## OPCODES IN NUMERICAL ORDER BY OPCODE ③

| Instruction Mnemonic | Format | Opcode Width (bits) | Opcode Binary | Shamt Binary | 11-bit Opcode Range (1) Start (Hex) | End (Hex) |
|---|---|---|---|---|---|---|
| B | B | 6 | 000101 | | 0A0 | 0BF |
| FMULS | R | 11 | 00011110001 | 000010 | 0F1 | |
| FDIVS | R | 11 | 00011110001 | 000110 | 0F1 | |
| FCMPS | R | 11 | 00011110001 | 001000 | 0F1 | |
| FADDS | R | 11 | 00011110001 | 001010 | 0F1 | |
| FSUBS | R | 11 | 00011110001 | 001110 | 0F1 | |
| FMULD | R | 11 | 00011110011 | 000010 | 0F3 | |
| FDIVD | R | 11 | 00011110011 | 000110 | 0F3 | |
| FCMPD | R | 11 | 00011110011 | 001000 | 0F3 | |
| FADDD | R | 11 | 00011110011 | 001010 | 0F3 | |
| FSUBD | R | 11 | 00011110011 | 001110 | 0F3 | |
| STURB | D | 11 | 00111000000 | | 1C0 | |
| LDURB | D | 11 | 00111000010 | | 1C2 | |
| B.cond | CB | 8 | 01010100 | | 2A0 | 2A7 |
| STURH | D | 11 | 01111000000 | | 3C0 | |
| LDURH | D | 11 | 01111000010 | | 3C2 | |
| AND | R | 11 | 10001010000 | | 450 | |
| ADD | R | 11 | 10001011000 | | 458 | |
| ADDI | I | 10 | 1001000100 | | 488 | 489 |
| ANDI | I | 10 | 1001001000 | | 490 | 491 |
| BL | B | 6 | 100101 | | 4A0 | 4BF |
| SDIV | R | 11 | 10011010110 | 000010 | 4D6 | |
| UDIV | R | 11 | 10011010110 | 000011 | 4D6 | |
| MUL | R | 11 | 10011011000 | 011111 | 4D8 | |
| SMULH | R | 11 | 10011011010 | | 4DA | |
| UMULH | R | 11 | 10011011110 | | 4DE | |
| ORR | R | 11 | 10101010000 | | 550 | |
| ADDS | R | 11 | 10101011000 | | 558 | |
| ADDIS | I | 10 | 1011000100 | | 588 | 589 |
| ORRI | I | 10 | 1011001000 | | 590 | 591 |
| CBZ | CB | 8 | 10110100 | | 5A0 | 5A7 |
| CBNZ | CB | 8 | 10110101 | | 5A8 | 5AF |
| STURW | D | 11 | 10111000000 | | 5C0 | |
| LDURSW | D | 11 | 10111000100 | | 5C4 | |
| STURS | R | 11 | 10111100000 | | 5E0 | |
| LDURS | R | 11 | 10111100010 | | 5E2 | |
| STXR | D | 11 | 11001000000 | | 640 | |
| LDXR | D | 11 | 11001000010 | | 642 | |
| EOR | R | 11 | 11001010000 | | 650 | |
| SUB | R | 11 | 11001011000 | | 658 | |
| SUBI | I | 10 | 1101000100 | | 688 | 689 |
| EORI | I | 10 | 1101001000 | | 690 | 691 |
| MOVZ | IM | 9 | 110100101 | | 694 | 697 |
| LSR | R | 11 | 11010011010 | | 69A | |
| LSL | R | 11 | 11010011011 | | 69B | |
| BR | R | 11 | 11010110000 | | 6B0 | |
| ANDS | R | 11 | 11101010000 | | 750 | |
| SUBS | R | 11 | 11101011000 | | 758 | |
| SUBIS | I | 10 | 1111000100 | | 788 | 789 |
| ANDIS | I | 10 | 1111001000 | | 790 | 791 |
| MOVK | IM | 9 | 111100101 | | 794 | 797 |
| STUR | D | 11 | 11111000000 | | 7C0 | |
| LDUR | D | 11 | 11111000010 | | 7C2 | |
| STURD | R | 11 | 11111100000 | | 7E0 | |
| LDURD | R | 11 | 11111100010 | | 7E2 | |

(1) Since I, B, and CB instruction formats have opcodes narrower than 11 bits, they occupy a range of 11-bit opcodes, e.g., the 6-bit B format occupies 32 ($2^5$) 11-bit opcodes.

