

▼ Notes on "EP" Library

Author Eric Allman

Copyright 2008, 2014–2015 Eric P. Allman. All rights reserved.

Date 2015-09-30

▼ 1 INTRODUCTION

This document describes the Enhanced Portability library. This is a reduced version of Eric's Portability library (designed for sendmail), removing many things that didn't work out or proved unnecessary, e.g., the entire I/O subsystem. It was originally intended to be used in sendmail, so some of the terminology is geared toward the email world; none the less, it should be generally useful.

▼ 1.1 Design Goals

- Portable, to the extent possible. Where not possible, there needs to be a clearly codified way to represent the externally visible semantic differences.
- Efficient.
- Customizable -- try to implement mechanism, not policy.
- TBD: It should be entirely UTF-8 internally. Any translations to other character sets should be done on input or output, and then only as strictly necessary.

▼ 1.2 Assumptions

Use of this library requires that you have a C compiler that is compliant with ANSI C as defined by ANSI/ISO 9899-1999. Also requires an environment that is at least Posix based on Posix.1-2008.

▼ 1.3 Conventions

- All externally visible names (i.e., those not declared "static" in a file) shall be named `ep_*` (for routine names) or `Ep*` (for variable names). In a few cases, the names may begin with `__ep` or `__Ep`; such names would be in the global namespace, but would be intended for use internal to the library only.

▼ 1.4 Terminology

▼ 1.4.1 Warning, Error, Severe, Abort

These words get used fairly loosely, so they are worth defining. In the context of libep:

- Warning means a condition that is expected in normal operations, but is not the usual case. Reading an end-of-file on a file might be a warning. Applications need to be aware of these, but are expected to either ignore them or recover easily. This can also be used for temporary errors which are likely to recover after a delay. For example, the inability to open a connection to a remote server might recover automatically if that server is re-started. However, this sort of warnings that persist should turn into permanent errors in a fashion appropriate for the application.
- Error means a situation that should not occur, but isn't terribly unusual. For example, an attempt to open a file that isn't accessible would be an error. Applications must be aware of such conditions and handle them gracefully.
- Severe means a situation that should not occur and requires exceptional handling. Severe errors are drastic conditions, but are not so severe that the application can't take some reasonable backout action.

- Abort means a situation so drastic that an application cannot be expected to make any reasonable recovery. These might include assertion errors and memory allocation failures during a critical step (e.g., something where backing out a single thread won't solve the problem). About the only thing an application can reasonably do is log an abort error and exit. In particular, an abort is appropriate when an attempt for an application to recover is likely to do additional damage. These should be extremely rare.

▼ 2 GENERAL ISSUES

All files using this library must use `"#include <ep/ep.h>".`

▼ 3 STATUS CODES

Almost all functions return an `EP_STAT` value. This is a short (integer-encoded) status value that gives you a brief idea of how severe the problem was and some idea of what it was, but not much else. Think of it as an `errno` equivalent. Functions returning any status other than OK are expected to provide some other way of returning detailed data.

`EP_STATS` are also used as message identifiers for logging (below).

Status codes are defined in `<ep/ep_stat.h>.`

▼ 3.1 Severities

Severities are:

EP_STAT_SEV_OK

Everything is fine. Detail may contain info. For messages, can be used for debugging.

EP_STAT_SEV_WARN

The function partially succeeded, but there is something that the application should be aware of, e.g., an end of file or a short data read. Alternatively, the function failed, but it might work again on a later try.

EP_STAT_SEV_ERROR

A normal error status. The call failed.

EP_STAT_SEV_SEVERE

A severe error status. The call failed, and the caller should try to back out.

EP_STAT_SEV_ABORT

A critical error occurred — you should clean up and exit as soon as possible; the program cannot be expected to operate correctly.

Some functions for testing values:

EP_STAT_SEV_ISOK(st)

Returns true if this is an `EP_STAT_SEV_OK` status code.

EP_STAT_SEV_WARN(st)

Returns true if this is an "warning" severity status code: `EP_STAT_SEV_WARN`.

EP_STAT_SEV_ISFAIL(st)

Returns true if this message is a "failure" severity status code: `EP_STAT_SEV_WARN` or higher.

EP_STAT_SEV_ISERROR(st)

Returns true if this is an "error" severity status code: `EP_STAT_SEV_ERROR`

EP_STAT_SEV_ISPERM(st)

Returns true if this message is a "permanent failure" severity status code: `EP_STAT_SEV_ERROR` or higher

EP_STAT_SEV_ISSEVERE(st)

Returns true if this is an "severe" severity status code: `EP_STAT_SEV_SEVERE`

EP_STAT_SEV_ISMAJOR(st)

Returns true if this message is a "major" severity status code: `EP_STAT_SEV_SEVERE` or higher

EP_STAT_SEV_ISABORT(st)

Returns true if this is an "abort" severity status code: `EP_STAT_SEV_ABORT`

▼ 3.2 Status Code Representation

Status codes are represented as four-part values: severity, registry, module, and detail. The severities are described above. Registries are globally registered by neophilic.com and are defined in `ep_registry.h`. There are some registries for general use; in particular, registry numbers between `0x001` and `0x1FF` are available for local (non-global) registry at the corporate or local level. Modules are defined by registries, and detail is defined by module. It is *never* acceptable to look at detail unless you recognize the module. (OK, you can print it out for debugging.) Severity = 3 bits, registry = 13 bits, module = 6 bits, detail = 10 bits.

Any severity where the top bit is zero is considered "OK", and the rest of the word is available to encode a non-negative integer.

Status codes are represented as structures to ensure type safety. Occasionally you might want to convert a status to or from a long int:

```
int      EP_STAT_TO_INT(EP_STAT stat)           // convert status to unsigned int
EP_STAT  EP_STAT_FROM_INT(unsigned int istat)  // convert unsigned integer to status
```

The constituent parts of the status code can also be extracted:

EP_STAT_SEV(st)
Returns the severity part of the status code.

EP_STAT_REGISTRY(st)
Returns the registry part of the status code.

EP_STAT_MODULE(st)
Returns the module part of the status code.

EP_STAT_DETAIL(st)
Returns the detail part of the status code.

To compare two statuses for equality, use `EP_STAT_IS_SAME(a, b)`.

As a special case, if the severity is `EP_STAT_SEV_OK` the rest of the word is ignored; this can be used to pass small integers (no more than 31 bits) of information.

▼ 3.3 Predefined Status Codes

All status codes from this library are in the `EP_REGISTRY_EPLIB` registry. There are several predefined status codes for generic use, all using module `EP_STAT_MOD_GENERIC`:

<code>EP_STAT_OK</code>	No error (also integer 0)
<code>EP_STAT_WARN</code>	Generic warning status
<code>EP_STAT_ERROR</code>	Generic error status
<code>EP_STAT_SEVERE</code>	Generic severe error status
<code>EP_STAT_ABORT</code>	Generic abortive status
<code>EP_STAT_OUT_OF_MEMORY</code>	Out of memory
<code>EP_STAT_ARG_OUT_OF_RANGE</code>	An argument was out of range
<code>EP_STAT_END_OF_FILE</code>	End of input
<code>EP_STAT_TIME_BADFORMAT</code>	Couldn't parse a date/time string

There is also a special module `EP_STAT_MOD_ERRNO` that encodes Posix-style `errno`s (i.e., use `EP_STAT_DETAIL` on codes returned by that module to get the Posix `errno` code).

