );
39 }
```

Here is the call graph for this function:



4.11.3.4 process__t* process__find__by__pid (pid__t pid)

Definition at line 41 of file process.c.

References process__t::next, NULL, and process__t::pid.

Referenced by process__create(), and process__destroy__by__pid().

```

41                                     {
42     process__t *p;
43
44     p = first_process;
45
46     while(p != NULL) {
47         if(p->pid == pid) {
48             return p;
49         }
50
51         p = p->next;
52     }
53
54     return NULL;
55 }
```

4.11.4 Variable Documentation

4.11.4.1 `process_t* first_process`

head of process descriptors linked list

Definition at line 11 of file process.c.

Referenced by `kinit()`.

4.11.4.2 `pid_t next_pid`

PID for next process creation.

Definition at line 8 of file process.c.

Referenced by `kinit()`, and `process_create()`.

4.11.4.3 `pte_t* page_directory_template`

template for the creation of a new page directory

Definition at line 17 of file process.c.

Referenced by `kinit()`.

4.11.4.4 `slab_cache_t process_slab_cache`

slab cache for allocation of process descriptors

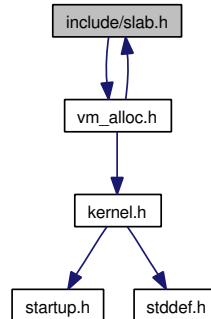
Definition at line 14 of file process.c.

Referenced by `kinit()`.

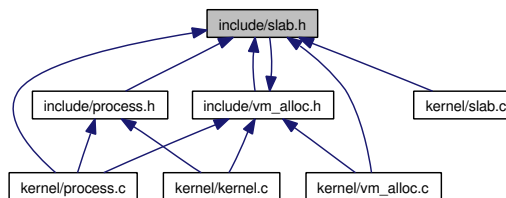
4.12 include/slab.h File Reference

```
#include <vm_alloc.h>
```

Include dependency graph for slab.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct **slab_header_t**
header of a slab
- struct **slab_cache_t**
data structure describing a cache

Typedefs

- typedef struct **slab_header_t** **slab_header_t**
- typedef struct **slab_cache_t** **slab_cache_t**

Functions

- void **slab_create** (struct **slab_cache_t** *cache, struct **vm_alloc_t** *pool, **size_t** obj_size, unsigned long flags)
- void **slab_destroy** (slab_cache_t *cache)
- **addr_t** **slab_alloc** (slab_cache_t *cache)
- void **slab_free** (slab_cache_t *cache, **addr_t** obj)
- void **slab_prepare** (slab_cache_t *cache, **addr_t** page)
Prepare a memory page for use as a slab.
- void **slab_add** (slab_header_t **head, slab_header_t *slab)
Add a slab to a linked list of slabs.
- void **slab_remove** (slab_header_t **head, slab_header_t *slab)
Remove a slab from a linked list of slab.

4.12.1 Typedef Documentation

4.12.1.1 typedef struct slab_cache_t slab_cache_t

Definition at line 47 of file slab.h.

4.12.1.2 typedef struct slab_header_t slab_header_t

Definition at line 21 of file slab.h.

4.12.2 Function Documentation

4.12.2.1 void slab_add (slab_header_t ** head, slab_header_t * slab)

Add a slab to a linked list of slabs.

Parameters:

head of list (typically &C->empty, &C->partial or &C->full of some cache C)

slab to add to list

Definition at line 136 of file slab.c.

References slab_header_t::next, NULL, and slab_header_t::prev.

Referenced by slab_alloc(), and vm_vfree_block().

```

136                                     {
137     slab->next = *head;
138     slab->prev = NULL;
139
140     (*head)->prev = slab;
141     *head = slab;
142 }

```

4.12.2.2 `addr_t slab_alloc (slab_cache_t * cache)`

TODO: handle the NULL pointer

Definition at line 27 of file slab.c.

References `slab_header_t::available`, `slab_cache_t::empty`, `slab_header_t::free_list`, `slab_cache_t::full`, `NULL`, `slab_cache_t::partial`, `slab_add()`, `slab_prepare()`, `slab_remove()`, `vm_alloc()`, `slab_cache_t::vm_allocator`, and `slab_cache_t::vm_flags`.

Referenced by `process_create()`, and `vm_vfree_block()`.

```

27                                     {
28     slab_header_t *slab;
29     addr_t addr;
30
31     /* use a partial slab if one is available... */
32     slab = cache->partial;
33     if(slab != NULL) {
34         addr = slab->free_list;
35         slab->free_list = *(addr_t *)addr;
36
37         /* maybe the slab is now full */
38         if(--slab->available == 0) {
39             slab_remove(&cache->partial, slab);
40             slab_add(&cache->full, slab);
41         }
42
43         return addr;
44     }
45
46     /* ... otherwise, use an empty slab ... */
47     slab = cache->empty;
48     if(slab != NULL) {
49         /* the slab is no longer empty */
50         slab_remove(&cache->empty, slab);
51         slab_add(&cache->partial, slab);
52
53         addr = slab->free_list;
54         slab->free_list = *(addr_t *)addr;
55
56         /* maybe the slab is now full */
57         if(--slab->available == 0) {
58             slab_remove(&cache->partial, slab);
59             slab_add(&cache->full, slab);

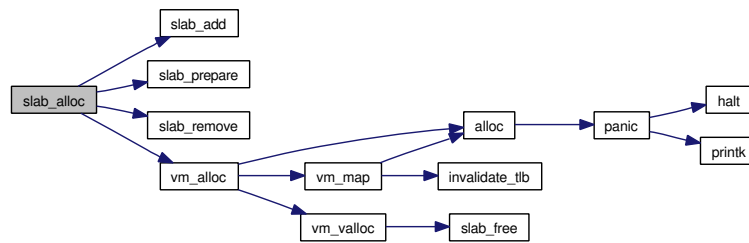
```

```

60     }
61
62     return addr;
63 }
64
65 /* ... and, as last resort, allocate a slab */
66 slab = (slab_header_t *)vm_alloc(cache->vm_allocator, cache->vm_flags);
67 slab_prepare(cache, (addr_t)slab);
68
69 /* this slab is not empty since we are allocating an object from it */
70 slab_add(&cache->partial, slab);
71
72 addr = slab->free_list;
73 slab->free_list = *(addr_t *)addr;
74
75 /* maybe the slab is now full */
76 if(--slab->available == 0) {
77     slab_remove(&cache->partial, slab);
78     slab_add(&cache->full, slab);
79 }
80
81 return addr;
82 }

```

Here is the call graph for this function:



4.12.2.3 void slab_create (struct slab_cache_t * cache, struct vm_alloc_t * pool, size_t obj_size, unsigned long flags)

Definition at line 7 of file slab.c.

References slab_cache_t::empty, slab_cache_t::full, NULL, slab_cache_t::obj_size, PAGE_SIZE, slab_cache_t::partial, slab_cache_t::per_slab, slab_cache_t::vm_allocator, and slab_cache_t::vm_flags.

Referenced by kinit().

```

11     {
12
13

```

```

14     cache->obj_size = obj_size;
15     cache->per_slab = ( PAGE_SIZE - sizeof(slab_header_t) ) / obj_size;
16     cache->empty = NULL;
17     cache->partial = NULL;
18     cache->full = NULL;
19     cache->vm_flags = flags;
20     cache->vm_allocator = pool;
21 }

```

4.12.2.4 void slab__destroy (slab__cache__t * *cache*)

Definition at line 23 of file slab.c.

```

23                                     {
24     /* TODO: implement slab_destroy */
25 }

```

4.12.2.5 void slab__free (slab__cache__t * *cache*, addr__t *obj*)

Definition at line 85 of file slab.c.

Referenced by vm__valloc().

```

85                                     {
86 }

```

4.12.2.6 void slab__prepare (slab__cache__t * *cache*, addr__t *page*)

Prepare a memory page for use as a slab.

Initialize fields of the slab header and create the free list.

Parameters:

cache slab cache to which the slab is to be added

page memory page from which to create a slab

ASSERTION: we assume "page" is the starting address of a page

ASSERTION: we assume at least one object can be allocated on slab

ASSERTION: we assume a physical memory page is mapped at "page"

Definition at line 93 of file slab.c.

References assert, slab_header_t::available, slab_header_t::free_list, NULL, slab__cache_t::obj_size, PAGE_MASK, PAGE_OFFSET_OF, PDE_OF, slab__cache_t::per_slab, PTE_OF, and VM_FLAG_PRESENT.

Referenced by `slab_alloc()`, and `vm_vfree_block()`.

```

93                                     {
94     unsigned int cx;
95     size_t obj_size;
96     count_t per_slab;
97     slab_header_t *slab;
98     addr_t *ptr;
99     addr_t next;
100
102     assert( PAGE_OFFSET_OF(page) == 0 );
103
105     assert( cache->per_slab > 0 );
106
108     assert( (*PDE_OF(page) & ~PAGE_MASK) != NULL && (*PDE_OF(page) & VM_FLAG_PRESENT) != 0 );
109     assert( (*PTE_OF(page) & ~PAGE_MASK) != NULL && (*PTE_OF(page) & VM_FLAG_PRESENT) != 0 );
110
111     obj_size = cache->obj_size;
112     per_slab = cache->per_slab;
113
114     /* initialize slab header */
115     slab = (slab_header_t *)page;
116     slab->available = per_slab;
117     slab->free_list = page + sizeof(slab_header_t);
118
119     /* create free list */
120     ptr = (addr_t *)slab->free_list;
121
122     for(cx = 0; cx < per_slab - 1; ++cx) {
123         next = ptr + obj_size;
124         *ptr = next;
125         ptr = (addr_t *)next;
126     }
127
128     *ptr = NULL;
129 }
```

4.12.2.7 void slab_remove (slab_header_t ** head, slab_header_t * slab)

Remove a slab from a linked list of slab.

Parameters:

head of list (typically `&C->empty`, `&C->partial` or `&C->full` of some cache C)

slab to remove from list

Definition at line 149 of file `slab.c`.

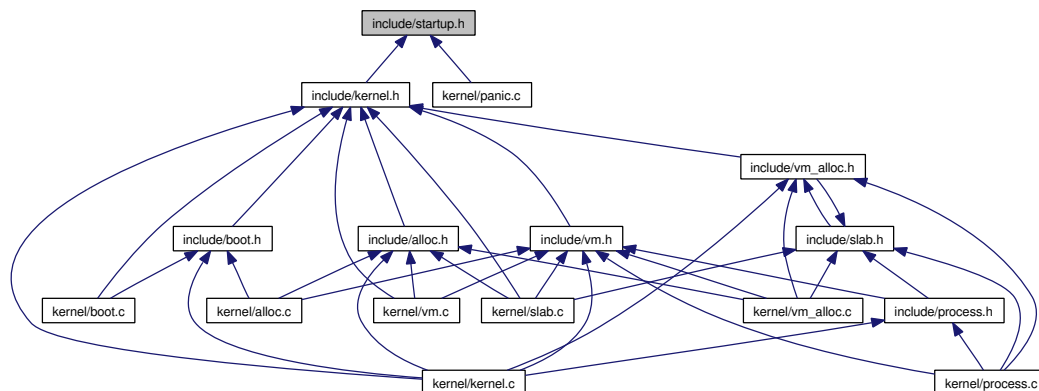
References `slab_header_t::next`, `NULL`, and `slab_header_t::prev`.

Referenced by `slab_alloc()`.