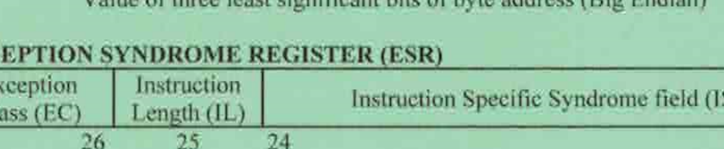
## IEEE 754 FLOATING-POINT STANDARD ④

$(-1)^S \times (1 + \text{Fraction}) \times 2^{(\text{Exponent} - \text{Bias})}$
where Single Precision Bias = 127,
Double Precision Bias = 1023

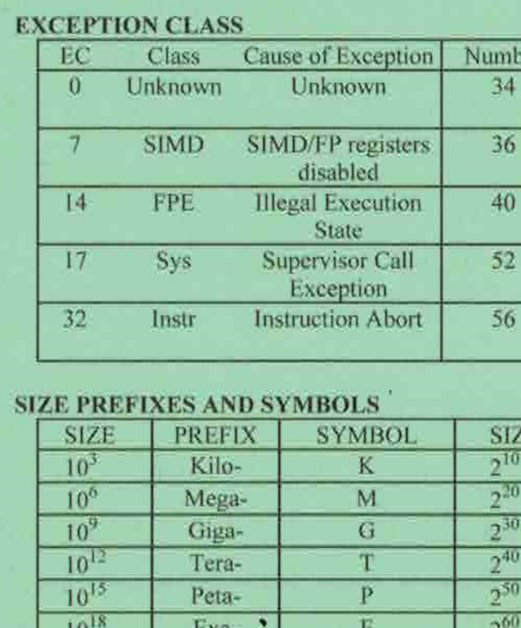
**IEEE 754 Symbols**

| Exponent | Fraction | Object |
|---|---|---|
| 0 | 0 | ± 0 |
| 0 | ≠ 0 | ± Denorm |
| 1 to MAX - 1 | anything | ± F1. Pt. Num. |
| MAX | 0 | ± ∞ |
| MAX | ≠ 0 | NaN |

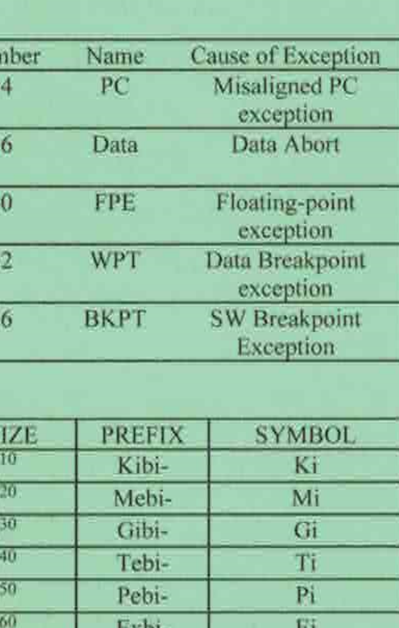
**IEEE Single Precision and Double Precision Formats:** S.P. MAX = 255, D.P. MAX = 2047



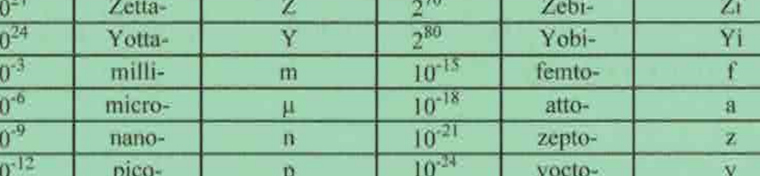

**MEMORY ALLOCATION**




**STACK FRAME**




**DATA ALIGNMENT**




Value of three least significant bits of byte address (Big Endian)

**EXCEPTION SYNDROME REGISTER (ESR)**


**EXCEPTION CLASS**

| EC | Class | Cause of Exception | Number | Name | Cause of Exception |
|---|---|---|---|---|---|
| 0 | Unknown | Unknown | 34 | PC | Misaligned PC exception |
| 7 | SIMD | SIMD/FP registers disabled | 36 | Data | Data Abort |
| 14 | FPE | Illegal Execution State | 40 | FPE | Floating-point exception |
| 17 | Sys | Supervisor Call Exception | 52 | WPT | Data Breakpoint exception |
| 32 | Instr | Instruction Abort | 56 | BKPT | SW Breakpoint Exception |

**SIZE PREFIXES AND SYMBOLS**

| SIZE | PREFIX | SYMBOL | SIZE | PREFIX | SYMBOL |
|---|---|---|---|---|---|
| $10^3$ | Kilo- | K | $2^{10}$ | Kibi- | Ki |
| $10^6$ | Mega- | M | $2^{20}$ | Mebi- | Mi |
| $10^9$ | Giga- | G | $2^{30}$ | Gibi- | Gi |
| $10^{12}$ | Tera- | T | $2^{40}$ | Tebi- | Ti |
| $10^{15}$ | Peta- | P | $2^{50}$ | Pebi- | Pi |
| $10^{18}$ | Exa- | E | $2^{60}$ | Exbi- | Ei |
| $10^{21}$ | Zetta- | Z | $2^{70}$ | Zebi- | Zi |
| $10^{24}$ | Yotta- | Y | $2^{80}$ | Yobi- | Yi |
| $10^{-3}$ | milli- | m | $10^{-15}$ | femto- | f |
| $10^{-6}$ | micro- | μ | $10^{-18}$ | atto- | a |
| $10^{-9}$ | nano- | n | $10^{-21}$ | zepto- | z |
| $10^{-12}$ | pico- | p | $10^{-24}$ | yocto- | y |