

Index

Symbols

`__errno`, 159
`__t_errno`, 159
`_r`, 227
`_REENTRANT`, 157

Numerics

32-bit architectures, 70

A

Ada, 140
`adb`, 161
adding
 to LWP pool, 202
 signals to mask, 32
`aio_errno`, 146
`AIO_INPROGRESS`, 146
`aio_result_t`, 145, 146
`aiocancel(3)`, 145, 146
`aioread(3)`, 145, 146
`aiowait(3)`, 146
`aiowrite(3)`, 145, 146
algorithms
 faster with MT, 3
 parallel, 244

 sequential, 244
alternate signal stacks, 8, 132
ANSI C, 161
application-level threads
 See user-level threads
architecture
 multiprocessor, 240
 SPARC, 70, 241, 243
assert statement, 104, 231
asynchronous
 event notification, 108
 I/O, 144, 145, 146
 semaphore use, 108
 signals, 132 to 138
Async-Signal-Safe
 category, 151
 functions, 137, 153
 and signal handlers, 140
atomic, defined, 70
automatic
 arrays, problems, 160
 LWP number adjustments, 130
 stack allocation, 62

B

barrier synchronization, 244
binary semaphores, 107

binding
 reasons to bind, 8, 130, 237, 239
 threads to LWPs, 202
 values to keys, 18, 208

bottlenecks, 233

bound threads, 6, 130, 237
 See also binding
 alternate signal stacks, 132
 concurrency, 238
 defined, 2
 mixing with unbound threads, 237
 no LWP caching, 237
 priority, 128
 reasons to bind, 8, 130
 scheduling class, 128

C

C++, 161
cache, defined, 240
caching
 not for bound thread LWPs, 237
 threads data structure, 234
changing the signal mask, 32, 205
coarse-grained locking, 230
code lock, 229, 231
code monitor, 229, 231
completion semantics, 139
concurrency, 230, 238, 239
 level, 202
 unbound threads, 190
`cond_broadcast(3T)`, 215, 216
`cond_init(3T)`, 220, 221
`cond_signal(3T)`, 215
`cond_wait(3T)`, 143
condition variables, 69, 87 to 105, 142
contention, 232, 233
continue execution, 189
coroutine linkage, 236
counting semaphores *See* semaphores
creating
 stacks, 62, 63, 64, 201, 203
 threads, 12 to 15, 234, 238

 thread-specific keys, 18, 19, 20, 21, 207, 208

critical section, 242

custom stack, 62, 203, 204

D

`-D_POSIX_C_SOURCE`, 157

`-D_REENTRANT`, 157

daemon threads, 202

data

 global, 18

 local, 18

 lock, 229, 230

 profile, 126

 races, 149

 shared, 6, 242

 thread specific, *See* thread-specific data

dbx, 161

deadlock, 159, 231, 232

debugging, 159 to 162

 adb, 161

 dbx, 161

deleting signals from mask, 32

destructor function, 19, 25

detached threads, 15, 48, 201

Dijkstra, E. W., 106

E

EAGAIN, 14, 19, 77, 93, 112, 191, 202

EBUSY, 77, 80, 81, 93, 101, 196, 197

EDEADLK, 15, 78, 111, 112

EFAULT, 194, 195, 196, 197 to 198

EINTR, 111, 112, 124, 133, 142, 143

EINVAL, 14, 15, 17, 20, 21, 27, 29, 31, 33, 38, 39, 47, 48, 49, 51, 52, 53, 54, 55, 56, 57, 58, 60, 64, 67, 72, 73, 74, 75, 77, 78, 79, 80, 81, 89, 90, 91, 93, 95, 96, 98, 100, 101, 109, 110, 111, 112, 113, 191, 194, 195, 196, 197 to 198, 203

ENOMEM, 19, 21, 72, 77, 89, 93, 202

ENOSPC, 109
ENOSYS, 28
ENOTSUP, 29, 53, 55
EPERM, 79, 109
errno, 22, 157, 159, 226
errno.h, 155
error checking, 31
ESRCH, 15, 17, 30, 31, 37, 189, 190
ETIME, 98
event notification, 108
examining the signal mask, 32, 205
exec(2), 120, 122, 124
execution resources, 190, 191, 238
exit(2), 124, 202
exit(3C), 34