```
149                                     {
150     if(slab->next != NULL) {
151         slab->next->prev = slab->prev;
152     }
153
154     if(slab->prev != NULL) {
155         slab->prev->next = slab->next;
156     }
157     else {
158         *head = slab->next;
159     }
160 }
```

4.13 include/startup.h File Reference

This graph shows which files directly or indirectly include this file:



Defines

- `#define` **KERNEL_STACK_SIZE** 8192

Functions

- `void` **start** (void)
- `void` **halt** (void)

4.13.1 Define Documentation

4.13.1.1 `#define` **KERNEL_STACK_SIZE** 8192

Definition at line 4 of file startup.h.

4.13.2 Function Documentation

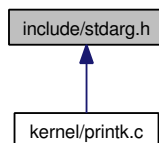
4.13.2.1 `void` **halt** (void)

Referenced by panic().

4.13.2.2 `void` **start** (void)

4.14 include/stdarg.h File Reference

This graph shows which files directly or indirectly include this file:



Defines

- `#define va_start(ap, parmN) __builtin_stdarg_start((ap), (parmN))`
- `#define va_arg __builtin_va_arg`
- `#define va_end __builtin_va_end`
- `#define va_copy(dest, src) __builtin_va_copy((dest), (src))`

Typedefs

- `typedef __builtin_va_list va_list`

4.14.1 Define Documentation

4.14.1.1 `#define va_arg __builtin_va_arg`

Definition at line 7 of file stdarg.h.

4.14.1.2 `#define va_copy(dest, src) __builtin_va_copy((dest), (src))`

Definition at line 9 of file stdarg.h.

4.14.1.3 `#define va_end __builtin_va_end`

Definition at line 8 of file stdarg.h.

4.14.1.4 `#define va_start(ap, parmN) __builtin_stdarg_start((ap), (parmN))`

Definition at line 6 of file stdarg.h.

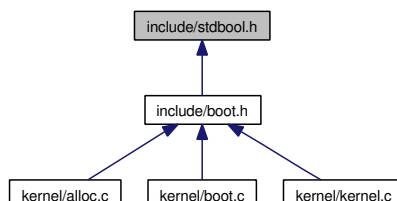
4.14.2 Typedef Documentation

4.14.2.1 typedef __builtin_va_list va_list

Definition at line 4 of file stdarg.h.

4.15 include/stdbool.h File Reference

This graph shows which files directly or indirectly include this file:



Defines

- `#define bool _Bool`
- `#define true 1`
- `#define false 0`
- `#define __bool_true_false_are_defined 1`

4.15.1 Define Documentation

4.15.1.1 `#define __bool_true_false_are_defined 1`

Definition at line 8 of file stdbool.h.

4.15.1.2 `#define bool _Bool`

Definition at line 4 of file stdbool.h.

4.15.1.3 `#define false 0`

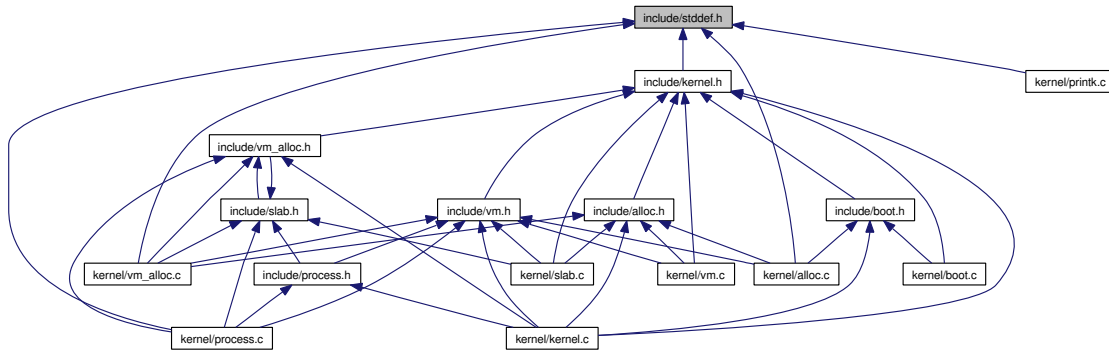
Definition at line 6 of file stdbool.h.

4.15.1.4 `#define true 1`

Definition at line 5 of file stdbool.h.

4.16 include/stddef.h File Reference

This graph shows which files directly or indirectly include this file:



Defines

- `#define NULL 0`
- `#define offsetof(type, member) ((size_t) &((type *)0) → member)`

Typedefs

- `typedef signed long ptrdiff_t`
- `typedef unsigned long size_t`
- `typedef int wchar_t`

4.16.1 Define Documentation

4.16.1.1 `#define NULL 0`

Definition at line 9 of file `stddef.h`.

Referenced by `kinit()`, `process_create()`, `process_find_by_pid()`, `slab_add()`, `slab_alloc()`, `slab_create()`, `slab_prepare()`, `slab_remove()`, `vm_create_pool()`, `vm_free()`, `vm_unmap()`, `vm_valloc()`, and `vm_vfree_block()`.

4.16.1.2 `#define offsetof(type, member) ((size_t) &((type *)0) → member)`

Definition at line 12 of file `stddef.h`.

4.16.2 Typedef Documentation

4.16.2.1 typedef signed long ptrdiff_t

Definition at line 4 of file stddef.h.

4.16.2.2 typedef unsigned long size_t

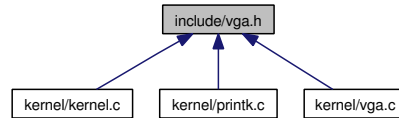
Definition at line 5 of file stddef.h.

4.16.2.3 typedef int wchar_t

Definition at line 6 of file stddef.h.

4.17 include/vga.h File Reference

This graph shows which files directly or indirectly include this file:



Defines

- #define **VGA_TEXT_VID_BASE** 0xb8000
- #define **VGA_MISC_OUT_WR** 0x3c2
- #define **VGA_MISC_OUT_RD** 0x3cc
- #define **VGA_CRTC_ADDR** 0x3d4
- #define **VGA_CRTC_DATA** 0x3d5
- #define **VGA_FB_FLAG_ACTIVE** 1
- #define **VGA_COLOR_BLACK** 0x00
- #define **VGA_COLOR_BLUE** 0x01
- #define **VGA_COLOR_GREEN** 0x02
- #define **VGA_COLOR_CYAN** 0x03
- #define **VGA_COLOR_RED** 0x04
- #define **VGA_COLOR_MAGENTA** 0x05
- #define **VGA_COLOR_BROWN** 0x06
- #define **VGA_COLOR_WHITE** 0x07
- #define **VGA_COLOR_GRAY** 0x08
- #define **VGA_COLOR_BRIGHTBLUE** 0x09
- #define **VGA_COLOR_BRIGHTGREEN** 0x0a
- #define **VGA_COLOR_BRIGHTCYAN** 0x0b
- #define **VGA_COLOR_BRIGHTRED** 0x0c
- #define **VGA_COLOR_BRIGHTMAGENTA** 0x0d
- #define **VGA_COLOR_YELLOW** 0x0e
- #define **VGA_COLOR_BRIGHTWHITE** 0x0f
- #define **VGA_COLOR_DEFAULT** VGA_COLOR_GREEN
- #define **VGA_COLOR_ERASE** VGA_COLOR_RED
- #define **VGA_LINES** 25
- #define **VGA_WIDTH** 80
- #define **VGA_TAB_WIDTH** 8
- #define **VGA_LINE(x)** ((x) / (VGA_WIDTH))
- #define **VGA_COL(x)** ((x) % (VGA_WIDTH))

Typedefs

- typedef unsigned int **vga_pos_t**

Functions

- void **vga_init** (void)
- void **vga_clear** (void)
- void **vga_print** (const char *message)
- void **vga_printn** (const char *message, unsigned int n)
- void **vga_putc** (char c)
- void **vga_scroll** (void)
- **vga_pos_t** **vga_get_cursor_pos** (void)
- void **vga_set_cursor_pos** (**vga_pos_t** pos)

4.17.1 Define Documentation

4.17.1.1 **#define VGA_COL(x) ((x) % (VGA_WIDTH))**

Definition at line 36 of file vga.h.

4.17.1.2 **#define VGA_COLOR_BLACK 0x00**

Definition at line 12 of file vga.h.

4.17.1.3 **#define VGA_COLOR_BLUE 0x01**

Definition at line 13 of file vga.h.

4.17.1.4 **#define VGA_COLOR_BRIGHTBLUE 0x09**

Definition at line 21 of file vga.h.

4.17.1.5 **#define VGA_COLOR_BRIGHTCYAN 0x0b**

Definition at line 23 of file vga.h.

4.17.1.6 **#define VGA_COLOR_BRIGHTGREEN 0x0a**

Definition at line 22 of file vga.h.

4.17.1.7 #define VGA_COLOR_BRIGHTMAGENTA 0x0d

Definition at line 25 of file vga.h.

4.17.1.8 #define VGA_COLOR_BRIGHTRED 0x0c

Definition at line 24 of file vga.h.

4.17.1.9 #define VGA_COLOR_BRIGHTWHITE 0x0f

Definition at line 27 of file vga.h.

4.17.1.10 #define VGA_COLOR_BROWN 0x06

Definition at line 18 of file vga.h.

4.17.1.11 #define VGA_COLOR_CYAN 0x03

Definition at line 15 of file vga.h.

4.17.1.12 #define VGA_COLOR_DEFAULT VGA_COLOR_GREEN

Definition at line 28 of file vga.h.

4.17.1.13 #define VGA_COLOR_ERASE VGA_COLOR_RED

Definition at line 29 of file vga.h.

Referenced by vga_clear(), and vga_scroll().

4.17.1.14 #define VGA_COLOR_GRAY 0x08

Definition at line 20 of file vga.h.

4.17.1.15 #define VGA_COLOR_GREEN 0x02

Definition at line 14 of file vga.h.

4.17.1.16 `#define VGA_COLOR_MAGENTA 0x05`

Definition at line 17 of file vga.h.

4.17.1.17 `#define VGA_COLOR_RED 0x04`

Definition at line 16 of file vga.h.

4.17.1.18 `#define VGA_COLOR_WHITE 0x07`

Definition at line 19 of file vga.h.

4.17.1.19 `#define VGA_COLOR_YELLOW 0x0e`

Definition at line 26 of file vga.h.

4.17.1.20 `#define VGA_CRTC_ADDR 0x3d4`

Definition at line 7 of file vga.h.

Referenced by `vga_get_cursor_pos()`, `vga_init()`, and `vga_set_cursor_pos()`.

4.17.1.21 `#define VGA_CRTC_DATA 0x3d5`

Definition at line 8 of file vga.h.

Referenced by `vga_get_cursor_pos()`, `vga_init()`, and `vga_set_cursor_pos()`.

4.17.1.22 `#define VGA_FB_FLAG_ACTIVE 1`

Definition at line 10 of file vga.h.

4.17.1.23 `#define VGA_LINE(x) ((x) / (VGA_WIDTH))`

Definition at line 35 of file vga.h.

4.17.1.24 `#define VGA_LINES 25`

Definition at line 31 of file vga.h.

Referenced by `vga_clear()`, and `vga_scroll()`.

4.17.1.25 `#define VGA_MISC_OUT_RD 0x3cc`

Definition at line 6 of file `vga.h`.

Referenced by `vga_init()`.

4.17.1.26 `#define VGA_MISC_OUT_WR 0x3c2`

Definition at line 5 of file `vga.h`.

Referenced by `vga_init()`.

4.17.1.27 `#define VGA_TAB_WIDTH 8`

Definition at line 33 of file `vga.h`.

4.17.1.28 `#define VGA_TEXT_VID_BASE 0xb8000`

Definition at line 4 of file `vga.h`.

Referenced by `vga_clear()`, and `vga_scroll()`.

4.17.1.29 `#define VGA_WIDTH 80`

Definition at line 32 of file `vga.h`.

Referenced by `vga_clear()`, and `vga_scroll()`.

4.17.2 Typedef Documentation

4.17.2.1 `typedef unsigned int vga_pos_t`

Definition at line 38 of file `vga.h`.

4.17.3 Function Documentation

4.17.3.1 `void vga_clear (void)`

Definition at line 25 of file `vga.c`.

References `VGA_COLOR_ERASE`, `VGA_LINES`, `VGA_TEXT_VID_BASE`, and `VGA_WIDTH`.

Referenced by `vga_init()`.

```

25         {
26     unsigned char *buffer = (unsigned char *)VGA_TEXT_VID_BASE;
27     unsigned int idx = 0;
28
29     while( idx < (VGA_LINES * VGA_WIDTH * 2) ) {
30         buffer[idx++] = 0x20;
31         buffer[idx++] = VGA_COLOR_ERASE;
32     }
33 }
```

4.17.3.2 `vga_pos_t vga_get_cursor_pos (void)`

Definition at line 50 of file `vga.c`.

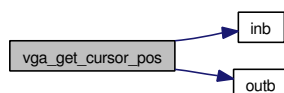
References `inb()`, `outb()`, `VGA_CRTC_ADDR`, and `VGA_CRTC_DATA`.

Referenced by `vga_print()`, `vga_printn()`, and `vga_putc()`.

```

50                                     {
51     unsigned char h, l;
52
53     outb(VGA_CRTC_ADDR, 0x0e);
54     h = inb(VGA_CRTC_DATA);
55     outb(VGA_CRTC_ADDR, 0x0f);
56     l = inb(VGA_CRTC_DATA);
57
58     return (h << 8) | l;
59 }
```

Here is the call graph for this function:



4.17.3.3 `void vga_init (void)`

Definition at line 7 of file `vga.c`.

References `inb()`, `outb()`, `vga_clear()`, `VGA_CRTC_ADDR`, `VGA_CRTC_DATA`, `VGA_MISC_OUT_RD`, and `VGA_MISC_OUT_WR`.

Referenced by `kinit()`.

```

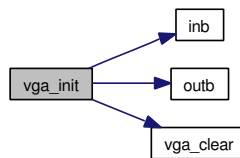
7     {
```

```

8   unsigned char data;
9
10  /* Set address select bit in a known state: CRTC regs at 0x3dx */
11  data = inb(VGA_MISC_OUT_RD);
12  data |= 1;
13  outb(VGA_MISC_OUT_WR, data);
14
15  /* Move cursor to line 0 col 0 */
16  outb(VGA_CRTC_ADDR, 0x0e);
17  outb(VGA_CRTC_DATA, 0x0);
18  outb(VGA_CRTC_ADDR, 0x0f);
19  outb(VGA_CRTC_DATA, 0x0);
20
21  /* Clear the screen */
22  vga_clear();
23 }

```

Here is the call graph for this function:



4.17.3.4 void vga_print (const char * message)

Definition at line 72 of file `vga.c`.

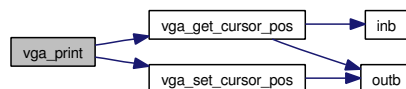
References `vga_get_cursor_pos()`, and `vga_set_cursor_pos()`.

```

72  {
73  unsigned short int pos = vga_get_cursor_pos();
74  char c;
75
76  while( (c = *(message++)) ) {
77      pos = vga_raw_putc(c, pos);
78  }
79
80  vga_set_cursor_pos(pos);
81 }

```

Here is the call graph for this function:



4.17.3.5 void vga_printn (const char * *message*, unsigned int *n*)

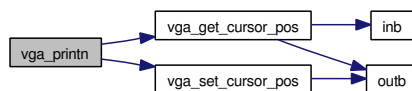
Definition at line 83 of file vga.c.

References `vga_get_cursor_pos()`, and `vga_set_cursor_pos()`.

```

83                                     {
84     vga_pos_t pos = vga_get_cursor_pos();
85     char c;
86
87     while(n) {
88         c = *(message++);
89         pos = vga_raw_putc(c, pos);
90         --n;
91     }
92
93     vga_set_cursor_pos(pos);
94 }
```

Here is the call graph for this function:



4.17.3.6 void vga_putc (char *c*)

Definition at line 96 of file vga.c.

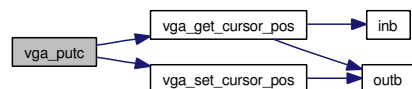
References `vga_get_cursor_pos()`, and `vga_set_cursor_pos()`.

Referenced by `print_hex_nibble()`, and `print_unsigned_int()`.

```

96     {
97     vga_pos_t pos = vga_get_cursor_pos();
98
99     pos = vga_raw_putc(c, pos);
100
101     vga_set_cursor_pos(pos);
102 }
```

Here is the call graph for this function:



4.17.3.7 void vga_scroll (void)

Definition at line 35 of file vga.c.

References VGA_COLOR_ERASE, VGA_LINES, VGA_TEXT_VID_BASE, and VGA_WIDTH.