▼ 3.4 Manipulating Status Codes

There are several routines to print error codes or create them on the fly. Note that `ep_stat_tostr` returns the buffer itself.

```
// create status code from UNIX errno
extern EP_STAT ep_stat_from_errno(
    int uerrno);

// return string representation of status
char *ep_stat_tostr(
    EP_STAT estat,
    char *buf,
    size_t bsize);

// return string representation of severity (in natural language)
const char *ep_stat_sev_tostr(
    int sev);

// print a status code and abort (never returns)
void ep_stat_abort(
    EP_STAT estat);
```

▼ 3.5 Creating New Status Codes

Libraries and applications can create their own specific error codes. There are four steps to do this:

1. Determine the registry. The registry name space is divided as follows:

0x000 (EP_REGISTRY_GENERIC)	reserved for generic status codes
0x001 (EP_REGISTRY_USER)	available for internal use to an application
0x002-0x07F	available for local, unregistered use, such as separate applications within an application suite
0x080-0x0FF	available for internal corporate registry, but not registered globally; conflicts may occur between organizations but not within an organization
0x100 (EP_REGISTRY_EPLIB)	reserved for libep
0x101-0x6FF	available for centrally managed global registry — contact the libep maintainers for an allocation
0x700-0x7FF	reserved

2. Determine the module(s) in which the error code should exist. These must be unique within a registry and in the range 0x00-0xFF.
3. Define the error codes you want to use using `EP_STAT_NEW`, e.g.,

```
#define FOO_STAT_ELEPHANT    EP_STAT_NEW(ERROR, EP_REGISTRY_FOO, MOD_BAR, 1)
#define FOO_STAT_GIRAFFE    EP_STAT_NEW(SEVERE, EP_REGISTRY_FOO, MOD_BAR, 2)
```

4. (Optional step) Define the strings associated with the error codes when they are printed. These are done by populating a table and then calling `ep_stat_register_strings`. For example:

```
struct ep_stat_reg_strings FooStatusCodes[] =
{
```

```

    FOO_STAT_ELEPHANT,    "elephant in the room",    },
    FOO_STAT_GIRAFFE,    "too tall",                },
    EP_STAT_OK,          NULL,                      }
}

ep_stat_reg_strings(FooStatusCodes);

```

▼ 4 INITIALIZATION

Although libep will generally work without initialization, in some cases you may need to give it information about your usage. To do this call `ep_lib_init`:

```

#include <ep/ep.h>

EP_STAT
ep_lib_init(uint32_t flags)

```

Flags can be:

EP_LIB_USEPTHREADS	Initialize the thread support
--------------------	-------------------------------

▼ 5 MEMORY ALLOCATION AND RESOURCE POOLS

▼ 5.1 Memory

Memory support is much like `malloc/free`, but with some additional functionality. One crucial difference is that most of these routines do not return if memory is exhausted; instead they can call a cleanup routine that might (for example) eliminate some old cache entries, or pick a "victim" thread to kill and reclaim its memory. If successful they can continue, otherwise the process is aborted.

```

#include <ep/ep_mem.h>

void *
ep_mem_malloc(size_t nbytes)      // allocate uninitialized memory

void *
ep_mem_zalloc(size_t nbytes)     // allocate zeroed memory

void *
ep_mem_ralloc(size_t nbytes)     // allocate randomized memory

void *
ep_mem_ealloc(size_t nbytes)     // allocate memory, failure OK

void *
ep_mem_realloc(size_t nbytes,    // reallocate (extend) memory
               void *curmem)

void *
ep_mem_falloc(size_t nbytes,     // allocate memory (see flags)
               uint32_t flags)

void
ep_mem_mfree(void *mem)          // free indicated memory

struct ep_malloc_functions
{
    void    *(*m_malloc)(size_t);
    void    *(*m_realloc)(void*, size_t);
    void    *(*m_valloc)(size_t);
    void    (*m_free)(void*);
};

```

```
void
ep_mem_set_malloc_functions(          // set underlying malloc functions
    struct ep_malloc_functions *funcs)
```

The `ep_mem_malloc`, `ep_mem_zalloc`, `ep_mem_ralloc`, and `ep_mem_realloc` are all implemented in terms of `ep_mem_falloc`, which uses flags to tune the behavior (see below). The primary interface is `ep_mem_malloc`, which returns uninitialized data; `ep_mem_zalloc` returns zeroed memory, and `ep_mem_ralloc` returns memory that is initialized to random or some other nonsensical data. The last would probably be used only for debugging, and can be turned on at runtime using a debug flag *XXX TBD*.

In all allocation schemes, the function returns a pointer to the allocated data — they cannot normally return `NULL` (but see below). If they cannot allocate the memory, they *do error recovery (XXX describe)*. If recovery fails, the allocation system will abort the process. However, `ep_mem_malloc` can return `NULL` on memory allocation failure, as can `ep_mem_falloc` if the `EP_MEM_F_FAILOK` flag bit is set (see below).

Flag bits are as follows:

EP_MEM_F_FAILOK

Permits the routine to return `NULL` on failure. This modifies the behavior described above. Note that if this is set every call to the `ep_*malloc` routines may potentially fail.

EP_MEM_F_ZERO

Zero any returned memory.

EP_MEM_F_TRASH

Randomize any returned memory.

EP_MEM_F_ALIGN

The application would prefer that the allocation is page-aligned. This is not available on all architectures, and other architectures do it automatically if the allocation is at least as large as a page.

EP_MEM_F_WAIT

If memory is unavailable, try to wait for it to become available (e.g., because another thread has released memory). *This is not yet implemented.*

Specifying `EP_MEM_F_ZERO` and `EP_MEM_F_TRASH` at the same time is undefined.

Since `ep_mem_[mzr]alloc` are implemented as macros, they can't be used as pointers to functions (e.g., for specifying a memory allocator callback to a third party app). For this reason, there are also `ep_mem_[mzr]alloc_f` "real" functions to be used in this context.

Generally, unthreaded code and most application code will probably be happy with the defaults. Threaded server code (which cannot be permitted to die) is expected to catch the out of memory condition, do some recovery operation such as terminating a task, and return `EP_MEM_STAT_TRYAGAIN` so the memory allocation can retry.

[[XXX Document `ep_set_malloc_functions` XXX]]

▼ 5.2 Resource Pools

Resources are allocatable global entities such as memory, file descriptors, etc. Resources can be collected together into pools and then freed in one call. Memory is specially handled to allow fast allocation from a pool --- specifically, a chunk of memory can be allocated from the heap to a pool and then sub-allocated as needed. Allocating memory from resource pools is particularly fast for small allocations. Also, pool allocations that are of a size that is a multiple of the page size are guaranteed to return a page-aligned pointer. This is particularly useful to allow the I/O level to implement zero-copy I/O.