F

finding
 minimum stack size, 203
 thread concurrency level, 191
 thread priority, 209
fine-grained locking, 230
flockfile(3S), 147
flowchart of compile options, 158
fork(2), 122, 124, 215
fork1(2), 122, 124
FORTRAN, 161, 176
funlockfile(3S), 147

G

getc(3S), 147
getc_unlocked(3S), 147
gethostbyname(3N), 227
gethostbyname_r(3N), 227
getrusage(3B), 127
global
 data, 229
 memory, 159
 side effects, 234
 state, 229

 variables, 22, 23, 225
global variables, 226

H

heap, malloc(3C) storage from, 16

I

I/O
 asynchronous, 144, 145
 nonsequential, 146
 standard, 147
 synchronous, 144
inheriting priority, 200
interrupt, 132
interval timer, 237
invariants, 104, 230

J

joining threads, 14, 48, 206

K

kernel context switching, 6
keys
 bind value to key, 208
 get specific key, 21, 208
 global into private, 23
 storing value of, 21, 208
kill(2), 132, 135

L

-lc, 157, 158
ld, 157, 158
libc, 154
libc, 153, 155, 158
libdl_stubs, 153
libintl, 153, 155
libm, 153, 155
libmalloc, 153, 155
libmapmalloc, 153, 155

libnsl, 154, 155, 159
 libposix4, 155
 libpthread, 155, 158
 library
 C routines, 225
 MT safety, 153
 threads, 155, 235
 libresolv, 154
 libsocket, 154, 155
 libthread, 5, 155, 158, 235
 libw, 154, 155
 libx11, 154
 lightweight processes, 7, 127 to 130, 235, 236
 adding an LWP, 202
 creation, 236
 debugging, 161
 defined, 2
 independence, 236
 multiplexing, 236
 not supported, 7
 profile state, 126
 shortage, 131
 special capabilities, 236
 in SunOS 4.0, 7
 and system calls, 237
 limits, resources, 127
 limits.h, 155
 linking, 155
 local variable, 227
 lock hierarchy, 232
 lock_lint, 83
 locking
 See also locks
 coarse grained, 230, 233
 code, 229
 conditional, 84
 data, 229
 fine-grained, 230, 233
 guidelines, 233
 invariants, 230
 LockLint tool, 163
 LockLint usage, 172
 locks
 See also locking
 mutual exclusion, 69 to 86, 122, 142
 readers/writer, 69, 198
 longjmp(3C), 127, 140
 LoopTool for parallelization, 176
 LoopTool reporter, 163
 -lpthread, 157, 158
 lseek(2), 147
 -lthread, 157, 158
 LWPs, *See* lightweight processes

M

main(), 234
 malloc(3C), 16
 Mandelbrot program, 164
 MAP_NORESERVE, 62
 MAP_SHARED, 124
 memory
 global, 159
 ordering, relaxed, 242
 strongly ordered, 241
 mmap(2), 62, 124
 monitor, code, 229, 231
 mprotect(2), 63, 203
 MT-Safe libraries, 153
 multiple-readers, single-writer locks, 198
 multiplexing with LWPs, 236
 multiprocessors, 239 to 244
 multithreading
 defined, 2
 mutex *See* mutual exclusion locks
 mutex_init(3T), 220, 221
 mutex_trylock(3T), 232
 mutual exclusion locks, 69 to 86, 122, 142

N

NDEBUG, 104
 netdir, 154
 netselect, 154

nice(2), 128, 129
 nondetached threads, 15, 33
 nonsequential I/O, 146
 null
 procedures, 158
 threads, 63, 203