```

35      {
36      unsigned char *di = (unsigned char *)VGA_TEXT_VID_BASE;
37      unsigned char *si = (unsigned char *) (VGA_TEXT_VID_BASE + 2 * VGA_WIDTH);
38      unsigned int idx;
39
40      for(idx = 0; idx < 2 * VGA_WIDTH * (VGA_LINES - 1); ++idx) {
41          *(di++) = *(si++);
42      }
43
44      for(idx = 0; idx < VGA_WIDTH; ++idx) {
45          *(di++) = 0x20;
46          *(di++) = VGA_COLOR_ERASE;
47      }
48 }
```

4.17.3.8 void vga_set_cursor_pos (vga_pos_t pos)

Definition at line 61 of file vga.c.

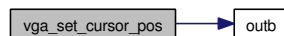
References outb(), VGA_CRTC_ADDR, and VGA_CRTC_DATA.

Referenced by vga_print(), vga_printn(), and vga_putc().

```

61      {
62      unsigned char h = pos >> 8;
63      unsigned char l = pos;
64
65      outb(VGA_CRTC_ADDR, 0x0e);
66      outb(VGA_CRTC_DATA, h);
67      outb(VGA_CRTC_ADDR, 0x0f);
68      outb(VGA_CRTC_DATA, l);
69 }
```

Here is the call graph for this function:

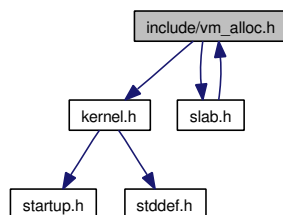


4.18 include/vm_alloc.h File Reference

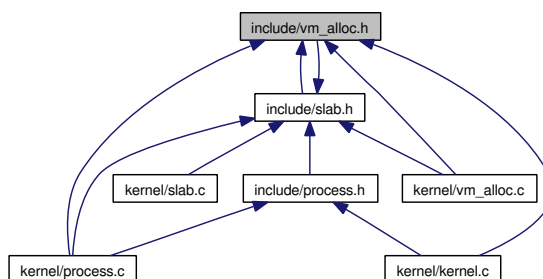
```
#include <kernel.h>
```

```
#include <slab.h>
```

Include dependency graph for vm_alloc.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct **vm_link_t**
links forming the linked lists of free virtual memory pages
- struct **vm_alloc_t**
data structure which keep tracks of free pages in a region of virtual memory

Typedefs

- typedef struct **vm_link_t** **vm_link_t**
- typedef struct **vm_alloc_t** **vm_alloc_t**

Functions

- void **vm_create_pool** (**vm_alloc_t** *pool, struct **slab_cache_t** *cache)
- **addr_t** **vm_valloc** (**vm_alloc_t** *pool)
Allocate a page of virtual memory (not backed by physical memory).
- void **vm_vfree** (**vm_alloc_t** *pool, **addr_t** addr)
Return a single page of virtual memory to a pool of available pages.
- void **vm_vfree_block** (**vm_alloc_t** *pool, **addr_t** addr, **size_t** size)
Return a block of contiguous virtual memory pages to a pool of available pages.
- **addr_t** **vm_alloc** (**vm_alloc_t** *pool, unsigned long flags)
Allocate a physical memory page and map it in virtual memory.
- void **vm_free** (**vm_alloc_t** *pool, **addr_t** addr)
*Free a physical page mapped in virtual memory (which was typically obtained through a call to **vm_map()** (p. 46)).*

Variables

- struct **vm_alloc_t** **global_pool**
- struct **slab_cache_t** **global_pool_cache**

4.18.1 Typedef Documentation

4.18.1.1 typedef struct **vm_alloc_t** **vm_alloc_t**

Definition at line 34 of file **vm_alloc.h**.

4.18.1.2 typedef struct **vm_link_t** **vm_link_t**

Definition at line 19 of file **vm_alloc.h**.

4.18.2 Function Documentation

4.18.2.1 `addr_t vm_alloc (vm_alloc_t * pool, unsigned long flags)`

Allocate a physical memory page and map it in virtual memory.

Parameters:

pool data structure managing the virtual memory region in which page will be mapped

flags flags for page mapping (passed as-is to **`vm_map()`** (p. 46))

TODO: handle the NULL pointer

Definition at line 146 of file `vm_alloc.c`.

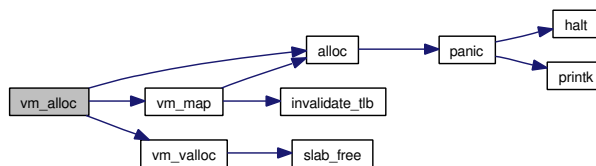
References `alloc()`, `PAGE_SIZE`, `vm_map()`, and `vm_valloc()`.

Referenced by `slab_alloc()`.

```

146                                     {
147     addr_t paddr, vaddr;
148
151     vaddr = vm_valloc(pool);
152     paddr = alloc(PAGE_SIZE);
153     vm_map(vaddr, paddr, flags);
154
155     return vaddr;
156 }
```

Here is the call graph for this function:



4.18.2.2 `void vm_create_pool (vm_alloc_t * pool, struct slab_cache_t * cache)`

Definition at line 13 of file `vm_alloc.c`.

References `vm_alloc_t::cache`, `vm_alloc_t::head`, `NULL`, and `vm_alloc_t::size`.

Referenced by `kinit()`.


```
13                                     {
14     pool->size = 0;
15     pool->head = NULL;
16     pool->cache = cache;
17 }
```

4.18.2.3 void vm_free (vm_alloc_t * *pool*, addr_t *addr*)

Free a physical page mapped in virtual memory (which was typically obtained through a call to **vm_map()** (p. 46)).

The physical memory is freed and the virtual page is returned to the virtual address space allocator.

Parameters:

pool data structure managing the virtual memory region to which the page is returned address of page to free

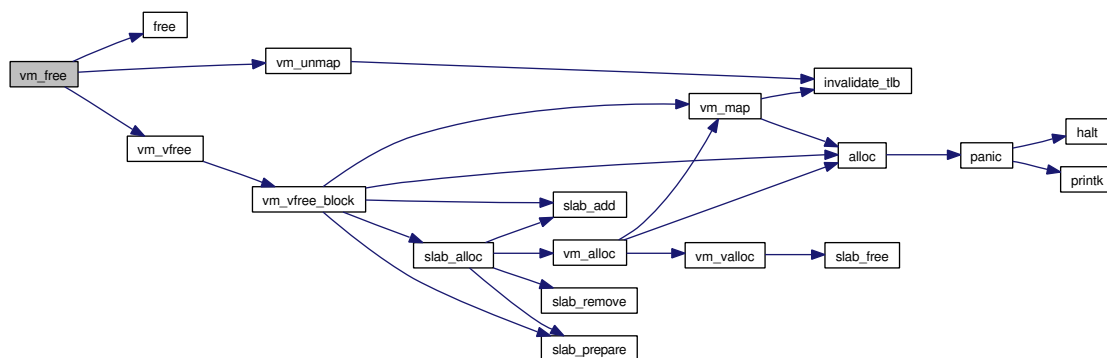
ASSERTION: address of page should not be the null pointer

Definition at line 165 of file vm_alloc.c.

References `assert()`, `free()`, `NULL`, `PAGE_MASK`, `PTE_OF`, `vm_unmap()`, and `vm_vfree()`.

```
165                                     {
166     addr_t paddr;
167
168     assert( addr != (addr_t)NULL );
169
170     paddr = (addr_t)(PTE_OF(addr) | ~PAGE_MASK);
171
172     vm_unmap(addr);
173     vm_vfree(pool, addr);
174     free(paddr);
175 }
176 }
```

Here is the call graph for this function:



4.18.2.4 `addr_t vm_valloc (vm_alloc_t * pool)`

Allocate a page of virtual memory (not backed by physical memory).

This page may then be used for temporary mappings, for example. Page is allocated from a specific virtual memory region managed by a `vm_alloc_t` (p. 17) data structure.

Parameters:

pool data structure managing the virtual memory region from which to allocate

Returns:

address of allocated page

ASSERTION: block size should be an integer number of pages

ASSERTION: returned address should be aligned with a page boundary

Definition at line 28 of file `vm_alloc.c`.

References `vm_link_t::addr`, `assert`, `vm_alloc_t::cache`, `vm_alloc_t::head`, `vm_link_t::next`, `NULL`, `PAGE_OFFSET_OF`, `PAGE_SIZE`, `vm_link_t::size`, and `slab_free()`.

Referenced by `vm_alloc()`.

```

28                                     {
29     addr_t addr;
30     vm_link_t *head;
31     size_t size;

```

```

32
33     head = pool->head;
34
35     /* no page available */
36     if(head == (addr_t)NULL) {
37         return (addr_t)NULL;
38     }
39
40     addr = head->addr;
41     size = head->size - PAGE_SIZE;
42
43     assert( PAGE_OFFSET_OF(size) == 0 );
44
45     /* if block is made of only one page, we remove it from the free list */
46     if(size == 0) {
47         pool->head = head->next;
48         slab_free(pool->cache, head);
49     }
50     else {
51         head->size = size;
52         head->addr += PAGE_SIZE;
53     }
54
55     assert( PAGE_OFFSET_OF(addr) == 0 );
56
57     return addr;
58 }

```

Here is the call graph for this function:



4.18.2.5 void vm_vfree (vm_alloc_t * pool, addr_t addr)

Return a single page of virtual memory to a pool of available pages.

Should not be used to free pages to which physical memory is still mapped (no physical memory is freed by this function). Use this function to return pages obtained by a call to **vm_valloc()** (p. 94) (and not **vm_alloc()** (p. 92)).

Parameters:

pool data structure managing the relevant virtual memory region

addr address of virtual page which must be freed

Definition at line 70 of file vm_alloc.c.

References PAGE_SIZE, and vm_vfree_block().

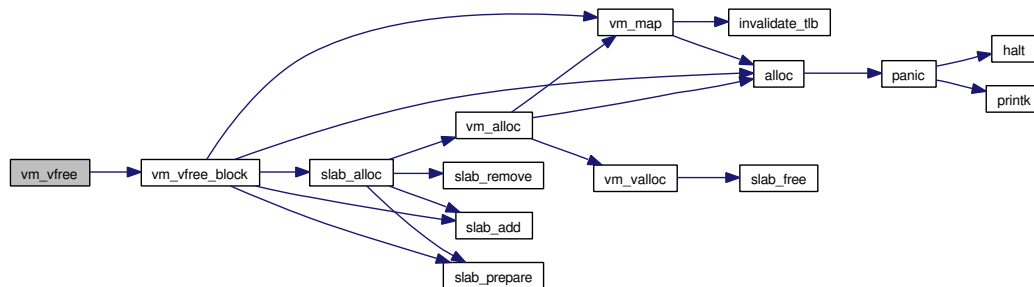
Referenced by vm_free().

```

70                                     {
71     vm_vfree_block(pool, addr, PAGE_SIZE);
72 }

```

Here is the call graph for this function:



4.18.2.6 void vm_vfree_block (vm_alloc_t * pool, addr_t addr, size_t size)

Return a block of contiguous virtual memory pages to a pool of available pages.

Should not be used to free pages to which physical memory is still mapped (no physical memory is freed by this function).

Parameters:

pool data structure managing the relevant virtual memory region

addr starting address of virtual memory block

size size of block

ASSERTION: we assume starting address is aligned on a page boundary

ASSERTION: we assume size of block is an integer number of pages

ASSERTION: address of block should not be the null pointer

Definition at line 82 of file vm_alloc.c.

References vm_link_t::addr, alloc(), assert, vm_alloc_t::cache, slab_cache_t::empty, vm_alloc_t::head, vm_link_t::next, NULL, PAGE_OFFSET_OF, PAGE_SIZE, slab_cache_t::partial, vm_link_t::size, slab_add(), slab_alloc(), slab_prepare(), slab_cache_t::vm_allocator, VM_FLAG_KERNEL, and vm_map().

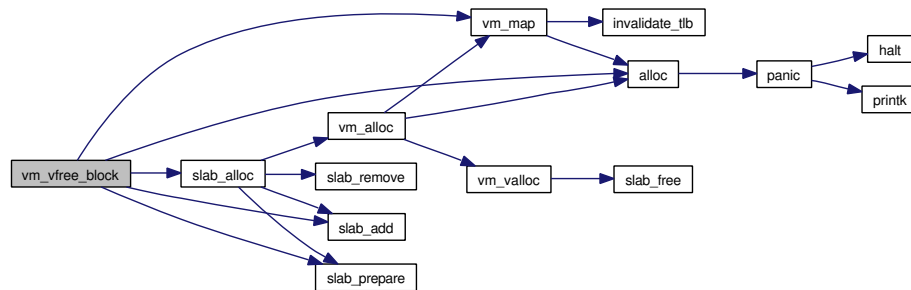
Referenced by vm_vfree().

