

NAME

bn_mul_words, bn_mul_add_words, bn_sqr_words, bn_div_words, bn_add_words, bn_sub_words, bn_mul_comba4, bn_mul_comba8, bn_sqr_comba4, bn_sqr_comba8, bn_cmp_words, bn_mul_normal, bn_mul_low_normal, bn_mul_recursive, bn_mul_part_recursive, bn_mul_low_recursive, bn_mul_high, bn_sqr_normal, bn_sqr_recursive, bn_expand, bn_wexpand, bn_expand2, bn_fix_top, bn_check_top, bn_print, bn_dump, bn_set_max, bn_set_high, bn_set_low - BIGNUM library internal functions

SYNOPSIS

```
#include <openssl/bn.h>

BN_ULONG bn_mul_words(BN_ULONG *rp, BN_ULONG *ap, int num, BN_ULONG w);
BN_ULONG bn_mul_add_words(BN_ULONG *rp, BN_ULONG *ap, int num,
BN_ULONG w);
void bn_sqr_words(BN_ULONG *rp, BN_ULONG *ap, int num);
BN_ULONG bn_div_words(BN_ULONG h, BN_ULONG l, BN_ULONG d);
BN_ULONG bn_add_words(BN_ULONG *rp, BN_ULONG *ap, BN_ULONG *bp,
int num);
BN_ULONG bn_sub_words(BN_ULONG *rp, BN_ULONG *ap, BN_ULONG *bp,
int num);

void bn_mul_comba4(BN_ULONG *r, BN_ULONG *a, BN_ULONG *b);
void bn_mul_comba8(BN_ULONG *r, BN_ULONG *a, BN_ULONG *b);
void bn_sqr_comba4(BN_ULONG *r, BN_ULONG *a);
void bn_sqr_comba8(BN_ULONG *r, BN_ULONG *a);

int bn_cmp_words(BN_ULONG *a, BN_ULONG *b, int n);

void bn_mul_normal(BN_ULONG *r, BN_ULONG *a, int na, BN_ULONG *b,
int nb);
void bn_mul_low_normal(BN_ULONG *r, BN_ULONG *a, BN_ULONG *b, int n);
void bn_mul_recursive(BN_ULONG *r, BN_ULONG *a, BN_ULONG *b, int n2,
int dna, int dnb, BN_ULONG *tmp);
void bn_mul_part_recursive(BN_ULONG *r, BN_ULONG *a, BN_ULONG *b,
int n, int tna, int tnb, BN_ULONG *tmp);
void bn_mul_low_recursive(BN_ULONG *r, BN_ULONG *a, BN_ULONG *b,
int n2, BN_ULONG *tmp);
void bn_mul_high(BN_ULONG *r, BN_ULONG *a, BN_ULONG *b, BN_ULONG *l,
int n2, BN_ULONG *tmp);

void bn_sqr_normal(BN_ULONG *r, BN_ULONG *a, int n, BN_ULONG *tmp);
void bn_sqr_recursive(BN_ULONG *r, BN_ULONG *a, int n2, BN_ULONG *tmp);

void mul(BN_ULONG r, BN_ULONG a, BN_ULONG w, BN_ULONG c);
void mul_add(BN_ULONG r, BN_ULONG a, BN_ULONG w, BN_ULONG c);
void sqr(BN_ULONG r0, BN_ULONG r1, BN_ULONG a);

BIGNUM *bn_expand(BIGNUM *a, int bits);
BIGNUM *bn_wexpand(BIGNUM *a, int n);
BIGNUM *bn_expand2(BIGNUM *a, int n);
void bn_fix_top(BIGNUM *a);

void bn_check_top(BIGNUM *a);
void bn_print(BIGNUM *a);
void bn_dump(BN_ULONG *d, int n);
```

```
void bn_set_max(BIGNUM *a);
void bn_set_high(BIGNUM *r, BIGNUM *a, int n);
void bn_set_low(BIGNUM *r, BIGNUM *a, int n);
```

DESCRIPTION

This page documents the internal functions used by the OpenSSL **BIGNUM** implementation. They are described here to facilitate debugging and extending the library. They are *not* to be used by applications.

