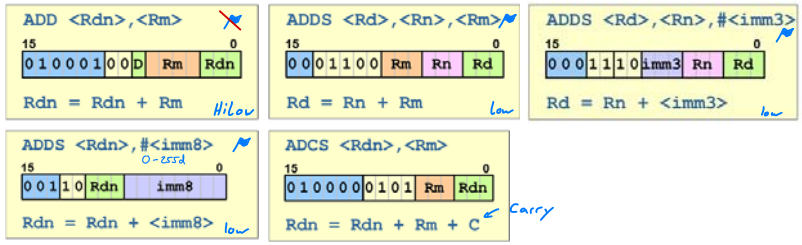
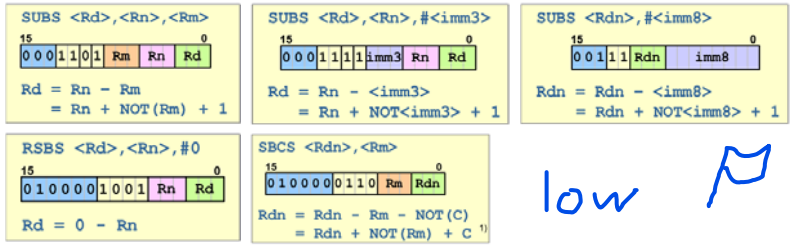
ARM v6-M Instruction Set

MOV

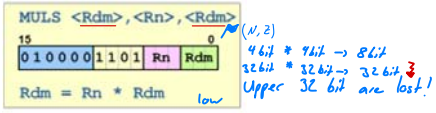
ADD



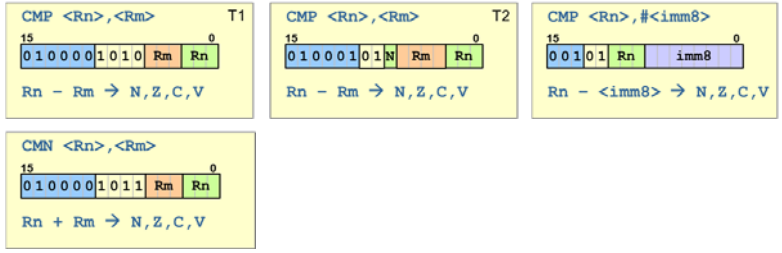
Subtract



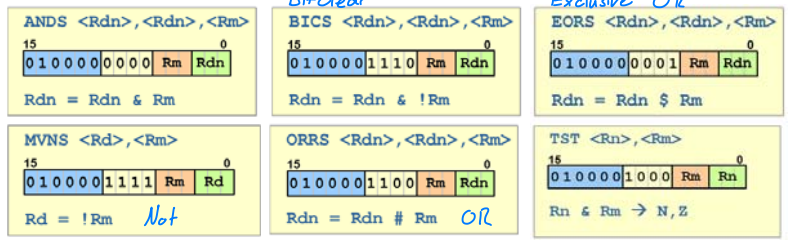
Multiply



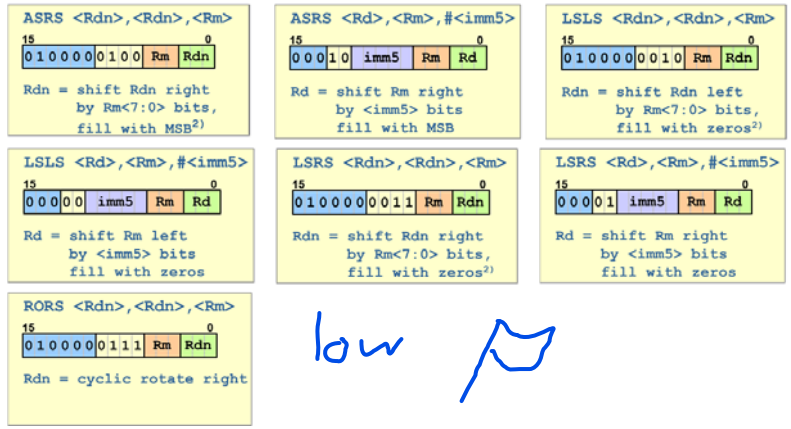
Compare



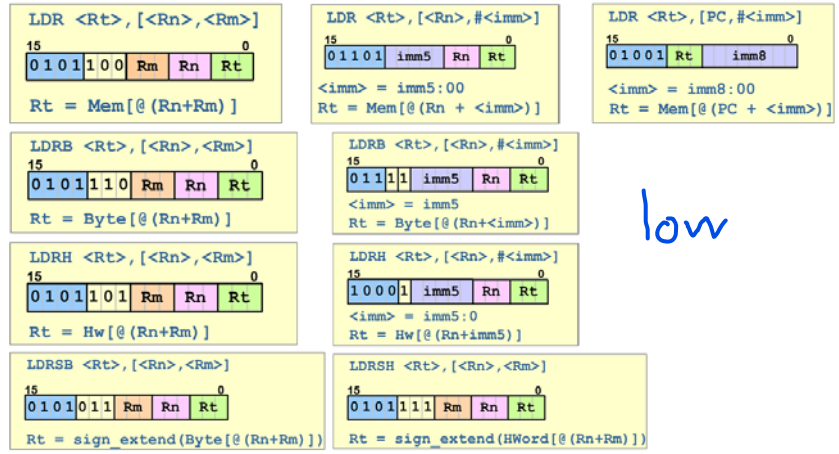
Logical (update N and Z flags)