```

82                                     {
83     addr_t phys_page;
84     vm_link_t *link;
85
86     assert( PAGE_OFFSET_OF(addr) == 0 );
87
88     assert( PAGE_OFFSET_OF(size) == 0 );
89
90     assert( addr != (addr_t)NULL );
91
92     /* The virtual address space allocator needs a slab cache from which to
93        allocate data structures for its free list. Also, each slab cache needs
94        a virtual address space allocator to allocate slabs when needed.
95
96        There can be a mutual dependency between the virtual address space
97        allocator and the slab cache. This is not a problem in general, but a
98        special bootstrapping procedure is needed for initialization of the
99        virtual address space allocator in that case. The virtual address space
100        allocator will actually "donate" a virtual page (backed by physical ram)
101        to the cache for use as a slab.
102
103        This case is handled here
104    */
105    if(pool->head == NULL) {
106        if(pool->cache->vm_allocator == pool) {
107            if(pool->cache->empty == NULL && pool->cache->partial == NULL) {
108                /* allocate a physical page for slab */
109                phys_page = alloc(PAGE_SIZE);
110
111                /* map page */
112                vm_map(addr, phys_page, VM_FLAG_KERNEL);
113
114                /* prepare the slab and add it to cache empty list */
115                slab_prepare(pool->cache, addr);
116                slab_add(&pool->cache->empty, addr);
117
118                size -= PAGE_SIZE;
119
120                /* if the block contained only one page, we have nothing left
121                   to free */
122                if(size == 0) {
123                    return;
124                }
125
126                addr += PAGE_SIZE;
127            }
128        }
129    }
130
131    link = (vm_link_t *)slab_alloc(pool->cache);
132    link->size = size;
133    link->addr = addr;
134
135    link->next = pool->head;
136    pool->head = link;
137 }

```

Here is the call graph for this function:



4.18.3 Variable Documentation

4.18.3.1 struct vm_alloc_t global_pool

Definition at line 8 of file `vm_alloc.c`.

Referenced by `kinit()`.

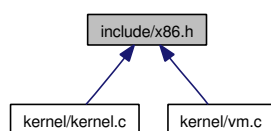
4.18.3.2 struct slab_cache_t global_pool_cache

Definition at line 10 of file `vm_alloc.c`.

Referenced by `kinit()`.

4.19 include/x86.h File Reference

This graph shows which files directly or indirectly include this file:



Defines

- `#define X86_FLAG_PG 31`

Functions

- void **invalidate_tlb** (**addr_t** vaddr)
- unsigned long **get_cr0** (void)
- unsigned long **get_cr1** (void)
- unsigned long **get_cr2** (void)
- unsigned long **get_cr3** (void)
- unsigned long **get_cr4** (void)
- void **set_cr0** (unsigned long val)
- void **set_cr0x** (unsigned long val)
- void **set_cr1** (unsigned long val)
- void **set_cr2** (unsigned long val)
- void **set_cr3** (unsigned long val)
- void **set_cr4** (unsigned long val)

4.19.1 Define Documentation

4.19.1.1 `#define X86_FLAG_PG 31`

Definition at line 4 of file x86.h.

4.19.2 Function Documentation

4.19.2.1 unsigned long get_cr0 (void)

4.19.2.2 unsigned long get_cr1 (void)

4.19.2.3 unsigned long get_cr2 (void)

4.19.2.4 unsigned long get_cr3 (void)

4.19.2.5 unsigned long get_cr4 (void)

4.19.2.6 void invalidate_tlb (addr_t *vaddr*)

Referenced by vm_map(), and vm_unmap().

4.19.2.7 void set_cr0 (unsigned long *val*)

4.19.2.8 void set_cr0x (unsigned long *val*)

4.19.2.9 void set_cr1 (unsigned long *val*)

4.19.2.10 void set_cr2 (unsigned long *val*)

4.19.2.11 void set_cr3 (unsigned long *val*)

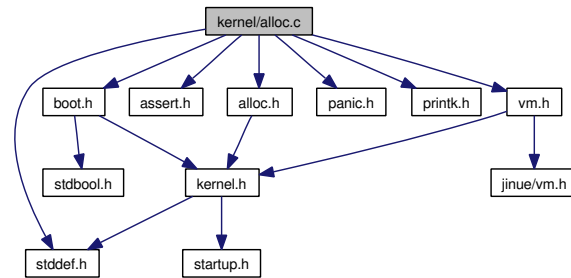
Referenced by kinit().

4.19.2.12 void set_cr4 (unsigned long *val*)

4.20 kernel/alloc.c File Reference

```
#include <alloc.h>
#include <assert.h>
#include <boot.h>
#include <panic.h>
#include <printk.h>
#include <stddef.h>
#include <vm.h>
```

Include dependency graph for alloc.c:



Functions

- void **alloc_init** (void)
- **addr_t** **alloc** (size_t size)
- void **free** (addr_t addr)

4.20.1 Function Documentation

4.20.1.1 addr_t alloc (size_t size)

ASSERTION: returned address should be aligned with a page boundary

Definition at line 97 of file alloc.c.

References `assert`, `PAGE_BITS`, `PAGE_MASK`, `PAGE_SIZE`, and `panic()`.

Referenced by `vm_alloc()`, `vm_map()`, and `vm_vfree_block()`.

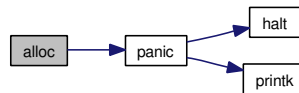
```
97     {
98     addr_t addr;
```

```

99     size_t pages;
100
101     pages = size >> PAGE_BITS;
102
103     if( (size & PAGE_MASK) != 0 ) {
104         ++pages;
105     }
106
107     if(_alloc_size < pages) {
108         panic("out of memory.");
109     }
110
111     addr = _alloc_addr;
112     _alloc_addr += pages * PAGE_SIZE;
113     _alloc_size -= pages;
114
116     assert( ((unsigned long)addr & PAGE_MASK) == 0 );
117
118     return addr;
119 }

```

Here is the call graph for this function:



4.20.1.2 void alloc_init (void)

Definition at line 13 of file alloc.c.

References e820_get_addr(), e820_get_size(), e820_get_type(), e820_is_available(), e820_is_valid(), kernel_region_top, kernel_start, PAGE_SIZE, panic(), and printk().

Referenced by kinit().

```

13     {
14         unsigned int idx;
15         unsigned int remainder;
16         bool avail;
17         size_t size;
18         e820_type_t type;
19         addr_t addr, fixed_addr, best_addr;
20         size_t fixed_size, best_size;
21
22         idx = 0;
23         best_size = 0;
24
25         /*printk("Dump of the BIOS memory map:\n");

```

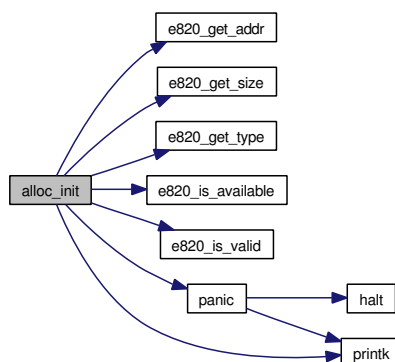
```
26     printk(" address size      type\n");*/
27     while( e820_is_valid(idx) ) {
28         addr = e820_get_addr(idx);
29         size = e820_get_size(idx);
30         type = e820_get_type(idx);
31         avail = e820_is_available(idx);
32
33         ++idx;
34
35         /*printk("(%x) %c %x %x %s\n",
36             avail?'*':' ',
37             addr,
38             size,
39             e820_type_description(type) );*/
40
41         if( !avail ) {
42             continue;
43         }
44
45         fixed_addr = addr;
46         fixed_size = size;
47
48         /* is the region completely under the kernel ? */
49         if(addr + size > kernel_start) {
50             /* is the region completely above the kernel ? */
51             if(addr < kernel_region_top) {
52                 /* if the region touches the kernel, we take only
53                  * the part above the kernel, if there is one... */
54                 if(addr + size <= kernel_region_top) {
55                     /* ... and apparently, there is none */
56                     continue;
57                 }
58
59                 fixed_addr = kernel_region_top;
60                 fixed_size -= fixed_addr - addr;
61             }
62         }
63
64         /* we must make sure the starting address is aligned on a
65          * page boundary. The size will eventually be divided
66          * by the page size, and thus need not be aligned. */
67         remainder = (unsigned int)fixed_addr % PAGE_SIZE;
68         if(remainder != 0) {
69             remainder = PAGE_SIZE - remainder;
70             if(fixed_size < remainder) {
71                 continue;
72             }
73
74             fixed_addr += remainder;
75             fixed_size -= remainder;
76         }
77
78         if(fixed_size > best_size) {
79             best_addr = fixed_addr;
80             best_size = fixed_size;
81         }
82     }
```

```

83
84     _alloc_addr = (addr_t)best_addr;
85     _alloc_size = best_size / PAGE_SIZE;
86
87     if(_alloc_size == 0) {
88         panic("no memory to allocate.");
89     }
90
91     printk("%u kilobytes (%u pages) available starting at %xh.\n",
92           _alloc_size * PAGE_SIZE / 1024,
93           _alloc_size,
94           _alloc_addr );
95 }

```

Here is the call graph for this function:



4.20.1.3 void free (addr_t addr)

ASSERTION: we assume starting address is aligned on a page boundary

Definition at line 121 of file alloc.c.

References `assert`, and `PAGE_OFFSET_OF`.

Referenced by `vm_free()`.

```

121     {
122         assert( PAGE_OFFSET_OF(addr) == 0 );
123     }

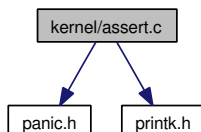
```

4.21 kernel/assert.c File Reference

```
#include <panic.h>
```

```
#include <printk.h>
```

Include dependency graph for assert.c:



Functions

- void **__assert_failed** (const char **expr*, const char **file*, unsigned int *line*, const char **func*)

4.21.1 Function Documentation

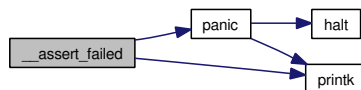
4.21.1.1 void **__assert_failed** (const char * *expr*, const char * *file*, unsigned int *line*, const char * *func*)

Definition at line 5 of file assert.c.

References panic(), and printk().

```
9             {
10
11     printk(
12         "ASSERTION FAILED [%s]: %s at line %u in function %s.\n",
13         expr, file, line, func );
14
15     panic("Assertion failed.");
16 }
```

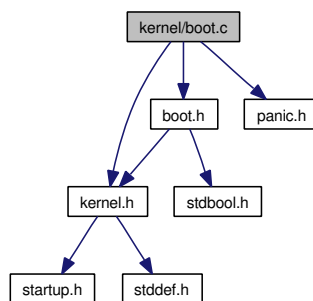
Here is the call graph for this function:



4.22 kernel/boot.c File Reference

```
#include <boot.h>
#include <kernel.h>
#include <panic.h>
```

Include dependency graph for boot.c:



Functions

- **addr_t e820_get_addr** (unsigned int idx)
- **size_t e820_get_size** (unsigned int idx)
- **e820_type_t e820_get_type** (unsigned int idx)
- **bool e820_is_valid** (unsigned int idx)
- **bool e820_is_available** (unsigned int idx)
- **const char * e820_type_description** (e820_type_t type)
- **boot_t * get_boot_data** (void)

Variables

- **e820_t * e820_map**
- **addr_t boot_data**

4.22.1 Function Documentation

4.22.1.1 addr_t e820_get_addr (unsigned int *idx*)

Definition at line 8 of file boot.c.

Referenced by alloc_init().

```
8             {
9     return (addr_t)(unsigned long)e820_map[idx].addr;
10 }
```

4.22.1.2 size_t e820_get_size (unsigned int *idx*)

Definition at line 12 of file boot.c.

References e820_t::size.

Referenced by alloc_init().

```
12             {
13     return (size_t)e820_map[idx].size;
14 }
```

4.22.1.3 e820_type_t e820_get_type (unsigned int *idx*)

Definition at line 16 of file boot.c.

References e820_t::type.

Referenced by alloc_init().

```
16             {
17     return e820_map[idx].type;
18 }
```

4.22.1.4 bool e820_is_available (unsigned int *idx*)

Definition at line 24 of file boot.c.

References E820_RAM.

Referenced by alloc_init().

```
24             {
25     return (e820_map[idx].type == E820_RAM);
26 }
```

4.22.1.5 bool e820_is_valid (unsigned int *idx*)

Definition at line 20 of file boot.c.

Referenced by alloc_init().

```
20                                     {
21     return (e820_map[idx].size != 0);
22 }
```

4.22.1.6 `const char* e820__type__description (e820__type__t type)`

Definition at line 28 of file boot.c.

References `E820__ACPI`, `E820__RAM`, and `E820__RESERVED`.

```
28                                     {
29     switch(type) {
30
31     case E820_RAM:
32         return "available";
33
34     case E820_RESERVED:
35         return "unavailable/reserved";
36
37     case E820_ACPI:
38         return "unavailable/acpi";
39
40     default:
41         return "unavailable/other";
42     }
43 }
```

4.22.1.7 `boot_t* get__boot__data (void)`

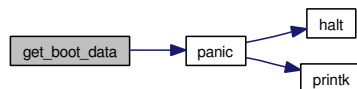
Definition at line 45 of file boot.c.

References `boot_data`, `BOOT_MAGIC`, `BOOT_SIGNATURE`, `boot_t::magic`, `panic()`, and `boot_t::signature`.

Referenced by `kinit()`.

```
45                                     {
46     boot_t *boot;
47
48     boot = (boot_t *)boot_data;
49
50     if(boot->signature != BOOT_SIGNATURE) {
51         panic("bad boot sector signature.");
52     }
53
54     if(boot->magic != BOOT_MAGIC) {
55         panic("bad boot sector magic.");
56     }
57
58     return boot;
59 }
```


Here is the call graph for this function:



4.22.2 Variable Documentation

4.22.2.1 `addr_t boot_data`

Definition at line 6 of file `boot.c`.

Referenced by `get_boot_data()`.

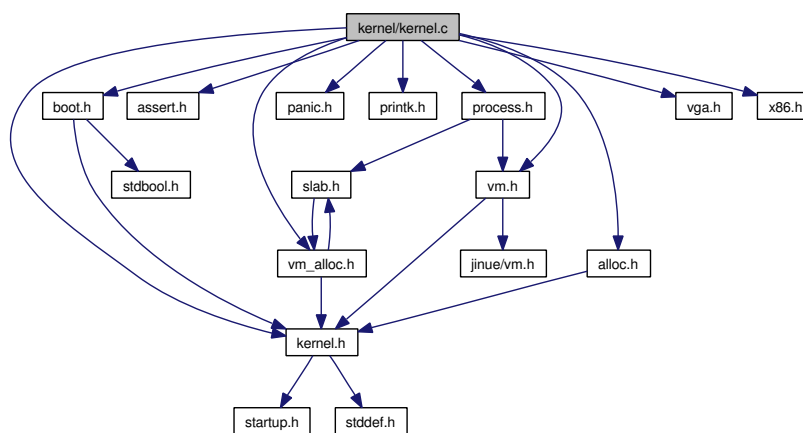
4.22.2.2 `e820_t* e820_map`

Definition at line 5 of file `boot.c`.

4.23 kernel/kernel.c File Reference

```
#include <alloc.h>
#include <assert.h>
#include <boot.h>
#include <kernel.h>
#include <panic.h>
#include <printk.h>
#include <process.h>
#include <vga.h>
#include <vm.h>
#include <vm_alloc.h>
#include <x86.h>
```

Include dependency graph for kernel.c:



Functions

- void **kernel** (void)
- void **kinit** (void)
- void **idle** (void)

Variables

- **size_t kernel_size**
size of the kernel image
- **addr_t kernel_top**
address of top of kernel image (`kernel_start + kernel_size`)
- **addr_t kernel_region_top**
top of region of memory mapped 1:1 (kernel image plus some pages for data structures allocated during initialization)
- **process_t idle_process**
process descriptor for first process (idle)

4.23.1 Function Documentation

4.23.1.1 void idle (void)

Definition at line 252 of file kernel.c.

Referenced by `kernel()`.