The heap used is the one that is current when `ep_rpool_new` is invoked.

```
#include <ep/ep_mem.h>

EP_RPOOL *
```

```

ep_rpool_new(const char *name,           // for debugging
             size_t qsize)              // min memory allocation quantum

EP_STAT
ep_rpool_free(EP_RPOOL *rp)            // free pool and all resources

void *
ep_rpool_malloc(EP_RPOOL *rp,          // the pool to allocate from
                size_t nbytes)         // number of bytes

void *
ep_rpool_zalloc(EP_RPOOL *rp,          // the pool to allocate from
                size_t nbytes)         // number of bytes

void *
ep_rpool_xalloc(EP_RPOOL *rp,          // the pool to allocate from
                size_t nbytes,         // number of bytes
                const char *filename,  // file name (for debugging)
                int lineno,           // line number (for debugging)
                uint32_t flags)       // flag bits (see below)

void *
ep_rpool_strdup(EP_RPOOL *rp,          // the pool to allocate from
                char *str)             // the string to save

void *
ep_rpool_realloc(EP_RPOOL *rp,         // pool to allocate from
                 void *old mem,        // old memory pointer
                 size_t oldsize,       // old allocation size
                 size_t newsize)       // new allocation size

void
ep_rpool_mfree(EP_RPOOL *rp,           // the pool to release to
               void *p);               // the memory

void
ep_rpool_mfreeto(EP_RPOOL *rp,         // the pool to release to
                 void *p);             // restore up the pool to here

EP_STAT
ep_rpool_attach(EP_RPOOL *rp,          // the resource pool
                void freefunc(void *arg), // a function to call on free
                void *arg)             // argument to pass to it

```

The `ep_rpool_mfreeto()` routine lets you treat rpool memory like a stack; this call releases everything allocated back to (and including) the pointer given. If `p == NULL`, the entire memory contents of the rpool are freed, but the rpool itself is still active. Deep care needs to be taken here: if a subordinate routine is called that allocates memory from the rpool, you may end up deallocating memory that is still in use. *Not implemented at this time.*

The `ep_rpool_attach()` routine is used to associate other resources (such as files) with a pool. The corresponding free functions will be invoked when the pool is freed.

In most cases, passing in `rp == NULL` treats the call like the corresponding heap allocation. In this case the caller is responsible for freeing the memory. For example, `ep_rpool_malloc(NULL, nbytes)` is equivalent to `ep_mem_malloc(nbytes)`.

The distinction between multiple heaps and resource pools are that heaps are not intended for application use other than for doing recovery for out-of-memory conditions. Pools are intended for general use. Pools are fast at allocation time (since they just grab space from the end of the pool) and fast at free time (since the entire pool can be deallocated at once); heaps are comparatively slow.

When any memory collections (heaps or pools) are freed, all objects allocated from that collection are freed (i.e., their destructors are automatically invoked).

▼ 5.3 Opening Memory as a File

```
FILE *
ep_fopensmem(void *buf,          // block of memory to open
              size_t bsize,      // size of that memory
              const char *mode)   // fopen(3) mode string
```

▼ 6 TIME

The ep library has a separate time abstraction. This is for two reasons: first, it guarantees that the number of seconds since January 1, 1970 will be sufficiently long to last past 2038 (this varies from system to system), and it includes a "tv_accuracy" (type float) to indicate the approximate accuracy of the clock relative to absolute time. For example, a clock synchronized from a GPS clock might be accurate within perhaps 100nsec, whereas a standard crystal clock synchronized once a day might only have an accuracy of a few seconds.

```
#include <ep/ep_time.h>

typedef struct
{
    int64_t    tv_sec;           // seconds since Jan 1, 1970
    int32_t    tv_nsec;         // nanoseconds
    float      tv_accuracy;      // clock accuracy in seconds
} EP_TIME_SPEC;

EP_STAT
ep_time_now(                    // return current time
    EP_TIME_SPEC *tv);

EP_STAT
ep_time_deltanow(               // return time in the future (or past)
    uint64_t delta_nanoseconds,
    EP_TIME_SPEC *tv);

void
ep_time_add_delta(              // add a delta to a time (delta may be negative)
    EP_TIME_SPEC *delta,
    EP_TIME_SPEC *tv);

bool
ep_time_before(                 // determine if A occurred before B
    EP_TIME_SPEC *a,
    EP_TIME_SPEC *b);

void
ep_time_from_nsec(              // create a time from a scalar number of nanoseconds
    int64_t delta,
    EP_TIME_SPEC *tv);

float
ep_time_accuracy(void);         // return putative clock accuracy

void
ep_time_setaccuracy(            // set the clock accuracy (may not be available)
    float accuracy);

void
ep_time_format(                 // format a time string into a buffer
    EP_TIME_SPEC *tv,
    char *buf,
    size_t bufsize,
    uint32_t flags);
```



```

void
ep_time_print(
    EP_TIME_SPEC *tv,
    FILE *fp,
    uint32_t flags);

// values for ep_time_format and ep_time_print flags
#define EP_TIME_FMT_DEFAULT    0           // pseudo-flag
#define EP_TIME_FMT_HUMAN     0x00000001   // format for humans
#define EP_TIME_FMT_NOFUZZ    0x00000002   // suppress accuracy printing

EP_STAT
ep_time_parse(
    const char *timestr,
    EP_TIME_SPEC *tv);

EP_STAT
ep_time_nanosleep(
    int64_t nanoseconds);

bool
EP_TIME_ISVALID(
    EP_TIME_SPEC *tv);

void
EP_TIME_INVALIDATE(
    EP_TIME_SPEC *tv);

```

"Human" formatted times are intended to be human readable, and may use non-ASCII characters. Otherwise the format is intended to be machine readable, e.g., using `ep_time_parse`.

▼ 7 DATA STRUCTURES

▼ 7.1 Property Lists

Not implemented at this time. A series of key=value pairs. Used for many things, including configuration files. For example, looking in the "configuration" property list for "mailer.local.timeout.connect" would return the connect timeout for the local mailer. *[[How does this deal with nested defaults — e.g., looking for timeout.connect if the full path cannot be found?]]*

```

EP_PLIST *
ep_plist_new(
    const char *name)           // for printing

EP_STAT
ep_plist_load(
    EP_PLIST *plp,              // the list to read into
    FILE *sp,                   // the stream to load from
    const char *prefix)         // prefix added to all properties

EP_STAT
ep_plist_set(
    EP_PLIST *plp,              // the plist in which to set
    const char *keyname,        // the name of the key to set
    const char *value)          // the value to set (will be copied)

const char *
ep_plist_get(
    EP_PLIST *plp,              // the plist to search
    const char *keyname)        // the name of the key to get

void
ep_plist_dump(
    EP_PLIST *plp,              // plist to print

```

```

        FILE *sp)                                // stream to print to

void
ep_plist_free(
    EP_PLIST *plp)                                // plist to free

```

A property list can be loaded from an external stream using `ep_plist_load`. The syntax of the file is a simple text file with "key=value" pairs on separate lines, with blank lines and those with # at the beginning of the line ignored. The values are strictly strings. *[[Does it make sense to type them?]]*

[[Note the overlap between plists and the `ep_adm` interface. Does this make sense?]]

Property lists can be printed using `ep_plist_dump`. The output format will be readable by `ep_plist_load`. For the time being, flags should always be 0.