The **BIGNUM** structure

```
typedef struct bignum_st BIGNUM;

struct bignum_st
{
    BN_ULONG *d; /* Pointer to an array of 'BN_BITS2' bit chunks. */
    int top; /* Index of last used d +1. */
    /* The next are internal book keeping for bn_expand. */
    int dmax; /* Size of the d array. */
    int neg; /* one if the number is negative */
    int flags;
};
```

The integer value is stored in **d**, a *malloc()*ed array of words (**BN_ULONG**), least significant word first. A **BN_ULONG** can be either 16, 32 or 64 bits in size, depending on the 'number of bits' (**BITS2**) specified in `openssl/bn.h`.

dmax is the size of the **d** array that has been allocated. **top** is the number of words being used, so for a value of 4, `bn.d[0]=4` and `bn.top=1`. **neg** is 1 if the number is negative. When a **BIGNUM** is 0, the **d** field can be **NULL** and **top** == 0.

flags is a bit field of flags which are defined in `openssl/bn.h`. The flags begin with **BN_FLG_**. The macros `BN_set_flags(b,n)` and `BN_get_flags(b,n)` exist to enable or fetch flag(s) **n** from **BIGNUM** structure **b**.

Various routines in this library require the use of temporary **BIGNUM** variables during their execution. Since dynamic memory allocation to create **BIGNUM**s is rather expensive when used in conjunction with repeated subroutine calls, the **BN_CTX** structure is used. This structure contains **BN_CTX_NUM** **BIGNUM**s, see [BN_CTX_start\(3\)](#).

Low-level arithmetic operations

These functions are implemented in C and for several platforms in assembly language:

`bn_mul_words(rp, ap, num, w)` operates on the **num** word arrays **rp** and **ap**. It computes **ap** * **w**, places the result in **rp**, and returns the high word (carry).

`bn_mul_add_words(rp, ap, num, w)` operates on the **num** word arrays **rp** and **ap**. It computes **ap** * **w** + **rp**, places the result in **rp**, and returns the high word (carry).

`bn_sqr_words(rp, ap, n)` operates on the **num** word array **ap** and the 2***num** word array **ap**. It computes **ap** * **ap** word-wise, and places the low and high bytes of the result in **rp**.

`bn_div_words(h, l, d)` divides the two word number (**h,l**) by **d** and returns the result.

`bn_add_words(rp, ap, bp, num)` operates on the **num** word arrays **ap**, **bp** and **rp**. It computes **ap** + **bp**, places the result in **rp**, and returns the high word (carry).

`bn_sub_words(rp, ap, bp, num)` operates on the **num** word arrays **ap**, **bp** and **rp**. It computes **ap** - **bp**, places the result in **rp**, and returns the carry (1 if **bp** > **ap**, 0 otherwise).

`bn_mul_comba4(r, a, b)` operates on the 4 word arrays **a** and **b** and the 8 word array **r**. It computes **a*****b** and places the result in **r**.

`bn_mul_comba8(r, a, b)` operates on the 8 word arrays **a** and **b** and the 16 word array **r**. It

computes $\mathbf{a}*\mathbf{b}$ and places the result in \mathbf{r} .

`bn_sqr_comba4(\mathbf{r} , \mathbf{a} , \mathbf{b})` operates on the 4 word arrays \mathbf{a} and \mathbf{b} and the 8 word array \mathbf{r} .

`bn_sqr_comba8(\mathbf{r} , \mathbf{a} , \mathbf{b})` operates on the 8 word arrays \mathbf{a} and \mathbf{b} and the 16 word array \mathbf{r} .

The following functions are implemented in C:

`bn_cmp_words(\mathbf{a} , \mathbf{b} , \mathbf{n})` operates on the \mathbf{n} word arrays \mathbf{a} and \mathbf{b} . It returns 1, 0 and -1 if \mathbf{a} is greater than, equal and less than \mathbf{b} .

`bn_mul_normal(\mathbf{r} , \mathbf{a} , \mathbf{na} , \mathbf{b} , \mathbf{nb})` operates on the \mathbf{na} word array \mathbf{a} , the \mathbf{nb} word array \mathbf{b} and the $\mathbf{na}+\mathbf{nb}$ word array \mathbf{r} . It computes $\mathbf{a}*\mathbf{b}$ and places the result in \mathbf{r} .

`bn_mul_low_normal(\mathbf{r} , \mathbf{a} , \mathbf{b} , \mathbf{n})` operates on the \mathbf{n} word arrays \mathbf{r} , \mathbf{a} and \mathbf{b} . It computes the \mathbf{n} low words of $\mathbf{a}*\mathbf{b}$ and places the result in \mathbf{r} .

`bn_mul_recursive(\mathbf{r} , \mathbf{a} , \mathbf{b} , $\mathbf{n2}$, \mathbf{dna} , \mathbf{dnb} , \mathbf{t})` operates on the word arrays \mathbf{a} and \mathbf{b} of length $\mathbf{n2}+\mathbf{dna}$ and $\mathbf{n2}+\mathbf{dnb}$ (\mathbf{dna} and \mathbf{dnb} are currently allowed to be 0 or negative) and the $2*\mathbf{n2}$ word arrays \mathbf{r} and \mathbf{t} . $\mathbf{n2}$ must be a power of 2. It computes $\mathbf{a}*\mathbf{b}$ and places the result in \mathbf{r} .