```
252         {  
253     while(1) {}  
254 }
```

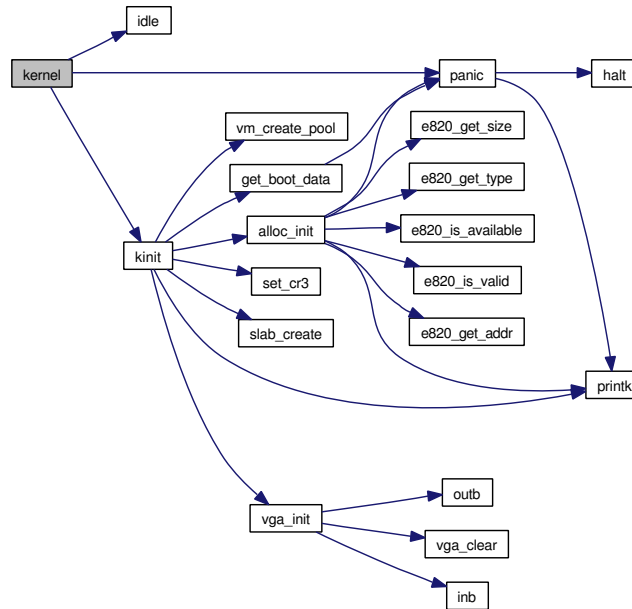
4.23.1.2 void kernel (void)

Definition at line 28 of file kernel.c.

References `idle()`, `kinit()`, and `panic()`.

```
28         {  
29     kinit();  
30     idle();  
31  
32     panic("idle() returned.");  
33 }
```

Here is the call graph for this function:



4.23.1.3 void kinit (void)

ASSERTION: we assume the kernel starts on a page boundary

ASSERTION: we assume kernel_start is aligned with a page directory entry boundary

ASSERTION: we assume kernel_start is aligned with a page directory entry boundary

TODO: remove

TODO: remove

TODO: /remove

Definition at line 35 of file kernel.c.

References alloc_init(), assert, process_t::cr3, first_process, get_boot_data(), global_pool, global_pool_cache, kernel_region_top, kernel_size, kernel_start, KLIMIT, process_t::name, process_t::next, next_pid, NULL, PAGE_DIRECTORY_ADDR, PAGE_DIRECTORY_OFFSET_OF, page_directory_template, PAGE_MASK, PAGE_OFFSET_OF, PAGE_SIZE, PAGE_TABLE_ENTRIES, PAGE_TABLE_OFFSET_OF, PAGE_TABLES_ADDR, process_t::pid, printk(), PROCESS_NAME_LENGTH,

process_slab_cache, set_cr3(), slab_create(), vga_init(), vm_create_pool(), VM_FLAG_KERNEL, VM_FLAG_PRESENT, VM_FLAG_READ_WRITE, VM_FLAG_USER, and VM_FLAGS_PAGE_TABLE.

Referenced by kernel().

```

35         {
36     pte_t *page_table1, *page_table2, *page_directory;
37     pte_t *pte;
38     addr_t addr;
39     unsigned long idx, idy;
40     unsigned long temp;
41
42     /* say hello */
43     vga_init();
44     printk("Kernel started.\n");
45
46     assert( PAGE_OFFSET_OF( (unsigned int)kernel_start ) == 0 );
47
48     assert( PAGE_TABLE_OFFSET_OF(PAGE_TABLES_ADDR) == 0 );
49     assert( PAGE_OFFSET_OF(PAGE_TABLES_ADDR) == 0 );
50
51     assert( PAGE_TABLE_OFFSET_OF(PAGE_DIRECTORY_ADDR) == 0 );
52     assert( PAGE_OFFSET_OF(PAGE_DIRECTORY_ADDR) == 0 );
53
54     printk("Kernel size is %u bytes.\n", kernel_size);
55
56     printk("kernel_region_top on entry: 0x%x\n", (unsigned long)kernel_region_top );
57
58     /* initialize data structures for caches and the global virtual page allocator */
59     slab_create(
60         &global_pool_cache,
61         &global_pool,
62         sizeof(vm_link_t),
63         VM_FLAG_KERNEL);
64
65     vm_create_pool(&global_pool, &global_pool_cache);
66
67     slab_create(&process_slab_cache, &global_pool,
68         sizeof(process_t), VM_FLAG_KERNEL);
69
70     /* allocate one page for page directory template just after the
71     kernel image. Since paging is not yet activated, virtual and
72     physical address are the same. */
73     page_directory_template = (pte_t *)kernel_region_top;
74     kernel_region_top += PAGE_SIZE;
75
76     /* allocate page tables for kernel data/code region (0..KLIMIT) and add
77     relevant entries to page directory template */
78     for(idx = 0; idx < PAGE_DIRECTORY_OFFSET_OF(KLIMIT); ++idx) {
79         page_table1 = kernel_region_top;
80         kernel_region_top += PAGE_SIZE;
81
82         page_directory_template[idx] = (pte_t)page_table1 | VM_FLAG_PRESENT | VM_FLAG_KERNEL;
83
84         for(idy = 0; idy < PAGE_TABLE_ENTRIES; ++idy) {
85             page_table1[idy] = 0;
86         }
87     }
88 }
89
```

```

90     }
91 }
92
93 while(idx < PAGE_TABLE_ENTRIES) {
94     page_directory_template[idx] = 0;
95     ++idx;
96 }
97
98 /* allocate and fill content of a page directory and two page tables
99    for the creation of the address space of the first process (idle) */
100 page_directory = kernel_region_top;
101 kernel_region_top += PAGE_SIZE;
102
103 page_table1 = kernel_region_top;
104 kernel_region_top += PAGE_SIZE;
105
106 page_table2 = kernel_region_top;
107 kernel_region_top += PAGE_SIZE;
108
109 for(idx = 0; idx < PAGE_TABLE_ENTRIES; ++idx) {
110     temp = page_directory_template[idx];
111     page_directory[idx] = temp;
112     page_table1[idx] = temp;
113 }
114
115 page_directory[PAGE_DIRECTORY_OFFSET_OF(PAGE_TABLES_ADDR)] =
116     (pte_t)page_table1 | VM_FLAG_PRESENT | VM_FLAG_USER | VM_FLAG_READ_WRITE;
117
118 page_directory[PAGE_DIRECTORY_OFFSET_OF(PAGE_DIRECTORY_ADDR)] =
119     (pte_t)page_table2 | VM_FLAG_PRESENT | VM_FLAG_USER | VM_FLAG_READ_WRITE;
120
121 page_table1[PAGE_DIRECTORY_OFFSET_OF(PAGE_TABLES_ADDR)] =
122     (pte_t)page_table1 | VM_FLAG_PRESENT | VM_FLAGS_PAGE_TABLE;
123
124 page_table1[PAGE_DIRECTORY_OFFSET_OF(PAGE_DIRECTORY_ADDR)] =
125     (pte_t)page_table2 | VM_FLAG_PRESENT | VM_FLAGS_PAGE_TABLE;
126
127 page_table2[0] = (pte_t)page_directory | VM_FLAG_PRESENT | VM_FLAGS_PAGE_TABLE;
128 for(idx = 1; idx < PAGE_TABLE_ENTRIES; ++idx) {
129     page_table2[idx] = 0;
130 }
131
132 /* create process descriptor for first process */
133 idle_process.pid = 0;
134 next_pid = 1;
135
136 idle_process.next = NULL;
137 first_process = &idle_process;
138
139 idle_process.cr3 = (addr_t)page_directory;
140
141 idle_process.name[0] = 'i';
142 idle_process.name[1] = 'd';
143 idle_process.name[2] = 'l';
144 idle_process.name[3] = 'e';
145 for(idx = 4; idx < PROCESS_NAME_LENGTH; ++idx) {
146     idle_process.name[idx] = 0;

```

```

147     }
148
149     /* perform 1:1 mapping of kernel image and data
150
151         note: page tables for memory region (0..KLIMIT) are contiguous
152             in memory */
153     page_table1 =
154         (pte_t *)page_directory[ PAGE_DIRECTORY_OFFSET_OF(kernel_start) ];
155     page_table1 = (pte_t *) ( (unsigned int)page_table1 & ~PAGE_MASK );
156
157     pte =
158         (pte_t *)&page_table1[ PAGE_TABLE_OFFSET_OF(kernel_start) ];
159
160     for(addr = kernel_start; addr < kernel_region_top; addr += PAGE_SIZE) {
161         *pte = (pte_t)addr | VM_FLAG_PRESENT | VM_FLAG_KERNEL;
162         ++pte;
163     }
164
165     printk("boot data: 0x%x\n", (unsigned long)get_boot_data() );
166
167     printk("page directory (0x%x):\n", (unsigned long)page_directory);
168     printk("  0x%x 0x%x 0x%x 0x%x 0x%x 0x%x 0x%x 0x%x\n",
169         (unsigned long)page_directory[0],
170         (unsigned long)page_directory[1],
171         (unsigned long)page_directory[2],
172         (unsigned long)page_directory[3],
173         (unsigned long)page_directory[4],
174         (unsigned long)page_directory[5],
175         (unsigned long)page_directory[6]
176     );
177
178     if(PAGE_DIRECTORY_OFFSET_OF(kernel_start) != 0) {
179         printk("OOPS: PAGE_DIRECTORY_OFFSET_OF(kernel_start) != 0 (%u)\n",
180             PAGE_DIRECTORY_OFFSET_OF(kernel_start));
181     }
182
183     if(PAGE_TABLE_OFFSET_OF(kernel_start) != 256) {
184         printk("PAGE_TABLE_OFFSET_OF(kernel_start) != 256 (%u)\n",
185             PAGE_TABLE_OFFSET_OF(kernel_start));
186     }
187
188     page_table1 =
189         (pte_t *)page_directory[0];
190     page_table1 = (pte_t *) ( (unsigned int)page_table1 & ~PAGE_MASK );
191     pte = (pte_t *)&page_table1[250];
192     printk("Page table 0 (0x%x) offset 250 (0x%x):\n", (unsigned long)page_table1, (unsigned long) pte);
193
194     for(idx = 0; idx < 42; ++idx) {
195         if(idx % 7 == 0) {
196             printk("  0x%x ", (unsigned long)pte[idx]);
197         }
198         else if(idx % 7 == 6) {
199             printk("0x%x\n", (unsigned long)pte[idx]);
200         }
201         else {
202             printk("0x%x ", (unsigned long)pte[idx]);
203         }
204     }

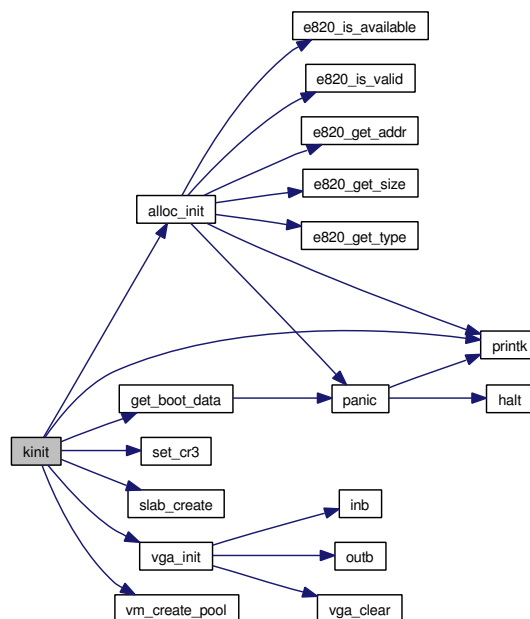
```

```

205     }
206
207     page_table1 =
208         (pte_t *)page_directory[4];
209     page_table1 = (pte_t *) ( (unsigned int)page_table1 & ~PAGE_MASK );
210     printk("page table 4 (0x%x):\n", (unsigned long)page_table1);
211     printk(" 0x%x 0x%x 0x%x 0x%x 0x%x 0x%x 0x%x\n",
212         (unsigned long)page_table1[0],
213         (unsigned long)page_table1[1],
214         (unsigned long)page_table1[2],
215         (unsigned long)page_table1[3],
216         (unsigned long)page_table1[4],
217         (unsigned long)page_table1[5],
218         (unsigned long)page_table1[6]
219     );
220
221     page_table1 =
222         (pte_t *)page_directory[5];
223     page_table1 = (pte_t *) ( (unsigned int)page_table1 & ~PAGE_MASK );
224     printk("page table 5 (0x%x):\n", (unsigned long)page_table1);
225     printk(" 0x%x 0x%x 0x%x 0x%x 0x%x 0x%x 0x%x\n",
226         (unsigned long)page_table1[0],
227         (unsigned long)page_table1[1],
228         (unsigned long)page_table1[2],
229         (unsigned long)page_table1[3],
230         (unsigned long)page_table1[4],
231         (unsigned long)page_table1[5],
232         (unsigned long)page_table1[6]
233     );
234
235     /* activate paging */
236     set_cr3( (unsigned long)page_directory );
237
238     /*temp = get_cr0();
239     temp |= (1 << X86_FLAG_PG);
240     set_cr0x(temp);*/
241
242     /* initialize page frame allocator */
243     alloc_init();
244 }

```


Here is the call graph for this function:



4.23.2 Variable Documentation

4.23.2.1 process_t idle_process

process descriptor for first process (idle)

Definition at line 25 of file kernel.c.

4.23.2.2 addr_t kernel_region_top

top of region of memory mapped 1:1 (kernel image plus some pages for data structures allocated during initialization)

Definition at line 22 of file kernel.c.

Referenced by alloc_init(), and kinit().

4.23.2.3 size_t kernel_size

size of the kernel image

Definition at line 15 of file kernel.c.

Referenced by kinit().

4.23.2.4 `addr_t` `kernel_top`

address of top of kernel image (`kernel_start` + `kernel_size`)

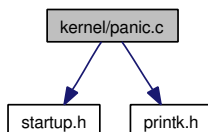
Definition at line 18 of file `kernel.c`.

4.24 kernel/panic.c File Reference

```
#include <startup.h>
```

```
#include <printk.h>
```

Include dependency graph for panic.c:



Functions

- void **panic** (const char *message)

4.24.1 Function Documentation

4.24.1.1 void panic (const char * *message*)

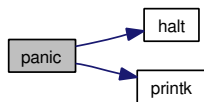
Definition at line 4 of file panic.c.

References `halt()`, and `printk()`.

Referenced by `__assert_failed()`, `alloc()`, `alloc_init()`, `get_boot_data()`, and `kernel()`.