Warning The property list is not guaranteed to be dumped in the same order items are inserted.

▼ 7.2 Hashes

```

#include <ep/ep_hash.h>

EP_HASH *
ep_hash_new(
    const char *name,                // for printing
    EP_HASH_HASH_FUNC *hfunc,       // alternate hash function
    int tabsize)                    // hash table function size

void
ep_hash_free(
    EP_HASH *hp)                    // hash to free

void *
ep_hash_search(
    const EP_HASH *hp,              // hash to search
    size_t keylen,                  // length of key
    const void *key)                // pointer to key

void *
ep_hash_insert(                     // returns old value for key
    EP_HASH *hp,                   // hash to modify
    size_t keylen,                  // length of key
    const void *key,                // pointer to key
    void *val)                      // value to insert

ep_hash_forall(EP_HASH *hp,         // hash to walk
    void (func)(                    // function to call
        int keylen,                 // key length
        const void *key,            // key value
        void *val,                  // value
        void *closure),             // from caller
    void *closure)                  // passed to func

ep_hash_dump(EP_TREE *tree,         // tree to dump
    FILE *sp)                       // stream to print on

```

[[Should `ep_hash_dump` take the same parameters as the usual object print routine? For that matter, should there be a separate `ep_hash_dump` routine, or should it just be a generic `ep_obj_dump`? Note that `ep_hash_dump` is not implemented at this time, but an internal (object-based) dump is.]]

▼ 7.3 Function Lists

```

#include <ep/ep_funclist.h>

EP_FUNCLIST *

```

```

ep_funclist_new(
    const char *name)        // name for printing/debugging

void
ep_funclist_free(EP_FUNCLIST *fp) // list to free

void
ep_funclist_push(EP_FUNCLIST *fp, // list to push to
                 void (*func)(void *), // the function to invoke
                 void *arg)          // an argument to pass to it

void
ep_funclist_pop(EP_FUNCLIST *fp) // list to pop from, value discarded

void
ep_funclist_clear(EP_FUNCLIST *fp) // list to clear

void
ep_funclist_invoke(EP_FUNCLIST *fp) // invoke all functions in list

```

▼ 8 CRYPTOGRAPHIC SUPPORT

The current implementation wraps the OpenSSL library, but it could be retargeted.

Before any cryptographic functions can be used, the library must be initialized:

```
void          ep_crypto_init(uint32_t flags)
```

At the moment flags is unused (just pass zero). There are also several general purpose definitions, useful for declaring buffers without memory allocation:

EP_CRYPTO_MAX_PUB_KEY	Maximum length of a public key
EP_CRYPTO_MAX_SEC_KEY	Maximum length of a secret key
EP_CRYPTO_MAX_DIGEST	Maximum length of a message digest
EP_CRYPTO_MAX_DER	Maximum length of a DER-encoded key

▼ 8.1 Key Management

Internally all keys are represented as EP_CRYPTO_KEY variables, defined in ep_crypto.h. External representations for keys may be either PEM (Privacy Enhanced Mail, represented as text) or DER (Distinguished Encoding Rules, represented in binary). PEM self identifies the type of key, but DER does not, so in some cases the key type needs to be pre-arranged.

```

// on-disk key formats
# define EP_CRYPTO_KEYFORM_UNKNOWN    0        // error
# define EP_CRYPTO_KEYFORM_PEM       1        // PEM (ASCII-encoded text)
# define EP_CRYPTO_KEYFORM_DER       2        // DER (binary ASN.1)

```

Internally, algorithms (e.g., for keys and hash/digest functions) are represented by a scalar value. Keys also have to be identified as public or secret.

[[Note: DH is not supported at this time.]]

```

// key types
# define EP_CRYPTO_KEYTYPE_UNKNOWN    0        // error
# define EP_CRYPTO_KEYTYPE_RSA       1        // RSA
# define EP_CRYPTO_KEYTYPE_DSA       2        // DSA
# define EP_CRYPTO_KEYTYPE_EC        3        // Elliptic curve
# define EP_CRYPTO_KEYTYPE_DH        4        // Diffie-Hellman

// flag bits
# define EP_CRYPTO_F_PUBLIC           0x0000   // public key (no flags set)

```

```
# define EP_CRYPTO_F_SECRET          0x0001  // secret key
```

Keys are represented as an `EP_CRYPTO_KEY`. New keys can be created by giving the type of the key desired, the length of the key in bits, and two other values that are interpreted by the key type. The first is primarily for RSA and gives the exponent, and the second is primarily for EC and gives the curve name.

```
EP_CRYPTO_KEY      *ep_crypto_key_create(
                    int keytype,
                    int keylen,
                    int keyexp,
                    const char *curve);
```

Keys can be read from or written to named files, open files, or memory. All the read routines create and return a new key data structure. If the `keyform` is `EP_CRYPTO_KEYFORM_PEM` then the `keytype` need not be specified.

```
EP_CRYPTO_KEY      *ep_crypto_key_read_file(
                    const char *filename,
                    int keytype,
                    int keyform,
                    uint32_t flags);
EP_CRYPTO_KEY      *ep_crypto_key_read_fp(
                    FILE *fp,
                    const char *filename,
                    int keytype,
                    int keyform,
                    uint32_t flags);
EP_CRYPTO_KEY      *ep_crypto_key_read_mem(
                    const void *buf,
                    size_t buflen,
                    int keytype,
                    int keyform,
                    uint32_t flags);
EP_STAT            ep_crypto_key_write_file(
                    EP_CRYPTO_KEY *key,
                    const char *filename,
                    int keyform,
                    int cipher,
                    uint32_t flags);
EP_STAT            ep_crypto_key_write_fp(
                    EP_CRYPTO_KEY *key,
                    FILE *fp,
                    int keyform,
                    int cipher,
                    uint32_t flags);
EP_STAT            ep_crypto_key_write_mem(
                    EP_CRYPTO_KEY *key,
                    void *buf,
                    size_t bufsize,
                    int keyform,
                    int cipher,
                    uint32_t flags);
```

When finished with a key it must be freed.

```
void                ep_crypto_key_free(
                    EP_CRYPTO_KEY *key);
```

There are also some utility routines. A public and a secret key can be compared to see if they match each other (same algorithm, keysize, etc.) using `ep_crypto_key_compat`. Various conversions are also included: `ep_crypto_keyform_byname` converts a text string (e.g., "pem") to an internal code, `ep_crypto_keytype_fromkey` returns the type of a key, and `ep_crypto_keytype_byname` converts a text string to a type.

```
EP_STAT            ep_crypto_key_compat(
```

```

                                const EP_CRYPTO_KEY *pubkey,
                                const EP_CRYPTO_KEY *seckey);
int                                ep_crypto_keyform_byname(
                                const char *fmt);
int                                ep_crypto_keytype_fromkey(
                                EP_CRYPTO_KEY *key);
int                                ep_crypto_keytype_byname(
                                const char *alg_name);

```

▼ 8.2 Message Digests (Hashes)