P

P operation, 106
 parallel
 algorithms, 244
 array computation, 237
 Pascal, 161
 PC, 6
 PC_GETCID, 128
 PC_GETCLINFO, 128
 PC_GETPARMS, 128
 PC_SETPARMS, 128
 per-process signal handler, 132
 per-thread signal handler, 132
 Peterson's Algorithm, 242
 PL/1 language, 134
 portability, 70
 POSIX 1003.4a, 3
 pread(2), 145, 147
 printf problem, 228
 printf(3S), 140
 priocntl(2), 128, 129
 priority, 6, 127, 128, 129, 236
 finding for a thread, 209
 inheritance, 200, 208, 209
 range, 209
 and scheduling, 209
 setting for a thread, 209
 process
 terminating, 34
 traditional UNIX, 1
 producer/consumer problem, 116, 221, 241
 profil(2), 126
 profiling an LWP, 126

programmer-allocated stack, 62, 63, 203, 204
 prolagen, 106
 pthread.h, 155
 pthread_atfork(3T), 33
 pthread_attr_
 getdetachstate(3T), 49
 pthread_attr_
 getinheritsched(3T), 56
 pthread_attr_
 getschedparam(3T), 58
 pthread_attr_
 getschedpolicy(3T), 54
 pthread_attr_getscope(3T), 52
 pthread_attr_
 getstackaddr(3T), 67
 pthread_attr_
 getstacksize(3T), 61
 pthread_attr_init(3T), 45
 pthread_attr_
 setdetachstate(3T), 47
 pthread_attr_
 setinheritsched(3T), 55
 pthread_attr_
 setschedparam(3T), 57
 pthread_attr_
 setschedpolicy(3T), 52
 pthread_attr_setscope(3T), 50
 pthread_attr_
 setstackaddr(3T), 64
 pthread_attr_
 setstacksize(3T), 60
 pthread_cancel(3T), 36
 pthread_cleanup_pop(3T), 40
 pthread_cleanup_push(3T), 40
 pthread_cond_broadcast(3T), 94, 99, 102, 133
 example, 100
 pthread_cond_destroy(3T), 101
 pthread_cond_init(3T), 92
 pthread_cond_signal(3T), 94, 96, 102, 103, 133

example, 97
 pthread_cond_timedwait(3T), 98, 142
 example, 99
 pthread_cond_wait(3T), 94, 102, 103, 133, 142
 example, 97
 pthread_condattr_destroy(3T), 89
 pthread_condattr_
 getpshared(3T), 91
 pthread_condattr_init(3T), 88
 pthread_condattr_
 setpshared(3T), 90
 pthread_create(3T), 13
 PTHREAD_CREATE_JOINABLE, 45
 pthread_detach(3T), 17
 pthread_equal(3T), 26
 pthread_exit(3T), 33, 34
 pthread_getschedparam(3T), 30
 pthread_getspecific(3T), 21, 23, 24
 pthread_join(3T), 14, 46, 61, 144
 pthread_keycreate(3T), 18, 24, 25
 example, 24
 pthread_keydelete(3T), 19
 pthread_kill(3T), 31, 135
 pthread_mutex_destroy(3T), 81
 pthread_mutex_init(3T), 76
 pthread_mutex_lock(3T), 78
 example, 82, 84, 85, 86
 pthread_mutex_trylock(3T), 80, 84
 pthread_mutex_unlock(3T), 79
 example, 82, 84, 85, 86
 pthread_mutexattr_destroy, 72
 pthread_mutexattr_
 destroy(3T), 73
 pthread_mutexattr_
 getpshared(3T), 75
 pthread_mutexattr_init(3T), 72
 pthread_mutexattr_
 setpshared(3T), 74
 pthread_once(3T), 27
 PTHREAD_PROCESS_PRIVATE, 71, 72, 74, 75, 88, 90
 PTHREAD_PROCESS_SHARED, 71, 72, 74, 75, 88, 90
 PTHREAD_PROCESS_SHARED, 116
 PTHREAD_SCOPE_PROCESS, 8, 45, 50
 PTHREAD_SCOPE_SYSTEM, 8, 50
 pthread_self(3T), 25
 pthread_setcancelstate(3T), 37
 pthread_setcanceltype(3T), 38
 pthread_setprio(3T), 128, 130
 pthread_setschedparam(3T), 29
 pthread_setspecific(3T), 20, 24, 25
 example, 24
 pthread_sigmask(3T), 32
 pthread_sigsetmask(3T), 135
 PTHREAD_STACK_MIN(), 63
 pthread_testcancel(3T), 39
 pthread_yield(3T), 28
 putc(3S), 147
 putc_unlocked(3S), 147
 pwrite(2), 145, 147