```
4      {
5          printk("KERNEL PANIC: %s\n", message);
6          halt();
7      }
```

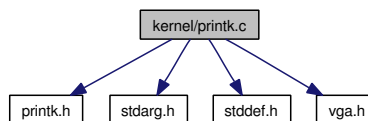
Here is the call graph for this function:



4.25 kernel/printk.c File Reference

```
#include <printk.h>
#include <stdarg.h>
#include <stddef.h>
#include <vga.h>
```

Include dependency graph for printk.c:



Functions

- void **print_unsigned_int** (unsigned int n)
- void **print_hex_nibble** (unsigned char byte)
- void **print_hex_b** (unsigned char byte)
- void **print_hex_w** (unsigned short word)
- void **print_hex_l** (unsigned long dword)
- void **print_hex_q** (unsigned long long qword)

4.25.1 Function Documentation

4.25.1.1 void print_hex_b (unsigned char *byte*)

Definition at line 107 of file printk.c.

References `print_hex_nibble()`.

```
107 {
108     print_hex_nibble( (char)byte );
109     print_hex_nibble( (char)(byte>>4) );
110 }
```

Here is the call graph for this function:



4.25.1.2 void print_hex_l (unsigned long *dword*)

Definition at line 120 of file printk.c.

References `print_hex_nibble()`.

```

120                                     {
121     int off;
122
123     for(off=32-4; off>=0; off-=4) {
124         print_hex_nibble( (char)(dword>>off) );
125     }
126 }
```

Here is the call graph for this function:



4.25.1.3 void print_hex_nibble (unsigned char *byte*)

Definition at line 93 of file printk.c.

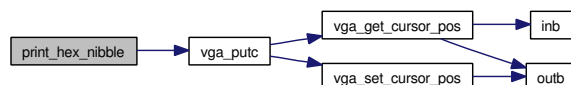
References `vga_putc()`.

Referenced by `print_hex_b()`, `print_hex_l()`, `print_hex_q()`, and `print_hex_w()`.

```

93                                     {
94     char c;
95
96     c = byte & 0xf;
97     if(c < 10) {
98         c += '0';
99     }
100     else {
101         c += ('a' - 10);
102     }
103
104     vga_putc(c);
105 }
```

Here is the call graph for this function:



4.25.1.4 void print_hex_q (unsigned long long *qword*)

Definition at line 128 of file printk.c.

References print_hex_nibble().

```

128                                     {
129     int off;
130
131     for(off=64-4; off>=0; off-=4) {
132         print_hex_nibble( (char)(qword>>off) );
133     }
134 }
```

Here is the call graph for this function:



4.25.1.5 void print_hex_w (unsigned short *word*)

Definition at line 112 of file printk.c.

References print_hex_nibble().

```

112                                     {
113     int off;
114
115     for(off=16-4; off>=0; off-=4) {
116         print_hex_nibble( (char)(word>>off) );
117     }
118 }
```

Here is the call graph for this function:



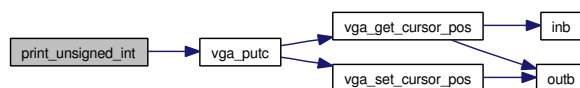
4.25.1.6 void print_unsigned_int (unsigned int *n*)

Definition at line 69 of file printk.c.

References vga_putc().

```
69                                     {
70     unsigned int flag = 0;
71     unsigned int pwr;
72     unsigned int digit;
73     char c;
74
75     if(n == 0) {
76         vga_putc('0');
77         return;
78     }
79
80     for(pwr = 1000 * 1000 * 1000; pwr > 0; pwr /= 10) {
81         digit = n / pwr;
82
83         if(digit != 0 || flag) {
84             c = (char)digit + '0';
85             vga_putc(c);
86
87             flag = 1;
88             n -= digit * pwr;
89         }
90     }
91 }
```

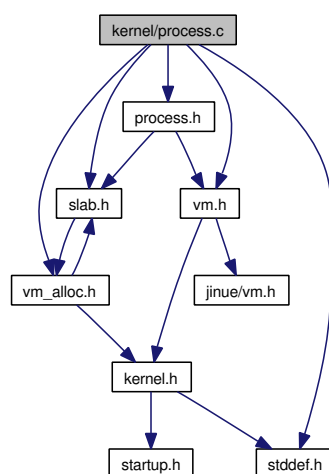
Here is the call graph for this function:



4.26 kernel/process.c File Reference

```
#include <process.h>
#include <slab.h>
#include <stddef.h>
#include <vm.h>
#include <vm_alloc.h>
```

Include dependency graph for process.c:



Functions

- `process_t * process_create (void)`
- `void process_destroy (process_t *p)`
- `void process_destroy_by_pid (pid_t pid)`
- `process_t * process_find_by_pid (pid_t pid)`

Variables

- `pid_t next_pid`
PID for next process creation.
- `process_t * first_process`
head of process descriptors linked list

- `slab_cache_t process_slab_cache`
slab cache for allocation of process descriptors
- `pte_t * page_directory_template`
template for the creation of a new page directory

4.26.1 Function Documentation

4.26.1.1 `process_t* process_create (void)`

Definition at line 20 of file process.c.

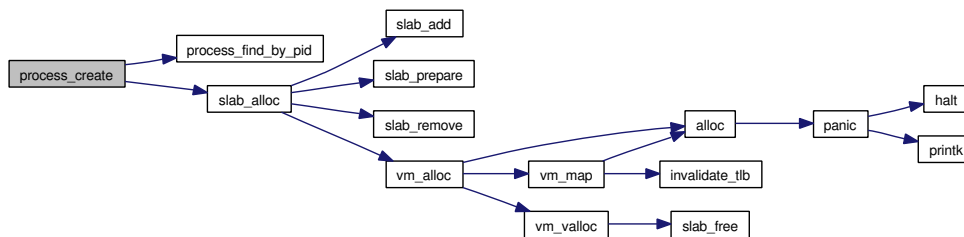
References `next_pid`, `NULL`, `process_t::pid`, `process_find_by_pid()`, and `slab_alloc()`.

```

20         {
21     process_t *p = slab_alloc(&process_slab_cache);
22     while( process_find_by_pid(next_pid) != NULL ) {
23         ++next_pid;
24     }
25     }
26     p->pid = next_pid++;
27     /* TODO: actual implementation */
28     return p;
29 }

```

Here is the call graph for this function:



4.26.1.2 `void process_destroy (process_t * p)`

Definition at line 33 of file process.c.

Referenced by `process_destroy_by_pid()`.

```

33         {
34     /* TODO: actual implementation */
35 }

```

4.26.1.3 void process__destroy__by__pid (pid_t pid)

Definition at line 37 of file process.c.

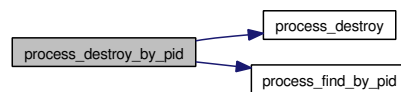
References process__destroy(), and process__find__by__pid().

```

37         {
38     process__destroy( process__find__by__pid(pid) );
39 }

```

Here is the call graph for this function:



4.26.1.4 process_t* process__find__by__pid (pid_t pid)

Definition at line 41 of file process.c.

References process_t::next, NULL, and process_t::pid.

Referenced by process__create(), and process__destroy__by__pid().

```

41         {
42     process_t *p;
43
44     p = first_process;
45
46     while(p != NULL) {
47         if(p->pid == pid) {
48             return p;
49         }
50
51         p = p->next;
52     }
53
54     return NULL;
55 }

```

4.26.2 Variable Documentation

4.26.2.1 `process_t* first_process`

head of process descriptors linked list

Definition at line 11 of file process.c.

Referenced by `kinit()`.

4.26.2.2 `pid_t next_pid`

PID for next process creation.

Definition at line 8 of file process.c.

Referenced by `kinit()`, and `process_create()`.

4.26.2.3 `pte_t* page_directory_template`

template for the creation of a new page directory

Definition at line 17 of file process.c.

Referenced by `kinit()`.

4.26.2.4 `slab_cache_t process_slab_cache`

slab cache for allocation of process descriptors

Definition at line 14 of file process.c.

Referenced by `kinit()`.

4.27 kernel/slab.c File Reference

```
#include <assert.h>
```

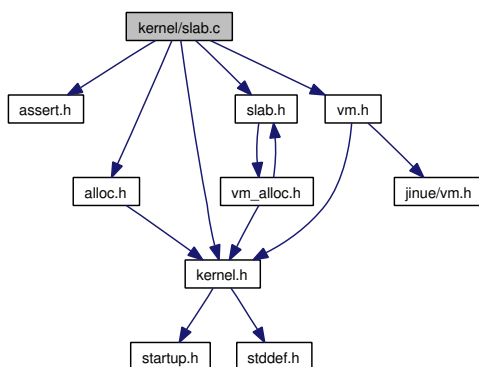
```
#include <alloc.h>
```

```
#include <kernel.h>
```

```
#include <slab.h>
```

```
#include <vm.h>
```

Include dependency graph for slab.c:



Functions

- void **slab_create** (slab_cache_t *cache, vm_alloc_t *pool, size_t obj_size, unsigned long flags)
- void **slab_destroy** (slab_cache_t *cache)
- addr_t **slab_alloc** (slab_cache_t *cache)
- void **slab_free** (slab_cache_t *cache, addr_t obj)
- void **slab_prepare** (slab_cache_t *cache, addr_t page)

Prepare a memory page for use as a slab.

- void **slab_add** (slab_header_t **head, slab_header_t *slab)

Add a slab to a linked list of slabs.

- void **slab_remove** (slab_header_t **head, slab_header_t *slab)

Remove a slab from a linked list of slab.

4.27.1 Function Documentation

4.27.1.1 void slab_add (slab_header_t ** head, slab_header_t * slab)

Add a slab to a linked list of slabs.

Parameters:

head of list (typically &C->empty, &C->partial or &C->full of some cache C)

slab to add to list

Definition at line 136 of file slab.c.

References slab_header_t::next, NULL, and slab_header_t::prev.

Referenced by slab_alloc(), and vm_vfree_block().

```

136                                     {
137     slab->next = *head;
138     slab->prev = NULL;
139
140     (*head)->prev = slab;
141     *head = slab;
142 }
```

4.27.1.2 addr_t slab_alloc (slab_cache_t * cache)

TODO: handle the NULL pointer

Definition at line 27 of file slab.c.

References slab_header_t::available, slab_cache_t::empty, slab_header_t::free_list, slab_cache_t::full, NULL, slab_cache_t::partial, slab_add(), slab_prepare(), slab_remove(), vm_alloc(), slab_cache_t::vm_allocator, and slab_cache_t::vm_flags.

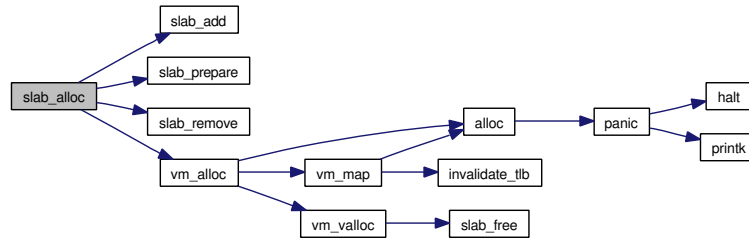
Referenced by process_create(), and vm_vfree_block().

```

27                                     {
28     slab_header_t *slab;
29     addr_t addr;
30
31     /* use a partial slab if one is available... */
32     slab = cache->partial;
33     if(slab != NULL) {
34         addr = slab->free_list;
35         slab->free_list = *(addr_t *)addr;
36 }
```

```
37         /* maybe the slab is now full */
38         if(--slab->available == 0) {
39             slab_remove(&cache->partial, slab);
40             slab_add(&cache->full, slab);
41         }
42
43         return addr;
44     }
45
46     /* ... otherwise, use an empty slab ... */
47     slab = cache->empty;
48     if(slab != NULL) {
49         /* the slab is no longer empty */
50         slab_remove(&cache->empty, slab);
51         slab_add(&cache->partial, slab);
52
53         addr = slab->free_list;
54         slab->free_list = *(addr_t *)addr;
55
56         /* maybe the slab is now full */
57         if(--slab->available == 0) {
58             slab_remove(&cache->partial, slab);
59             slab_add(&cache->full, slab);
60         }
61
62         return addr;
63     }
64
65     /* ... and, as last resort, allocate a slab */
66     slab = (slab_header_t *)vm_alloc(cache->vm_allocator, cache->vm_flags);
67     slab_prepare(cache, (addr_t)slab);
68
69     /* this slab is not empty since we are allocating an object from it */
70     slab_add(&cache->partial, slab);
71
72     addr = slab->free_list;
73     slab->free_list = *(addr_t *)addr;
74
75     /* maybe the slab is now full */
76     if(--slab->available == 0) {
77         slab_remove(&cache->partial, slab);
78         slab_add(&cache->full, slab);
79     }
80
81     return addr;
82 }
83 }
```

Here is the call graph for this function:



4.27.1.3 void slab_create (slab_cache_t * cache, vm_alloc_t * pool, size_t obj_size, unsigned long flags)

Definition at line 7 of file slab.c.

References `slab_cache_t::empty`, `slab_cache_t::full`, `NULL`, `slab_cache_t::obj_size`, `PAGE_SIZE`, `slab_cache_t::partial`, `slab_cache_t::per_slab`, `slab_cache_t::vm_allocator`, and `slab_cache_t::vm_flags`.

Referenced by `kinit()`.