Several message digest (cryptographic hash) algorithms are supported. Text can be converted to one of these values, and the algorithm type can be extracted from the internal form.

```

// digest algorithms (no more than 4 bits)
# define EP_CRYPTO_MD_NULL        0
# define EP_CRYPTO_MD_SHA1        1
# define EP_CRYPTO_MD_SHA224      2
# define EP_CRYPTO_MD_SHA256      3
# define EP_CRYPTO_MD_SHA384      4
# define EP_CRYPTO_MD_SHA512      5

int                                ep_crypto_md_alg_byname(
                                const char *alname);
int                                ep_crypto_md_type(
                                EP_CRYPTO_MD *md);

```

Digests (type EP_CRYPTO_MD) can be created, freed, and cloned. Cloning lets an application compute the a fixed part of a digest (perhaps an unchanging header) and then produce separate digests for individual records.

```

EP_CRYPTO_MD                      *ep_crypto_md_new(
                                int md_alg_id);
EP_CRYPTO_MD                      *ep_crypto_md_clone(
                                EP_CRYPTO_MD *base_md);
void                                ep_crypto_md_free(
                                EP_CRYPTO_MD *md);

```

The typical lifetime of a digest is to be created (as above), updated with additional data, possibly multiple times, and then finalized to give the output hash.

```

EP_STAT                          ep_crypto_md_update(
                                EP_CRYPTO_MD *md,
                                void *data,
                                size_t dsize);
EP_STAT                          ep_crypto_md_final(
                                EP_CRYPTO_MD *md,
                                void *dbuf,
                                size_t dbufsize);

```

▼ 8.3 Signing and Verification

Signing and verification are quite similar. A new internal structure is created, using the same type as a message digest, data is added to the existing hash, possibly multiple times, the signature is created or verified, and finally the structure is freed.

```

# define EP_CRYPTO_MAX_SIG        (1024 * 8)

EP_CRYPTO_MD                      *ep_crypto_sign_new(
                                EP_CRYPTO_KEY *skey,
                                int md_alg_id);
void                                ep_crypto_sign_free(
                                EP_CRYPTO_MD *md);
EP_STAT                          ep_crypto_sign_update(

```

```

        EP_CRYPTO_MD *md,
        void *dbuf,
        size_t dbufsize);
EP_STAT      ep_crypto_sign_final(
        EP_CRYPTO_MD *md,
        void *sbuf,
        size_t *sbufsize);

EP_CRYPTO_MD      *ep_crypto_vrfy_new(
        EP_CRYPTO_KEY *pkey,
        int md_alg_id);
void      ep_crypto_vrfy_free(
        EP_CRYPTO_MD *md);
EP_STAT      ep_crypto_vrfy_update(
        EP_CRYPTO_MD *md,
        void *dbuf,
        size_t dbufsize);
EP_STAT      ep_crypto_vrfy_final(
        EP_CRYPTO_MD *md,
        void *obuf,
        size_t obufsize);

```

▼ 8.4 Encryption and Decryption (Asymmetric)

To be supplied.

▼ 8.5 Encryption and Decryption (Symmetric Ciphers)

Symmetric Ciphers are driven by a Chaining Mode (how subsequent blocks have the key modified to prevent replay and brute force attacks) and the actual cipher itself. The chaining modes are:

EP_CRYPTO_MODE_CBC	Cipher Block Chaining
EP_CRYPTO_MODE_CFB	Cipher Feedback mode
EP_CRYPTO_MODE_OFB	Output Feedback mode

The various cipher algorithms (which is equivalent to the key type) are:

EP_CRYPTO_SYMKEY_NONE	Error/unencrypted
EP_CRYPTO_SYMKEY_AES128	Advanced Encr Std, 128-bit key
EP_CRYPTO_SYMKEY_AES192	Advanced Encr Std, 192-bit key
EP_CRYPTO_SYMKEY_AES256	Advanced Encr Std, 256-bit key
EP_CRYPTO_SYMKEY_CAMELLIA128	Camellia, 128-bit key
EP_CRYPTO_SYMKEY_CAMELLIA192	Camellia, 192-bit key
EP_CRYPTO_SYMKEY_CAMELLIA256	Camellia, 256-bit key
EP_CRYPTO_SYMKEY_DES	Data Encryption Standard, single, 56-bit key
EP_CRYPTO_SYMKEY_3DES	Data Encryption Standard, triple, 128-bit key (112-bit effective)
EP_CRYPTO_SYMKEY_IDEA	International Data Encryption Alg, 128-bit key

One value from each table are "or"ed together to specify a full symmetric cipher. The rest of the interface is as follows:

```

/*
**      The cipher is set to encrypt or decrypt when the context
**      is created.
**

```

```

**      ep_crypto_cipher_crypt is just shorthand for a single
**      call to ep_crypto_cipher_cryptblock followed by a single
**      call to ep_crypto_cipher_finish. Finish pads out any
**      remaining block and returns that data.
*/

EP_CRYPTO_CIPHER_CTX      *ep_crypto_cipher_new(
                        uint32_t ciphertype,      // mode + keytype & len
                        uint8_t *key,             // the key
                        uint8_t *iv,              // initialization vector
                        bool enc);                // true => encrypt

void                      ep_crypto_cipher_free(
                        EP_CRYPTO_CIPHER_CTX *cipher);

EP_STAT                  ep_crypto_cipher_crypt(
                        EP_CRYPTO_CIPHER_CTX *cipher,
                        void *in,                 // input data
                        size_t inlen,             // input length
                        void *out,               // output buffer
                        size_t outlen);           // output buf size

EP_STAT                  ep_crypto_cipher_cryptblock(
                        EP_CRYPTO_CIPHER_CTX *cipher,
                        void *in,                 // input data
                        size_t inlen,             // input length
                        void *out,               // output buffer
                        size_t outlen);           // output buf size

EP_STAT                  ep_crypto_cipher_finish(
                        EP_CRYPTO_CIPHER_CTX *cipher,
                        void *out,               // output buffer
                        size_t outlen);           // output buf size

```

▼ 8.6 Cryptography-specific Error Codes

There are several status codes that may be returned from the cryptography routines. These are all in module EP_STAT_MOD_CRYPTO.

EP_STAT_CRYPTO_DIGEST	Failed to update or finalize a digest (hash)
EP_STAT_CRYPTO_SIGN	Failed to update or finalize a digest for signing
EP_STAT_CRYPTO_VRFY	Failed to update or finalize a digest for verification
EP_STAT_CRYPTO_BADSIG	Signature did not match
EP_STAT_CRYPTO_KEYTYPE	Unknown key type
EP_STAT_CRYPTO_KEYFORM	Unknown key format
EP_STAT_CRYPTO_CONVERT	Couldn't read or write a key
EP_STAT_CRYPTO_KEYCREATE	Couldn't create a new key
EP_STAT_CRYPTO_KEYCOMPAT	Public and secret keys are incompatible
EP_STAT_CRYPTO_CIPHER	Symmetric cipher failure

▼ 9 APPLICATION SUPPORT

The following routines are intended to provide useful support to applications, but are not otherwise fundamental

▼ 9.1 Printing Flag Words, Etc.

```

#include <ep/ep_prflags.h>

void

```

```

ep_prflags(
    u_int32 flagword,           // the flags word to print
    EP_PRFLAGS_DESC *flaglist, // descriptor of flags
    FILE *out)                 // output stream

typedef struct ep_prflags_desc
{
    u_int32 bits;           // bits to compare against
    u_int32 mask;           // mask against flagword
    char *name;             // printable name
} EP_PRFLAGS_DESC;