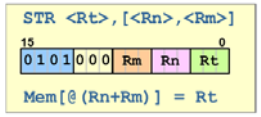
Shift/Rotate

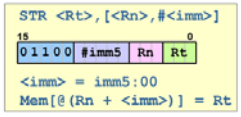


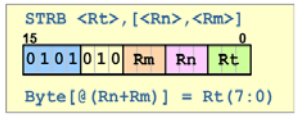
Load

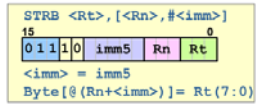


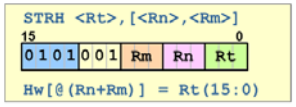
Store

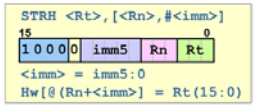








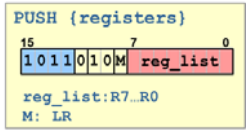


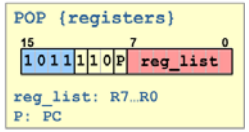


low

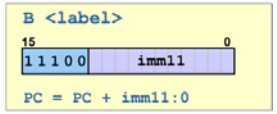
Load/Store Multiple

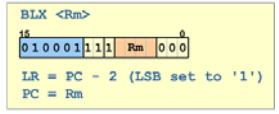
Push/Pop

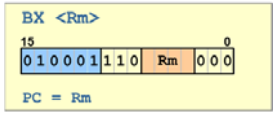


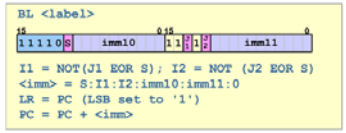


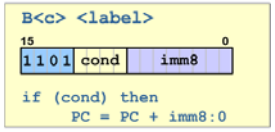
Branch





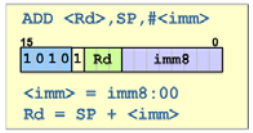


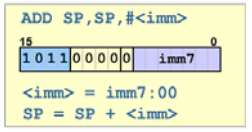


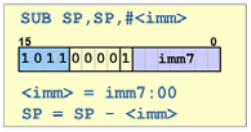


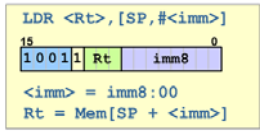
cond	short	Flag	cond	short	Flag	cond	short	Flag
0000	EQ	Z == 1	0110	VS	V == 1	1100	GT	Z == 0 and N == V
0001	NE	Z == 0	0111	VC	V == 0	1101	LE	Z == 1 or N != V
0010	CS/HS	C == 1	1000	HI	C == 1 and Z == 0	1110	AL	always
0011	CC/LO	C == 0	1001	LS	C == 0 or Z == 1	1111	--	--
0100	MI	N == 1	1010	GE	N == V			
0101	PL	N == 0	1011	LT	N != V			

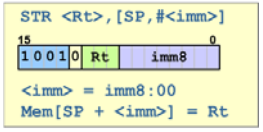
Stack Operations





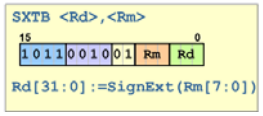


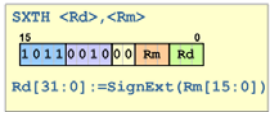


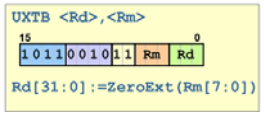


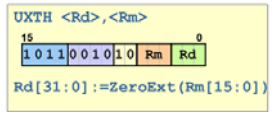
low

Extend









low

Pseudo Instructions

```
LDR <Rt>, <label>   =>  LDR <Rt>, [PC, #<imm>]
LDR <Rt>, =<value>  =>  LDR <Rt>, [PC, #<imm>]
                        …
                        Literalpool
                        DCD  value
```

Weitere Befehle

```
REV    REV16  REVSH  SVC    CPSID  CPSIE  SETEND  BKPT   NOP    SEV
WFE    WFI    YIELD
```

Thumb® 16-bit Instruction Set
Quick Reference Card

This card lists all Thumb instructions available on Thumb-capable processors earlier than ARM®v6T2. In addition, it lists all Thumb-2 16-bit instructions.
The instructions shown on this card are all 16-bit in Thumb-2, except where noted otherwise.
All registers are Lo (R0-R7) except where specified. Hi registers are R8-R15.