```

11         {
12
13
14     cache->obj_size = obj_size;
15     cache->per_slab = ( PAGE_SIZE - sizeof(slab_header_t) ) / obj_size;
16     cache->empty = NULL;
17     cache->partial = NULL;
18     cache->full = NULL;
19     cache->vm_flags = flags;
20     cache->vm_allocator = pool;
21 }
```

4.27.1.4 void slab_destroy (slab_cache_t * cache)

Definition at line 23 of file slab.c.

```

23                                     {
24     /* TODO: implement slab_destroy */
25 }
```

4.27.1.5 void slab_free (slab_cache_t * cache, addr_t obj)

Definition at line 85 of file slab.c.

Referenced by `vm__valloc()`.

```
85                                     {
86 }
```

4.27.1.6 `void slab__prepare (slab__cache_t * cache, addr_t page)`

Prepare a memory page for use as a slab.

Initialize fields of the slab header and create the free list.

Parameters:

cache slab cache to which the slab is to be added

page memory page from which to create a slab

ASSERTION: we assume "page" is the starting address of a page

ASSERTION: we assume at least one object can be allocated on slab

ASSERTION: we assume a physical memory page is mapped at "page"

Definition at line 93 of file `slab.c`.

References `assert`, `slab__header_t::available`, `slab__header_t::free_list`, `NULL`, `slab__cache_t::obj_size`, `PAGE_MASK`, `PAGE_OFFSET_OF`, `PDE_OF`, `slab__cache_t::per_slab`, `PTE_OF`, and `VM_FLAG_PRESENT`.

Referenced by `slab__alloc()`, and `vm__vfree_block()`.

```
93                                     {
94     unsigned int cx;
95     size_t obj_size;
96     count_t per_slab;
97     slab_header_t *slab;
98     addr_t *ptr;
99     addr_t next;
100
101
102     assert( PAGE_OFFSET_OF(page) == 0 );
103
104
105     assert( cache->per_slab > 0 );
106
107
108     assert( (*PDE_OF(page) & ~PAGE_MASK) != NULL && (*PDE_OF(page) & VM_FLAG_PRESENT) != 0 );
109     assert( (*PTE_OF(page) & ~PAGE_MASK) != NULL && (*PTE_OF(page) & VM_FLAG_PRESENT) != 0 );
110
111     obj_size = cache->obj_size;
112     per_slab = cache->per_slab;
113
114     /* initialize slab header */
115     slab = (slab_header_t *)page;
116     slab->available = per_slab;
117     slab->free_list = page + sizeof(slab_header_t);
```



```
118
119     /* create free list */
120     ptr = (addr_t *)slab->free_list;
121
122     for(cx = 0; cx < per_slab - 1; ++cx) {
123         next = ptr + obj_size;
124         *ptr = next;
125         ptr = (addr_t *)next;
126     }
127
128     *ptr = NULL;
129 }
```

4.27.1.7 void slab_remove (slab_header_t ** head, slab_header_t * slab)

Remove a slab from a linked list of slab.

Parameters:

head of list (typically &C->empty, &C->partial or &C->full of some cache C)

slab to remove from list

Definition at line 149 of file slab.c.

References slab_header_t::next, NULL, and slab_header_t::prev.

Referenced by slab_alloc().

```
149                                     {
150     if(slab->next != NULL) {
151         slab->next->prev = slab->prev;
152     }
153
154     if(slab->prev != NULL) {
155         slab->prev->next = slab->next;
156     }
157     else {
158         *head = slab->next;
159     }
160 }
```

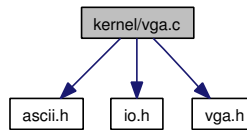
4.28 kernel/vga.c File Reference

```
#include <ascii.h>
```

```
#include <io.h>
```

```
#include <vga.h>
```

Include dependency graph for vga.c:



Functions

- void **vga_init** (void)
- void **vga_clear** (void)
- void **vga_scroll** (void)
- **vga_pos_t** **vga_get_cursor_pos** (void)
- void **vga_set_cursor_pos** (**vga_pos_t** pos)
- void **vga_print** (const char *message)
- void **vga_printn** (const char *message, unsigned int n)
- void **vga_putc** (char c)

4.28.1 Function Documentation

4.28.1.1 void vga_clear (void)

Definition at line 25 of file vga.c.

References `VGA_COLOR_ERASE`, `VGA_LINES`, `VGA_TEXT_VID_BASE`, and `VGA_WIDTH`.

Referenced by `vga_init()`.

```

25      {
26      unsigned char *buffer = (unsigned char *)VGA_TEXT_VID_BASE;
27      unsigned int idx = 0;
28
29      while( idx < (VGA_LINES * VGA_WIDTH * 2) ) {
30          buffer[idx++] = 0x20;
31          buffer[idx++] = VGA_COLOR_ERASE;
32      }
33  }
```

4.28.1.2 vga_pos_t vga_get_cursor_pos (void)

Definition at line 50 of file vga.c.

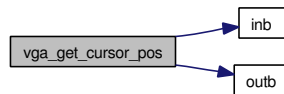
References `inb()`, `outb()`, `VGA_CRTC_ADDR`, and `VGA_CRTC_DATA`.

Referenced by `vga_print()`, `vga_printn()`, and `vga_putc()`.

```

50      {
51      unsigned char h, l;
52
53      outb(VGA_CRTC_ADDR, 0x0e);
54      h = inb(VGA_CRTC_DATA);
55      outb(VGA_CRTC_ADDR, 0x0f);
56      l = inb(VGA_CRTC_DATA);
57
58      return (h << 8) | l;
59 }
```

Here is the call graph for this function:

**4.28.1.3 void vga_init (void)**

Definition at line 7 of file vga.c.

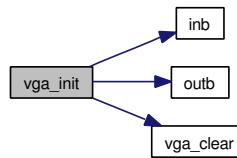
References `inb()`, `outb()`, `vga_clear()`, `VGA_CRTC_ADDR`, `VGA_CRTC_DATA`, `VGA_MISC_OUT_RD`, and `VGA_MISC_OUT_WR`.

Referenced by `kinit()`.

```

7      {
8      unsigned char data;
9
10     /* Set address select bit in a known state: CRTC regs at 0x3dx */
11     data = inb(VGA_MISC_OUT_RD);
12     data |= 1;
13     outb(VGA_MISC_OUT_WR, data);
14
15     /* Move cursor to line 0 col 0 */
16     outb(VGA_CRTC_ADDR, 0x0e);
17     outb(VGA_CRTC_DATA, 0x0);
18     outb(VGA_CRTC_ADDR, 0x0f);
19     outb(VGA_CRTC_DATA, 0x0);
20
21     /* Clear the screen */
22     vga_clear();
23 }
```

Here is the call graph for this function:



4.28.1.4 void vga_print (const char * *message*)

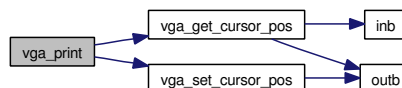
Definition at line 72 of file vga.c.

References `vga_get_cursor_pos()`, and `vga_set_cursor_pos()`.

```

72         {
73     unsigned short int pos = vga_get_cursor_pos();
74     char c;
75
76     while( (c = *(message++)) ) {
77         pos = vga_raw_putc(c, pos);
78     }
79
80     vga_set_cursor_pos(pos);
81 }
```

Here is the call graph for this function:



4.28.1.5 void vga_printn (const char * *message*, unsigned int *n*)

Definition at line 83 of file vga.c.

References `vga_get_cursor_pos()`, and `vga_set_cursor_pos()`.

```

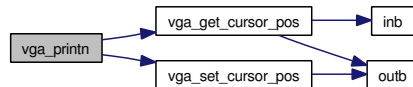
83         {
84     vga_pos_t pos = vga_get_cursor_pos();
85     char c;
86
87     while(n) {
88         c = *(message++);
89         pos = vga_raw_putc(c, pos);
90     }
```

```

90     --n;
91 }
92
93     vga_set_cursor_pos(pos);
94 }

```

Here is the call graph for this function:



4.28.1.6 void vga_putc (char c)

Definition at line 96 of file vga.c.

References `vga_get_cursor_pos()`, and `vga_set_cursor_pos()`.

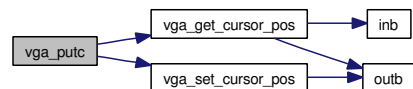
Referenced by `print_hex_nibble()`, and `print_unsigned_int()`.

```

96     {
97     vga_pos_t pos = vga_get_cursor_pos();
98
99     pos = vga_raw_putc(c, pos);
100
101     vga_set_cursor_pos(pos);
102 }

```

Here is the call graph for this function:



4.28.1.7 void vga_scroll (void)

Definition at line 35 of file vga.c.

References `VGA_COLOR_ERASE`, `VGA_LINES`, `VGA_TEXT_VID_BASE`, and `VGA_WIDTH`.

```

35     {
36     unsigned char *di = (unsigned char *)VGA_TEXT_VID_BASE;
37     unsigned char *si = (unsigned char *) (VGA_TEXT_VID_BASE + 2 * VGA_WIDTH);

```

```
38     unsigned int idx;
39
40     for(idx = 0; idx < 2 * VGA_WIDTH * (VGA_LINES - 1); ++idx) {
41         *(di++) = *(si++);
42     }
43
44     for(idx = 0; idx < VGA_WIDTH; ++idx) {
45         *(di++) = 0x20;
46         *(di++) = VGA_COLOR_ERASE;
47     }
48 }
```

4.28.1.8 void vga_set_cursor_pos (vga_pos_t pos)

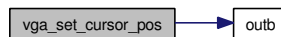
Definition at line 61 of file vga.c.

References `outb()`, `VGA_CRTC_ADDR`, and `VGA_CRTC_DATA`.

Referenced by `vga_print()`, `vga_printn()`, and `vga_putc()`.

```
61                                     {
62     unsigned char h = pos >> 8;
63     unsigned char l = pos;
64
65     outb(VGA_CRTC_ADDR, 0x0e);
66     outb(VGA_CRTC_DATA, h);
67     outb(VGA_CRTC_ADDR, 0x0f);
68     outb(VGA_CRTC_DATA, l);
69 }
```

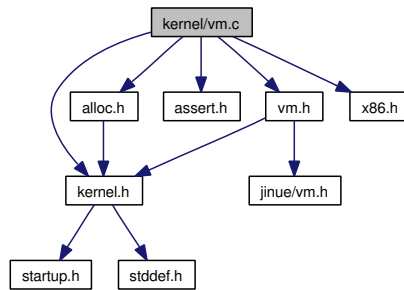
Here is the call graph for this function:



4.29 kernel/vm.c File Reference

```
#include <kernel.h>
#include <alloc.h>
#include <assert.h>
#include <vm.h>
#include <x86.h>
```

Include dependency graph for vm.c:



Functions

- void **vm_map** (**addr_t** vaddr, **addr_t** paddr, unsigned long flags)
Map a page frame (physical page) to a virtual memory page.
- void **vm_unmap** (**addr_t** addr)
Unmap a page from virtual memory.

4.29.1 Function Documentation

4.29.1.1 void vm_map (addr_t vaddr, addr_t paddr, unsigned long flags)

Map a page frame (physical page) to a virtual memory page.

Parameters:

vaddr virtual address of mapping

paddr address of page frame

flags flags used for mapping (see VM_FLAG_x constants in vm.h)

ASSERTION: we assume vaddr is aligned on a page boundary

ASSERTION: we assume paddr is aligned on a page boundary

Definition at line 14 of file vm.c.

References alloc(), assert, invalidate_tlb(), PAGE_OFFSET_OF, PAGE_SIZE, PAGE_TABLE_ENTRIES, PAGE_TABLE_OF, PAGE_TABLE_PTE_OF, PDE_OF, PTE_OF, VM_FLAG_PRESENT, VM_FLAG_READ_WRITE, VM_FLAG_USER, and VM_FLAGS_PAGE_TABLE.

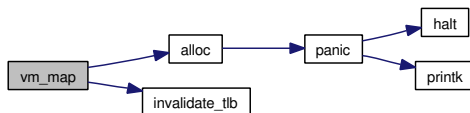
Referenced by vm_alloc(), and vm_vfree_block().

```

14                                     {
15     pte_t *pte, *pde;
16     addr_t page_table;
17     int idx;
18
19     assert( PAGE_OFFSET_OF(vaddr) == 0 );
20
21     assert( PAGE_OFFSET_OF(paddr) == 0 );
22
23     /* get page directory entry */
24     pde = PDE_OF(vaddr);
25
26     /* check if page table must be created */
27     if( !(*pde & VM_FLAG_PRESENT) ) {
28         /* allocate a new page table */
29         page_table = alloc(PAGE_SIZE);
30
31         /* map page table in the region of memory reserved for that purpose */
32         pte = PAGE_TABLE_PTE_OF(vaddr);
33         *pte = (pte_t)page_table | VM_FLAGS_PAGE_TABLE | VM_FLAG_PRESENT;
34
35         /* obtain virtual address of new page table */
36         pte = PAGE_TABLE_OF(vaddr);
37
38         /* invalidate TLB entry for new page table */
39         invalidate_tlb( (addr_t)pte );
40
41         /* zero content of page table */
42         for(idx = 0; idx < PAGE_TABLE_ENTRIES; ++idx) {
43             pte[idx] = 0;
44         }
45
46         /* link to page table from page directory */
47         *pde = (pte_t)page_table | VM_FLAG_USER | VM_FLAG_READ_WRITE | VM_FLAG_PRESENT;
48     }
49
50     /* perform the actual mapping */
51     pte = PTE_OF(vaddr);
52     *pte = (pte_t)paddr | flags | VM_FLAG_PRESENT;
53
54     /* invalidate TLB entry for newly mapped page */
55     invalidate_tlb(vaddr);
56 }

```


Here is the call graph for this function:



4.29.1.2 void vm_unmap(addr_t addr)

Unmap a page from virtual memory.

Parameters:

addr address of page to unmap

ASSERTION: we assume `addr` is aligned on a page boundary

Definition at line 64 of file `vm.c`.

References `assert`, `invalidate_tlb()`, `NULL`, `PAGE_OFFSET_OF`, and `PTE_OF`.

Referenced by `vm_free()`.