```

For example, given a descriptor of:

```

0x0000, 0x0003, "READ",
0x0001, 0x0003, "WRITE",
0x0002, 0x0003, "READWRITE",
0x0003, 0x0003, "[INVALID MODE]",
0x0004, 0x0004, "NONBLOCK",
0x0008, 0x0008, "APPEND",
0, 0, NULL

```

then a flagword of 0x0009 would print:

```
0009<WRITE,APPEND>
```

▼ 9.2 Printing Helpers

A few routines to make it easier to create string versions of other type variables, e.g., for `ep_stat_post`.

```

#include <ep/ep_pcv_t.h>

char *ep_pcv_t_str(size_t osize,           // output buffer size
                  char *obuf,              // output buffer
                  const char *val)          // value to convert

char *ep_pcv_t_int(size_t osize,           // output buffer size
                  char *obuf,              // output buffer
                  int base,                 // base of value
                  int val)                 // value to convert

```

All of these return their input buffer.

The routine `ep_pcv_t_str` truncates the value to the indicated size. If the value won't fit, it renders "*beginning...end*" where *end* is the last three bytes of the value.

▼ 9.3 Application Messages

Associated with status printing.

```

#include <ep/ep_app.h>

void ep_app_warn(const char *fmt,           // printf-style format
                 ...)

void ep_app_error(const char *fmt,          // printf-style format
                 ...)

void ep_app_abort(const char *fmt,          // printf-style format
                 ...)

```

The first two just print messages; the final prints the message and does not return. They all use printf formats.

```
const char *
```



```
ep_app_getprogname(void) // get current program name
```

This is a portability wrapper that returns the name of the current program (essentially, the last component of argv[0]).

▼ 9.4 Printing Memory

To print out a block of binary memory, use ep_hexdump.

```
#include <ep/ep_hexdump.h>

void
ep_hexdump(void *bufp,           // block of memory to print
            size_t buflen,       // size of that block
            FILE *fp,            // output file
            int format,          // see description
            size_t offset);      // offset
```

This prints a block of memory as a hexadecimal dump, optionally with an ASCII rendition. The offset printed starts at the `offset` parameter (zero to make the printed offsets be relative to `bufp`). The `format` may be `EP_HEXDUMP_HEX` to print only the hexadecimal or `EP_HEXDUMP_ASCII` to also show the bytes interpreted as ASCII (unprintable characters are substituted).

▼ 10 DEBUGGING, TRACING, ASSERTIONS

Named flags, each settable from 0 to 127.

When setting flags, wildcards can be used (only "*" supported for now).

```
#include <ep/ep_dbg.h>

void
ep_dbg_init(void) // initialize debugging

void
ep_dbg_set(const char *fspec) // set debug flags (command line)

void
ep_dbg_setto(const char *fpattern, // flag pattern
             int level);           // level

EP_DBG flag EP_DBG_INIT( // opaque structure for flag
                        name, // external name of flag
                        desc); // description (internal use only)

int
ep_dbg_level(EP_DBG *flag) // return level of given flag

bool
ep_dbg_test(EP_DBG *flag, // true if flag set to >= value
            int value)

void
ep_dbg_printf(fmt, ...) // print to EpStStddbg

void
ep_dbg_cprintf(EP_DBG *flag, // if flag level >= value,
               int value,    // print fmt etc as though printf.
               fmt, ...)

void
ep_dbg_setfile(FILE *fp) // set debug output to indicated file

void
```

```
ep_dbg_getfile(void)           // return current debug output file
```

Assertions all in `<ep/ep_assert.h>`:

```
#include <ep/ep_assert.h>

EP_ASSERT_REQUIRE(expression)    // input to routines
EP_ASSERT_ENSURE(expression)    // output from routines
EP_ASSERT_INVARIANT(expression) // loop invariants
EP_ASSERT(expression)           // miscellaneous assertions

ep_assert_abort(char *msg);      // abort process
```

▼ 11 THREAD SUPPORT

These are mostly wrappers around the pthreads library, but they will print errors if the `ep_thr` debug flag is set to at least 4.

```
#include <ep/ep_thr.h>

int
ep_thr_mutex_init(EP_THR_MUTEX *mtx, int type);

int
ep_thr_mutex_destroy(EP_THR_MUTEX *mtx);

int
ep_thr_mutex_lock(EP_THR_MUTEX *mtx);

int
ep_thr_mutex_trylock(EP_THR_MUTEX *mtx);

int
ep_thr_mutex_unlock(EP_THR_MUTEX *mtx);

int
ep_thr_mutex_check(EP_THR_MUTEX *mtx);

int
ep_thr_cond_init(EP_THR_COND *cv);

int
ep_thr_cond_destroy(EP_THR_COND *cv);

int
ep_thr_cond_signal(EP_THR_COND *cv);

int
ep_thr_cond_wait(EP_THR_COND *cv, EP_THR_MUTEX *mtx, EP_TIME_SPEC *timeout);

int
ep_thr_cond_broadcast(EP_THR_COND *cv);

int
ep_thr_rwlock_init(EP_THR_RWLOCK *rwl);

int
ep_thr_rwlock_destroy(EP_THR_RWLOCK *rwl);

int
ep_thr_rwlock_rdlock(EP_THR_RWLOCK *rwl);

int
ep_thr_rwlock_tryrdlock(EP_THR_RWLOCK *rwl);
```

```

int
ep_thr_rwlock_wrlock(EP_THR_RWLOCK *rwl);

int
ep_thr_rwlock_tryrwlock(EP_THR_RWLOCK *rwl);

int
ep_thr_rwlock_unlock(EP_THR_RWLOCK *rwl);

```

The `ep_thr_*_check` routines check the structures for consistency and print an error; this is only for debugging. *This should be expanded to include spawning threads etc.; for the time being just use the pthreads primitives.*

There is also a basic thread pool implementation:

```

#include <ep/ep_thr.h>

void
ep_thr_pool_init(
    int min_threads,
    int max_threads,
    uint32_t flags);

void
ep_thr_pool_run(
    void (*func)(void *),
    void *arg);

```

Thread pools are initially started with `min_threads` workers (which may be zero; defaults to the `libep_thr.pool.min_workers` administrative parameter, or 1 if that is not set). Threads will be spawned as necessary up to `max_threads` total workers (defaults to `libep_thr.pool.max_workers`; if that is not set, defaults to twice the number of cores available).

Threads are run in essentially the same way as spawning a pthreads thread; this is really just a convenience wrapper around that so resources can be better controlled.

▼ 12 LOGGING

Messages may be logged together with a status code:

```

#include <ep/ep_log.h>

void
ep_log_init(
    const char *tag,
    int logfac,
    FILE *logfile,
    const char *fname);

void
ep_log(
    EP_STAT estat,
    const char *fmt,
    ...)