Key to Tables				
§	See Table **ARM architecture versions**.		`<loreglist+LR>`	A comma-separated list of Lo registers. plus the LR, enclosed in braces, { and }.
`<loreglist>`	A comma-separated list of Lo registers, enclosed in braces, { and }.		`<loreglist+PC>`	A comma-separated list of Lo registers. plus the PC, enclosed in braces, { and }.

Operation		§	Assembler	Updates	Action	Notes
Move	Immediate		`MOVS Rd, #<imm>`	N Z	Rd := imm	imm range 0-255.
	Lo to Lo		`MOVS Rd, Rm`	N Z	Rd := Rm	Synonym of `LSLS Rd, Rm, #0`
	Hi to Lo, Lo to Hi, Hi to Hi		`MOV Rd, Rm`		Rd := Rm	Not Lo to Lo.
	Any to Any	6	`MOV Rd, Rm`		Rd := Rm	Any register to any register.
Add	Immediate 3		`ADDS Rd, Rn, #<imm>`	N Z C V	Rd := Rn + imm	imm range 0-7.
	All registers Lo		`ADDS Rd, Rn, Rm`	N Z C V	Rd := Rn + Rm	
	Hi to Lo, Lo to Hi, Hi to Hi		`ADD Rd, Rd, Rm`		Rd := Rd + Rm	Not Lo to Lo.
	Any to Any	T2	`ADD Rd, Rd, Rm`		Rd := Rd + Rm	Any register to any register.
	Immediate 8		`ADDS Rd, Rd, #<imm>`	N Z C V	Rd := Rd + imm	imm range 0-255.
	With carry		`ADCS Rd, Rd, Rm`	N Z C V	Rd := Rd + Rm + C-bit	
	Value to SP		`ADD SP, SP, #<imm>`		SP := SP + imm	imm range 0-508 (word-aligned).
	Form address from SP		`ADD Rd, SP, #<imm>`		Rd := SP + imm	imm range 0-1020 (word-aligned).
	Form address from PC		`ADR Rd, <label>`		Rd := label	label range PC to PC+1020 (word-aligned).
Subtract	Lo and Lo		`SUBS Rd, Rn, Rm`	N Z C V	Rd := Rn – Rm	
	Immediate 3		`SUBS Rd, Rn, #<imm>`	N Z C V	Rd := Rn – imm	imm range 0-7.
	Immediate 8		`SUBS Rd, Rd, #<imm>`	N Z C V	Rd := Rd – imm	imm range 0-255.
	With carry		`SBCS Rd, Rd, Rm`	N Z C V	Rd := Rd – Rm – NOT C-bit	
	Value from SP		`SUB SP, SP, #<imm>`		SP := SP – imm	imm range 0-508 (word-aligned).
	Negate		`RSBS Rd, Rn, #0`	N Z C V	Rd := – Rn	Synonym: `NEGS Rd, Rn`
Multiply	Multiply		`MULS Rd, Rm, Rd`	N Z * *	Rd := Rm * Rd	* C and V flags unpredictable in §4T, unchanged in §5T and above
Compare			`CMP Rn, Rm`	N Z C V	update APSR flags on Rn – Rm	Can be Lo to Lo, Lo to Hi, Hi to Lo, or Hi to Hi.
	Negative		`CMN Rn, Rm`	N Z C V	update APSR flags on Rn + Rm	
	Immediate		`CMP Rn, #<imm>`	N Z C V	update APSR flags on Rn – imm	imm range 0-255.
Logical	AND		`ANDS Rd, Rd, Rm`	N Z	Rd := Rd AND Rm	
	Exclusive OR		`EORS Rd, Rd, Rm`	N Z	Rd := Rd EOR Rm	
	OR		`ORRS Rd, Rd, Rm`	N Z	Rd := Rd OR Rm	
	Bit clear		`BICS Rd, Rd, Rm`	N Z	Rd := Rd AND NOT Rm	
	Move NOT		`MVNS Rd, Rm`	N Z	Rd := NOT Rm	
	Test bits		`TST Rn, Rm`	N Z	update APSR flags on Rn AND Rm	
Shift/rotate	Logical shift left		`LSLS Rd, Rm, #<shift>`	N Z C*	Rd := Rm << shift	Allowed shifts 0-31. * C flag unaffected if shift is 0.
			`LSLS Rd, Rd, Rs`	N Z C*	Rd := Rd << Rs[7:0]	* C flag unaffected if Rs[7:0] is 0.
	Logical shift right		`LSRS Rd, Rm, #<shift>`	N Z C	Rd := Rm >> shift	Allowed shifts 1-32.
			`LSRS Rd, Rd, Rs`	N Z C*	Rd := Rd >> Rs[7:0]	* C flag unaffected if Rs[7:0] is 0.
	Arithmetic shift right		`ASRS Rd, Rm, #<shift>`	N Z C	Rd := Rm ASR shift	Allowed shifts 1-32.
			`ASRS Rd, Rd, Rs`	N Z C*	Rd := Rd ASR Rs[7:0]	* C flag unaffected if Rs[7:0] is 0.
	Rotate right		`RORS Rd, Rd, Rs`	N Z C*	Rd := Rd ROR Rs[7:0]	* C flag unaffected if Rs[7:0] is 0.