```

64      {
65      pte_t *pte;
66
67      assert( PAGE_OFFSET_OF(addr) == 0 );
68
69      pte = PTE_OF(addr);
70      *pte = NULL;
71
72      /* TODO: is this really necessary? */
73      invalidate_tlb(addr);
74  }
75  }
```

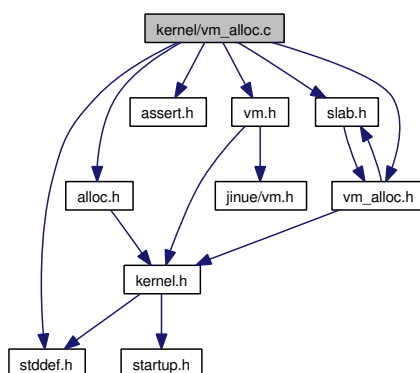
Here is the call graph for this function:



4.30 kernel/vm_alloc.c File Reference

```
#include <alloc.h>
#include <assert.h>
#include <slab.h>
#include <stddef.h>
#include <vm.h>
#include <vm_alloc.h>
```

Include dependency graph for vm_alloc.c:



Functions

- void **vm_create_pool** (vm_alloc_t *pool, slab_cache_t *cache)
- addr_t **vm_valloc** (vm_alloc_t *pool)
Allocate a page of virtual memory (not backed by physical memory).
- void **vm_vfree** (vm_alloc_t *pool, addr_t addr)
Return a single page of virtual memory to a pool of available pages.
- void **vm_vfree_block** (vm_alloc_t *pool, addr_t addr, size_t size)
Return a block of contiguous virtual memory pages to a pool of available pages.
- addr_t **vm_alloc** (vm_alloc_t *pool, unsigned long flags)
Allocate a physical memory page and map it in virtual memory.

- void **vm_free** (**vm_alloc_t** *pool, **addr_t** addr)

*Free a physical page mapped in virtual memory (which was typically obtained through a call to **vm_map()** (p. 46)).*

Variables

- **vm_alloc_t** global_pool
- **slab_cache_t** global_pool_cache

4.30.1 Function Documentation

4.30.1.1 **addr_t** vm_alloc (**vm_alloc_t** * pool, unsigned long flags)

Allocate a physical memory page and map it in virtual memory.

Parameters:

pool data structure managing the virtual memory region in which page will be mapped

flags flags for page mapping (passed as-is to **vm_map()** (p. 46))

TODO: handle the NULL pointer

Definition at line 146 of file vm_alloc.c.

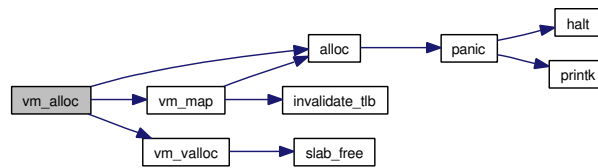
References alloc(), PAGE_SIZE, vm_map(), and vm_valloc().

Referenced by slab_alloc().

```

146                                     {
147     addr_t paddr, vaddr;
148
151     vaddr = vm_valloc(pool);
152     paddr = alloc(PAGE_SIZE);
153     vm_map(vaddr, paddr, flags);
154
155     return vaddr;
156 }
```

Here is the call graph for this function:



4.30.1.2 void vm_create_pool (vm_alloc_t * pool, slab_cache_t * cache)

Definition at line 13 of file vm_alloc.c.

References vm_alloc_t::cache, vm_alloc_t::head, NULL, and vm_alloc_t::size.

Referenced by kinit().

```

13                                     {
14     pool->size = 0;
15     pool->head = NULL;
16     pool->cache = cache;
17 }
```

4.30.1.3 void vm_free (vm_alloc_t * pool, addr_t addr)

Free a physical page mapped in virtual memory (which was typically obtained through a call to **vm_map()** (p. 46)).

The physical memory is freed and the virtual page is returned to the virtual address space allocator.

Parameters:

pool data structure managing the virtual memory region to which the page is returned address of page to free

ASSERTION: address of page should not be the null pointer

Definition at line 165 of file vm_alloc.c.

References assert, free(), NULL, PAGE_MASK, PTE_OF, vm_unmap(), and vm_vfree().

```

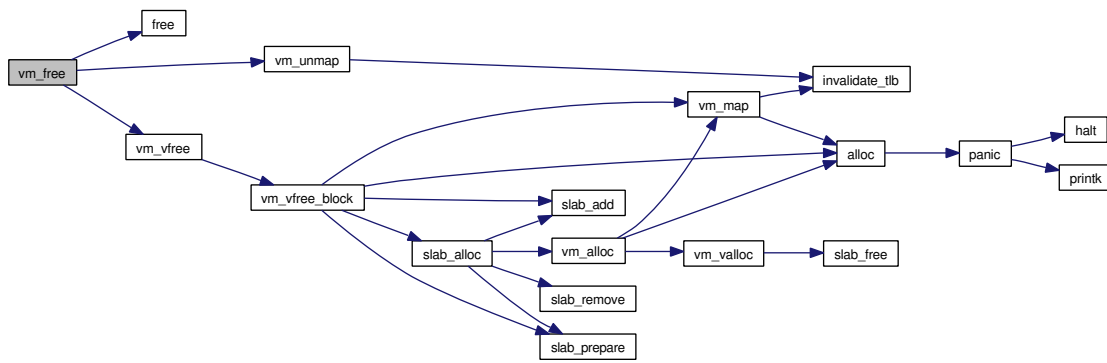
165                                     {
```

```

166     addr_t paddr;
167
169     assert( addr != (addr_t)NULL );
170
171     paddr = (addr_t)(*PTE_OF(addr) | ~PAGE_MASK);
172
173     vm_unmap(addr);
174     vm_vfree(pool, addr);
175     free(paddr);
176 }

```

Here is the call graph for this function:



4.30.1.4 addr_t vm_valloc (vm_alloc_t * pool)

Allocate a page of virtual memory (not backed by physical memory).

This page may then be used for temporary mappings, for example. Page is allocated from a specific virtual memory region managed by a **vm_alloc_t** (p. 17) data structure.

Parameters:

pool data structure managing the virtual memory region from which to allocate

Returns:

address of allocated page

ASSERTION: block size should be an integer number of pages

ASSERTION: returned address should be aligned with a page boundary

Definition at line 28 of file vm_alloc.c.

References `vm_link_t::addr`, `assert`, `vm_alloc_t::cache`, `vm_alloc_t::head`, `vm_link_t::next`, `NULL`, `PAGE_OFFSET_OF`, `PAGE_SIZE`, `vm_link_t::size`, and `slab_free()`.

Referenced by `vm_alloc()`.

```

28                                     {
29     addr_t addr;
30     vm_link_t *head;
31     size_t size;
32
33     head = pool->head;
34
35     /* no page available */
36     if(head == (addr_t)NULL) {
37         return (addr_t)NULL;
38     }
39
40     addr = head->addr;
41     size = head->size - PAGE_SIZE;
42
43     assert( PAGE_OFFSET_OF(size) == 0 );
44
45     /* if block is made of only one page, we remove it from the free list */
46     if(size == 0) {
47         pool->head = head->next;
48         slab_free(pool->cache, head);
49     }
50     else {
51         head->size = size;
52         head->addr += PAGE_SIZE;
53     }
54
55     assert( PAGE_OFFSET_OF(addr) == 0 );
56
57     return addr;
58 }

```

Here is the call graph for this function:



4.30.1.5 void `vm_vfree` (`vm_alloc_t * pool`, `addr_t addr`)

Return a single page of virtual memory to a pool of available pages.

Should not be used to free pages to which physical memory is still mapped (no physical memory is freed by this function). Use this function to return pages obtained by a call to `vm_valloc()` (p. 94) (and not `vm_alloc()` (p. 92)).

Parameters:

pool data structure managing the relevant virtual memory region

addr address of virtual page which must be freed

Definition at line 70 of file vm_alloc.c.

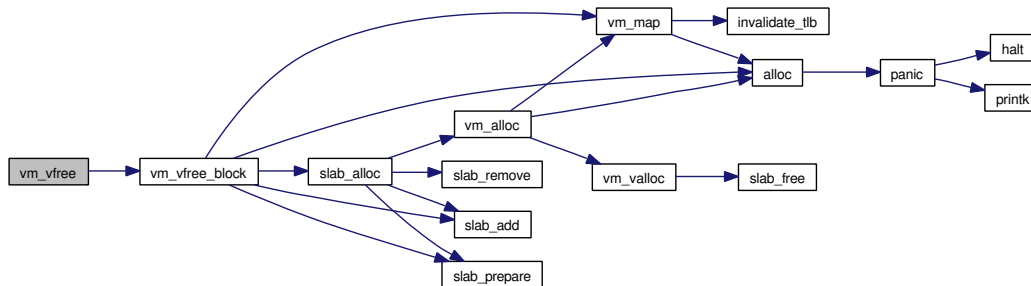
References PAGE_SIZE, and vm_vfree_block().

Referenced by vm_free().

```

70                                     {
71     vm_vfree_block(pool, addr, PAGE_SIZE);
72 }
```

Here is the call graph for this function:



4.30.1.6 void vm_vfree_block (vm_alloc_t * *pool*, addr_t *addr*, size_t *size*)

Return a block of contiguous virtual memory pages to a pool of available pages.

Should not be used to free pages to which physical memory is still mapped (no physical memory is freed by this function).

Parameters:

pool data structure managing the relevant virtual memory region

addr starting address of virtual memory block

size size of block

ASSERTION: we assume starting address is aligned on a page boundary

ASSERTION: we assume size of block is an integer number of pages

ASSERTION: address of block should not be the null pointer

Definition at line 82 of file vm_alloc.c.

References vm_link_t::addr, alloc(), assert, vm_alloc_t::cache, slab_cache_t::empty, vm_alloc_t::head, vm_link_t::next, NULL, PAGE_OFFSET_OF, PAGE_SIZE, slab_cache_t::partial, vm_link_t::size, slab_add(), slab_alloc(), slab_prepare(), slab_cache_t::vm_allocator, VM_FLAG_KERNEL, and vm_map().

Referenced by vm_vfree().

```

82                                     {
83     addr_t phys_page;
84     vm_link_t *link;
85
86     assert( PAGE_OFFSET_OF(addr) == 0 );
87
88     assert( PAGE_OFFSET_OF(size) == 0 );
89
90     assert( addr != (addr_t)NULL );
91
92     /* The virtual address space allocator needs a slab cache from which to
93        allocate data structures for its free list. Also, each slab cache needs
94        a virtual address space allocator to allocate slabs when needed.
95
96        There can be a mutual dependency between the virtual address space
97        allocator and the slab cache. This is not a problem in general, but a
98        special bootstrapping procedure is needed for initialization of the
99        virtual address space allocator in that case. The virtual address space
100        allocator will actually "donate" a virtual page (backed by physical ram)
101        to the cache for use as a slab.
102
103        This case is handled here
104    */
105    if(pool->head == NULL) {
106        if(pool->cache->vm_allocator == pool) {
107            if(pool->cache->empty == NULL && pool->cache->partial == NULL) {
108                /* allocate a physical page for slab */
109                phys_page = alloc(PAGE_SIZE);
110
111                /* map page */
112                vm_map(addr, phys_page, VM_FLAG_KERNEL);
113
114                /* prepare the slab and add it to cache empty list */
115                slab_prepare(pool->cache, addr);
116                slab_add(&pool->cache->empty, addr);
117
118                size -= PAGE_SIZE;
119
120                /* if the block contained only one page, we have nothing left
121                   to free */
122                if(size == 0) {
123                    return;
124                }
125
126                addr += PAGE_SIZE;
127            }
128        }
129    }
130

```

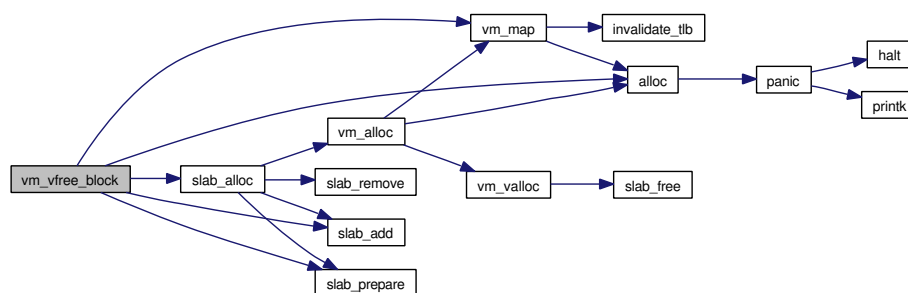


```

131     }
132 }
133
134 link = (vm_link_t *)slab_alloc(pool->cache);
135 link->size = size;
136 link->addr = addr;
137
138 link->next = pool->head;
139 pool->head = link;
140 }

```

Here is the call graph for this function:



4.30.2 Variable Documentation

4.30.2.1 vm_alloc_t global_pool

Definition at line 8 of file `vm_alloc.c`.

Referenced by `kinit()`.

4.30.2.2 slab_cache_t global_pool_cache

Definition at line 10 of file `vm_alloc.c`.

Referenced by `kinit()`.

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