R

read(2), 146, 147
 readers/writer locks, 69, 198
 realtime, 237
 scheduling, 127, 129
 red zone, 62, 63, 203
 reentrant, 229
 See also _REENTRANT
 described, 229
 functions, 151, 152
 strategies for making, 229
 register state, 6
 relaxed memory ordering, 242
 remote procedure call *See* RPC
 replacing signal mask, 32
 resume execution, 189
 RPC, 4, 154, 234
 RT, *See* realtime

`rw_rdlock(3T)`, 195
`rw_tryrdlock(3T)`, 195
`rw_trywrlock(3T)`, 197
`rw_unlock(3T)`, 197
`rw_wrlock(3T)`, 196
`rwlock_destroy(3T)`, 198
`rwlock_init(3T)`, 193, 220

S

`SA_RESTART`, 143
safety, threads interfaces, 149 to 154
scheduling
 class, 127 to 130
 compute-bound threads, 191
 priorities, 208
 realtime, 127, 129
 system class, 127
 timeshare, 127, 128
`sem_destroy(3T)`, 113
`sem_init(3T)`, 108
 example, 114
`sem_post(3T)`, 106, 110
 example, 115
`sem_trywait(3T)`, 106, 112
`sem_wait(3T)`, 111
 example, 115
`sema_init(3T)`, 220
`sema_post(3T)`, 153
semaphores, 69, 106 to 118
 binary, 107
 counting, defined, 2
sending signal to thread, 31, 205
sequential algorithms, 244
`setjmp(3C)`, 127, 139, 140
shared data, 6, 229
shared-memory multiprocessor, 241
`SIG_BLOCK`, 32
`SIG_DFL`, 132
`SIG_IGN`, 132
`SIG_SETMASK`, 32
`SIG_UNBLOCK`, 32

`sigaction(2)`, 132, 133, 143
`sigaltstack(2)`, 132
`SIGFPE`, 133, 139
`SIGILL`, 133
`SIGINT`, 133, 138, 143
`SIGIO`, 133, 146
`siglongjmp(3C)`, 139, 140
`signal(2)`, 132
`signal(5)`, 132
`signal.h`, 31, 32, 155, 205
signals
 access mask, 32, 205
 add to mask, 32
 asynchronous, 132 to 138
 delete from mask, 32
 handler, 132, 137
 inheritance, 200
 masks, 6
 pending, 189, 200
 replace current mask, 32
 send to thread, 31, 205
 `SIG_BLOCK`, 32
 `SIG_SETMASK`, 32
 `SIG_UNBLOCK`, 32
 `SIGSEGV`, 61
 stack, 132
 unmasked and caught, 142
`sigprocmask(2)`, 135
`SIGPROF`, 125
`SIGSEGV`, 61, 133
`sigsend(2)`, 132
`sigsetjmp(3C)`, 140
`sigtimedwait(2)`, 137
`SIGVTALRM`, 125
`sigwait(2)`, 135, 137, 138, 140
`SIGWAITING`, 131
single-threaded
 assumptions, 225
 code, 70
 defined, 2
 processes, 124
size of stack, 60, 62, 201, 203, 204
stack, 234, 237