```

This interface can simultaneously log to `syslog` (if `logfac` is a valid facility code), an open file (e.g., `stderr`; `NULL` disables this), and a disk file (ignored if `fname == NULL`). The status code is logged together with the printf-style message. The syslog severity is determined from the severity of the status code: `OK` codes log an `LOG_INFO` message, `WARN` codes log a `LOG_WARNING` message, `ERROR` codes log a `LOG_ERR` message, `SEVERE` codes log a `LOG_CRIT` message, and `ABORT` codes log a `LOG_ALERT` message.

▼ 13 ARGUMENT CRACKING

Not implemented at this time. To help with parsing command line arguments. A descriptor is declared as follows:

```
#include <ep/ep_crackargv.h>

unsigned long      NTests;
long              Seed;
static char        *FileName;

EP_CAV_DESCR      ArgvDescriptor[] =
{
    { "debug",          EP_CAV_TYPE(debug),      'D',      5,
      "Debug",          "debug-flags",          NULL,
      EP_CAV_FLAG_NOARGS
    },
    { "ntests",          EP_CAV_TYPE(ulong),      'n',      1,
      "Number of tests", NULL,
      EP_CAV_FLAG_REQUIRED
    },
    { "seed",            EP_CAV_TYPE(long),        's',      1,
      NULL,              NULL,
      EP_CAV_FLAG_NONE
    },
    { NULL,              EP_CAV_TYPE(string),     '\0',     0,
      NULL,              NULL,
      EP_CAV_FLAG_NONE
    }
    EP_CAV_DESCR_END
};
```

The `ep_crackargv` routine is then called with an argument vector and a descriptor:

```
stat = ep_crackargv(const char **argv, const EP_CAV_DESCR *descr);
```

The argument vector is then matched to the descriptor and appropriate bindings done. Duplicate and missing flags are diagnosed and all conversions are done.

The fields in the descriptor are:

- The long name. On Unix, this is matched against arguments beginning "--". This is case independent.
- The data type. This is always `EP_CAV_TYPE(something)`, which calls the conversion routine named `ep_cvt_txt_to_something` passing it the value as a text string and a pointer to the output location (see below).
- The short (single character) name. On Unix, this is matched against arguments beginning "-". Flags without values can be combined into one flag -- that is, if "-a -b" sets two boolean flags, "-ab" does the same thing.
- The number of bytes of the long name that must match. This allows abbreviation of names. See below.
- The prompt. If flags are required and a prompt is available, `ep_crackargv` can prompt for missing parameters. Not yet implemented.
- The usage message to describe this parameter. Defaults to the long name.
- The value pointer. A pointer to the data area in which to store the results. If NULL, this parameter cannot accept a value.
- Flag bits, as described below.

Long flag names can be abbreviated. All characters of the command line must match the descriptor, but only the number indicated in the "must match" field need be present. For example, given a name in the descriptor of "ntests" with a "must match" field of 2 will match "--ntests", "--ntes", "--nt", but not "--ntext", "--n", or "--nteststotry".

Flag bits include:

EP_CAV_FLAG_NONE

No special processing

EP_CAV_FLAG_NOARGS
This parameter takes no arguments (e.g., a boolean)

EP_CAV_FLAG_NOMORE
This consumes all remaining arguments (normally EP_CAV_TYPE(Vector))

EP_CAV_FLAG_MULTVAL
There can be multiple values for this parameter (only relevant for flags)

EP_CAV_FLAG_REQUIRED
If this parameter is missing it is an error

Predefined types and the type of the corresponding value pointer are:

bool bool_t * Booleans. Should have EP_CAV_FLAG_NOARGS. string const char ** Strings. long long * Signed long integers. ulong unsigned long * Unsigned long integers. double double * Double point floating point. vector const char *** Vectors. Must have the EP_CAV_FLAG_MULTVAL flag set. Can only be one, and it must be at the end. debug NULL Sets debug flags

To appear:

int8 int8_t * uint8 uint8_t * int16 int16_t * uint16 uint16_t * int32 int32_t * uint32 uint32_t * int64 int64_t * uint64 uint64_t * admparam const char *

Administrative parameters (see ep_adm_getintparam and ep_adm_getstrparam). The value pointer is the name of the parameter to set.

New parameter types can be trivially created by defining new routines named ep_cvt_txt_to_type that take a const char * as input and a type * output pointer. They return EP_STAT. Conversion errors should fail.

▼ 14 MISCELLANEOUS STUFF

```
EP_UT_BITSET(uint32 bits,          // return true if any bits...
             uint32_t word)       // ... are set in word

/*
EP_UT_SETBIT(uint32_t bits,        // set these bits...
             uint32_t word)       // ... in this word

EP_UT_CLRBIT(uint32 bits,         // clear these bits...
             uint32_t word)       // ... in this word
*/

EP_UT_BITMAP(                     // declare bitmap
    name,                         // name of bitmap to declare
    nbits)                       // number of bits in map

EP_UT_CLRBITMAP(                  // clear bitmap
    name)                        // bitmap to clear

EP_UT_BITNSET(int bitn,           // true if bit number bitn is set...
             bitmap)             // ... in this map

EP_UT_SETBITN(int bitn,           // set bit number bitn...
             bitmap)             // ... in this map

EP_UT_CLRBITN(int bitn,           // clear bit number bitn...
             bitmap)             // ... in this map

EP_GEN_DEADBEEF                  // a value you can use to trash memory
```

Warning There is no checking for the BITMAP routines (EP_UT_BITNSET, EP_UT_SETBITN, EP_UT_CLRBITN) to ensure that the bit indicated is in range for the size of the bitmap.

▼ 15 INTERACTION WITH THE ENVIRONMENT

▼ 15.1 Global Administrative Parameters

There are a bunch of parameters that we would prefer to be settable at run time. We'll model this on `sysctl(8)`. Before accessing parameters you must read them using `ep_adm_readparams`. This routine takes a name and then looks for a file in a search path. That path may be set using the `PARAM_PATH` environment variable, and defaults to:

```
.ep_adm_params:~/.ep_adm_params:/usr/local/etc/ep_adm_params:/etc/ep_adm_params
```

For example, searching for a name such as "defaults" will first try to read the file `.ep_adm_params/defaults`. If that is found the search stops, otherwise it tries `~/.ep_adm_params/defaults`, and so forth. New values replace old ones, so programs that want to search more than one file should start with the most generic one and continue to the least generic one.

```
#include <ep/ep_adm.h>

void
ep_adm_readparams(
    const char *name)           // basename of the parameter file

int
ep_adm_getintparam(
    const char *name,           // name of the parameter
    int default)                // value if parameter not set

long
ep_adm_getlongparam(
    const char *name,           // name of the parameter
    long default)               // value if parameter not set

bool
ep_adm_getboolparam(
    const char *name,           // name of the parameter
    bool default)               // value if parameter not set

const char *
ep_adm_getstrparam(
    const char *name,           // name of the parameter
    char *default)              // value if parameter not set
```

Names are structured kind of like `sysctl` arguments or X Resource names, e.g., "libep.stream.hfile.bsize". You must read one or more parameter files before getting parameters.

