

**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\(3\)](#)