`bn_mul_part_recursive(\mathbf{r} , \mathbf{a} , \mathbf{b} , \mathbf{n} , \mathbf{tna} , \mathbf{tnb} , \mathbf{tmp})` operates on the word arrays \mathbf{a} and \mathbf{b} of length $\mathbf{n}+\mathbf{tna}$ and $\mathbf{n}+\mathbf{tnb}$ and the $4*\mathbf{n}$ word arrays \mathbf{r} and \mathbf{tmp} .

`bn_mul_low_recursive(\mathbf{r} , \mathbf{a} , \mathbf{b} , $\mathbf{n2}$, \mathbf{tmp})` operates on the $\mathbf{n2}$ word arrays \mathbf{r} and \mathbf{tmp} and the $\mathbf{n2}/2$ word arrays \mathbf{a} and \mathbf{b} .

`bn_mul_high(\mathbf{r} , \mathbf{a} , \mathbf{b} , \mathbf{l} , $\mathbf{n2}$, \mathbf{tmp})` operates on the $\mathbf{n2}$ word arrays \mathbf{r} , \mathbf{a} , \mathbf{b} and \mathbf{l} (?) and the $3*\mathbf{n2}$ word array \mathbf{tmp} .

`BN_mul()` calls `bn_mul_normal()`, or an optimized implementation if the factors have the same size: `bn_mul_comba8()` is used if they are 8 words long, `bn_mul_recursive()` if they are larger than `BN_MULL_SIZE_NORMAL` and the size is an exact multiple of the word size, and `bn_mul_part_recursive()` for others that are larger than `BN_MULL_SIZE_NORMAL`.

`bn_sqr_normal(\mathbf{r} , \mathbf{a} , \mathbf{n} , \mathbf{tmp})` operates on the \mathbf{n} word array \mathbf{a} and the $2*\mathbf{n}$ word arrays \mathbf{tmp} and \mathbf{r} .

The implementations use the following macros which, depending on the architecture, may use “long long” C operations or inline assembler. They are defined in `bn_lcl.h`.

`mul(\mathbf{r} , \mathbf{a} , \mathbf{w} , \mathbf{c})` computes $\mathbf{w}*\mathbf{a}+\mathbf{c}$ and places the low word of the result in \mathbf{r} and the high word in \mathbf{c} .

`mul_add(\mathbf{r} , \mathbf{a} , \mathbf{w} , \mathbf{c})` computes $\mathbf{w}*\mathbf{a}+\mathbf{r}+\mathbf{c}$ and places the low word of the result in \mathbf{r} and the high word in \mathbf{c} .

`sqr($\mathbf{r0}$, $\mathbf{r1}$, \mathbf{a})` computes $\mathbf{a}*\mathbf{a}$ and places the low word of the result in $\mathbf{r0}$ and the high word in $\mathbf{r1}$.

Size changes

`bn_expand()` ensures that \mathbf{b} has enough space for a `bits` bit number. `bn_wexpand()` ensures that \mathbf{b} has enough space for an \mathbf{n} word number. If the number has to be expanded, both macros call `bn_expand2()`, which allocates a new \mathbf{d} array and copies the data. They return `NULL` on error, \mathbf{b} otherwise.

The `bn_fix_top()` macro reduces `$\mathbf{a} \rightarrow \mathbf{top}$` to point to the most significant non-zero word plus one when \mathbf{a} has shrunk.

Debugging

`bn_check_top()` verifies that `(($\mathbf{a} \rightarrow \mathbf{top}$) >= 0 && ($\mathbf{a} \rightarrow \mathbf{top}$) <= ($\mathbf{a} \rightarrow \mathbf{dmax}$)`. A violation will cause the program to abort.

`bn_print()` prints \mathbf{a} to stderr. `bn_dump()` prints \mathbf{n} words at \mathbf{d} (in reverse order, i.e. most significant word first) to stderr.

`bn_set_max()` makes \mathbf{a} a static number with a `\mathbf{dmax}` of its current size. This is used by `bn_set_low()` and `bn_set_high()` to make \mathbf{r} a read-only `BIGNUM` that contains the \mathbf{n} low or high

words of **a**.

If **BN_DEBUG** is not defined, *bn_check_top()*, *bn_print()*, *bn_dump()* and *bn_set_max()* are defined as empty macros.

SEE ALSO

[bn\(3\)](#)