address, 64, 201
 boundaries, 61
 creation, 64, 201
 custom, 203
 deallocation, 203
 minimum size, 62, 203
 overflows, 62
 parameters, 16
 pointer, 6
 programmer-allocated, 62, 63, 203, 204
 red zone, 62, 63, 203
 returning a pointer to, 151
 size, 60, 62, 201, 203, 204
 stack_base, 64, 201
 stack_size, 60, 201
 standard I/O, 147
 standards, 3
 start_routine, 201
 static storage, 159, 225
 stdio, 22, 157
 store buffer, 243
 storing thread key value, 21, 208
 streaming a tape drive, 145
 strongly ordered memory, 241
 strtoupper, 154
 suspending a new thread, 201
 swap space, 62
 synchronization objects, 69 to 118
 condition variables, 69, 87 to 105
 mutex locks, 69 to 86
 readers/writer locks, 198
 semaphores, 69, 106 to 116, 216 to 222
 synchronous I/O, 144, 145
 system calls
 handling errors, 226
 and LWP, 237
 system scheduling class, 127

T

tape drive, streaming, 145
 terminating

a process, 34
 threads, 15
 THR_BOUND, 202
 thr_continue(3T), 201
 thr_create(3T), 200, 203, 208
 THR_DAEMON, 202
 THR_DETACHED, 201
 thr_exit(3T), 202, 205
 thr_getconcurrency(3T), 191
 thr_getprio(3T), 209
 thr_getspecific(3T), 208
 thr_join(3T), 206
 thr_keycreate(3T), 207
 thr_kill(3T), 153
 thr_min_stack(3T), 201, 203
 THR_NEW_LWP, 191, 202, 238
 thr_self(3T), 204
 thr_setconcurrency(3T), 190, 202, 237, 238
 thr_setprio(3T), 209
 thr_setspecific(3T), 208
 thr_sigsetmask(3T), 153
 THR_SUSPENDED, 201
 thr_yield(3T), 204, 233
 Thread Analyzer main window, 166
 Thread Analyzer tool, 163
 thread.h, 155
 thread-directed signal, 137
 thread-private storage, 6
 threads
 compute-bound, 191
 concurrency *See* concurrency
 creating, 12 to 15, 200 to 203, 234, 238
 daemon, 202
 defined, 2
 detached, 15, 48, 201
 exit codes, 15
 identifiers, 15, 25, 26, 27, 33, 201, 202, 204
 initial, 34
 joining, 14, 34, 206
 keys *See* keys

- library, 155, 235
- lightweight processes *See* lightweight processes
- nondetached, 15, 33
- null, 63, 203
- priority *See* priority
- private data, 18
- safety, 149 to 154
- signals *See* signals
- stacks *See* stack, 151
- suspended, 189
- suspending, 201
- synchronizing, 69 to 118
- terminating, 15, 33, 205
- thread-specific data *See* thread-specific data, 226
- unbound *See* unbound threads
- user-level, 2, 5, 6
- thread-specific data, 18 to 25
 - global, 22, 23, 24
 - global into private, 23
 - new storage class, 226
 - private, 22
- time slicing, 130
- time-out, 99, 215
- timeshare scheduling class, 127, 128, 129
- tiuser.h, 159
- TLI, 154, 159
- tools
 - adb, 161
 - dbx, 161
 - debugger, 161
 - lock_lint, 83
- total store order, 243
- trap, 132
- TS, *See* timeshare scheduling class
- TSD, *See* thread-specific data

U

- unbound threads, 127
 - alternate signal stacks, 132
 - caching, 234
 - concurrency, 190, 238

- defined, 2
- disadvantage, 237
- mixing with bound threads, 237
- priorities, 127, 208
- reasons not to bind, 234, 237
- and scheduling, 127, 130
- and thr_
 - setconcurrency(3T), 19
 - 0, 238
- and pthread_setprio(3T), 128, 130
- unistd.h, 155
- UNIX, 1, 3, 5, 133, 144, 146, 226
- user space, 6
- user-level threads, 2, 5, 6
- USYNC_PROCESS, 71, 88, 193, 210, 213, 217, 220, 221, 238
- USYNC_THREAD, 71, 88, 193, 210, 213, 217, 220

V

- V operation, 106
- variables
 - condition, 69, 87 to 105, 118
 - global, 225, 226
 - primitive, 70
- verhogen, 106
- vfork(2), 122

W

- write(2), 146, 147

X

- XDR, 154