▼ 15.2 Terminal Video Sequences and Characters

Mostly for debugging use. Right now compiled in for ANSI xterms.

```
#include <ep/ep_string.h>

struct epVidSequences
{
    const char    *vidnorm;      // set video to normal
    const char    *vidbold;      // set video to bold
    const char    *vidfaint;     // set video to faint
    const char    *vidstout;     // set viadeo to "standout"
    const char    *viduline;     // set video to underline
    const char    *vidblink;     // set video to blink
    const char    *vidinv;       // set video to invert
    const char    *vidfgblack;   // set foreground black
    const char    *vidfgred;     // set foreground red
    const char    *vidfggreen;   // set foreground green
```

```

    const char    *vidfgyellow;    // set foreground yellow
    const char    *vidfgblue;      // set foreground blue
    const char    *vidfgmagenta;   // set foreground magenta
    const char    *vidfgcyan;      // set foreground cyan
    const char    *vidfgwhite;     // set foreground white
    const char    *vidbgblack;     // set background black
    const char    *vidbgred;       // set background red
    const char    *vidbggreen;     // set background green
    const char    *vidbgyellow;    // set background yellow
    const char    *vidbgblue;      // set background blue
    const char    *vidbgmagenta;   // set background magenta
    const char    *vidbgcyan;      // set background cyan
    const char    *vidbtwhite;     // set background white
} *EpVid;

struct epCharSequences
{
    const char    *lquote;         // left quote sequence
    const char    *rquote;         // right quote sequence
    const char    *copyright;      // copyright symbol
    const char    *degree;         // degree symbol
    const char    *micro;          // micro symbol
    const char    *plusminus;      // +/- symbol
    const char    *times;          // mathematical times symbol
    const char    *divide;         // mathematical division symbol
    const char    *null;           // "null" symbol
    const char    *notequal;       // mathematical "not equal" symbol
    const char    *unprintable;    // substitution for unprintable characters
    const char    *paragraph;      // paragraph symbol
    const char    *section;        // section symbol
    const char    *notsign;        // logical not symbol
    const char    *infinity;       // infinity symbol
} *EpChar;

EP_STAT    ep_str_vid_set(        // set video style
    const char    *type);         // NULL, "none", or "ansi"

EP_STAT    ep_str_char_set(       // set special characters
    const char    *type);         // character set (see below)

```

These structures contain character sequences used for printing video controls and special characters respectively. The `ep_str_vid_set` routines allows you to choose the video escape sequences. Passing `NULL` causes an educated guess at the default on the basis of the `TERM` environment variable. Any `TERM` setting beginning with "xterm" is the same as specifying "ansi" as the type and anything else is the same as specifying "none" as the type (which sets all the video strings to null strings). Blessedly, xterm doesn't seem to render blink, nor faint or standout. Bold and blink are both rendered in bold. So, for best results use bold, underline, and inv (and of course norm).

The `ep_str_char_set` allows you to set special character encodings. Its parameter may be `NULL` (which guesses based on the `LANG` environment variable), "ascii", "iso-8859-1", "iso-latin-1", "utf-8", or "utf8". The mappings are shown in the following table:

Name	ASCII	Other Charset
lquote	`	«
rquote	'	»
copyright	(c)	©
degree	deg	°
micro	u	μ
plusminus	+/-	±

times	*	×
divide	/	÷
null	NULL	∅
notequal	!=	≠
unprintable	?	⌘
paragraph	pp.	¶
section	sec.	§
notsign	(not)	¬
infinity	(inf)	∞

Other values may be added to this table as needed.

Example:

```
fprintf(ep_dbg_getfile(), "Input was %s%s%s\n",
        EpVidSeq.lquote, input, EpVidSeq.rquote);
```

▼ 16 TRANSLATIONS

Simple string translations for certain external formats, for example as might be used by URLs or Quoted-Printable.

```
#include <ep/ep_xlate.h>

int
ep_xlate_in(
    const void *ext,          // external (encoded) string input
    uchar_t *out,            // pointer to output buffer
    size_t olen,              // length of output buffer
    char stopchar,            // input char to stop at
    uint32_t how)             // what kind of translations to do
```

Translates an external form (with encodings) into internal form (potentially 8-bit binary). Returns the number of output bytes. The "how" parameter tells what translations to do -- they can be combined:

▼ EP_XLATE "how" Bits

EP_XLATE_PERCENT	Translate "%xx" like ESMTTP
EP_XLATE_BSLASH	Translate backslash escapes like C
EP_XLATE_AMPER	Translate "&name;" like HTML
EP_XLATE_PLUS	Translate "+xx" like DNSs
EP_XLATE_EQUAL	Translate "=xx" like quoted-printable
EP_XLATE_8BIT	Translate 8-bit characters (ep_xlate_out only)
EP_XLATE_NPRINT	Translate non-printable characters (ep_xlate_out only)

```
int
ep_xlate_out(
    const void *in,           // internal (not encoded) input string
    size_t ilen,              // length of in
    FILE *osp,                // encoded output stream pointer
    const char *forbid,        // list of characters to encode
    uint32_t how)             // how to do output translations
```

Unlike input, it doesn't make sense to list more than one of EP_XLATE_PERCENT, EP_XLATE_BSLASH,

EP_XLATE_EQUAL, and EP_XLATE_PLUS. If none are listed, EP_XLATE_PLUS is assumed. EP_XLATE_8BIT can be added to encode all 8-bit characters and EP_XLATE_NPRINT translates all unprintable characters (as determined by `isprint(3)`, which generally does understand locales). Returns the number of bytes output to the indicated `osp`.

Note [[Arguably they should both use streams for both input and output.]]

There are also routines to encode/decode binaries in base64.

```
#include <ep/ep_b64.h>

EP_STAT
ep_b64_encode(
    const void *bin,           // binary data to encode
    size_t bsize,             // size of bin to encode
    char *txt,                 // text output buffer
    size_t tsize,             // size of output buffer
    const char *encoding)      // type of encoding (see below)

EP_STAT
ep_b64_decode(
    const char *txt,           // text to decode
    size_t tsize,             // stop after tsize characters
    void *bin,                 // binary output buffer
    size_t bsize,             // size of bin buffer
    const char *encoding)      // type of encoding (see below)

#define EP_B64_NOWRAP         0x00    // never wrap lines
#define EP_B64_WRAP64         0x01    // wrap at 64 characters
#define EP_B64_WRAP76         0x02    // wrap at 76 characters
#define EP_B64_WRAPMASK      0x03    // bit mask for wrapping
#define EP_B64_PAD             0x04    // pad with '='
#define EP_B64_IGNCRUD         0x08    // ignore unrecognized chars

// encodings for common standards
#define EP_B64_ENC_MIME        "+/N"   // WRAP76  PAD  IGNCRUD
#define EP_B64_ENC_PEM        "+/E"   // WRAP64  PAD  -IGNCRUD
#define EP_B64_ENC_URL         "-_@"   // NOWRAP  -PAD  -IGNCRUD
```

The encoding is a three character string. The first two characters are used to represent the codes for positions 62 and 63 (these are the only two that are not letters or digits). The third is used as flag bits to indicate variations for various encodings. The three most common strings are included as defined constants (for MIME email, Privacy Enhanced Mail, and URLs).

▼ 17 XXX TO BE DONE

- Document `ep_pprint`.
- Document `ep_dumpfds` (shows open file descriptors (for debugging)).
- Document `ep_fread_unlocked`.