Thumb 16-bit Instruction Set
Quick Reference Card

Operation		§	Assembler	Action	Notes
Load	with immediate offset, word		`LDR Rd, [Rn, #<imm>]`	Rd := [Rn + imm]	imm range 0-124, multiple of 4.
	halfword		`LDRH Rd, [Rn, #<imm>]`	Rd := ZeroExtend([Rn + imm][15:0])	Clears bits 31:16. imm range 0-62, even.
	byte		`LDRB Rd, [Rn, #<imm>]`	Rd := ZeroExtend([Rn + imm][7:0])	Clears bits 31:8. imm range 0-31.
	with register offset, word		`LDR Rd, [Rn, Rm]`	Rd := [Rn + Rm]	
	halfword		`LDRH Rd, [Rn, Rm]`	Rd := ZeroExtend([Rn + Rm][15:0])	Clears bits 31:16
	signed halfword		`LDRSH Rd, [Rn, Rm]`	Rd := SignExtend([Rn + Rm][15:0])	Sets bits 31:16 to bit 15
	byte		`LDRB Rd, [Rn, Rm]`	Rd := ZeroExtend([Rn + Rm][7:0])	Clears bits 31:8
	signed byte		`LDRSB Rd, [Rn, Rm]`	Rd := SignExtend([Rn + Rm][7:0])	Sets bits 31:8 to bit 7
	PC-relative		`LDR Rd, <label>`	Rd := [label]	label range PC to PC+1020 (word-aligned).
	SP-relative		`LDR Rd, [SP, #<imm>]`	Rd := [SP + imm]	imm range 0-1020, multiple of 4.
	Multiple, not including base		`LDM Rn!, <loreglist>`	Loads list of registers (not including Rn)	Always updates base register, Increment After.
	Multiple, including base		`LDM Rn, <loreglist>`	Loads list of registers (including Rn)	Never updates base register, Increment After.
Store	with immediate offset, word		`STR Rd, [Rn, #<imm>]`	[Rn + imm] := Rd	imm range 0-124, multiple of 4.
	halfword		`STRH Rd, [Rn, #<imm>]`	[Rn + imm][15:0] := Rd[15:0]	Ignores Rd[31:16]. imm range 0-62, even.
	byte		`STRB Rd, [Rn, #<imm>]`	[Rn + imm][7:0] := Rd[7:0]	Ignores Rd[31:8]. imm range 0-31.
	with register offset, word		`STR Rd, [Rn, Rm]`	[Rn + Rm] := Rd	
	halfword		`STRH Rd, [Rn, Rm]`	[Rn + Rm][15:0] := Rd[15:0]	Ignores Rd[31:16]
	byte		`STRB Rd, [Rn, Rm]`	[Rn + Rm][7:0] := Rd[7:0]	Ignores Rd[31:8]
	SP-relative, word		`STR Rd, [SP, #<imm>]`	[SP + imm] := Rd	imm range 0-1020, multiple of 4.
	Multiple		`STM Rn!, <loreglist>`	Stores list of registers	Always updates base register, Increment After.
Push	Push		`PUSH <loreglist>`	Push registers onto full descending stack	
	Push with link		`PUSH <loreglist+LR>`	Push LR and registers onto full descending stack	
Pop	Pop		`POP <loreglist>`	Pop registers from full descending stack	
	Pop and return	4T	`POP <loreglist+PC>`	Pop registers, branch to address loaded to PC	
	Pop and return with exchange	5T	`POP <loreglist+PC>`	Pop, branch, and change to ARM state if address[0] = 0	
If-Then	If-Then	T2	`IT{pattern} {cond}`	Makes up to four following instructions conditional, according to pattern. pattern is a string of up to three letters. Each letter can be T (Then) or E (Else).	The first instruction after IT has condition cond. The following instructions have condition cond if the corresponding letter is T, or the inverse of cond if the corresponding letter is E. See Table **Condition Field**.
Branch	Conditional branch		`B{cond} <label>`	If {cond} then PC := label	label must be within – 252 to + 258 bytes of current instruction. See Table **Condition Field**.
	Compare, branch if (non) zero	T2	`CB{N}Z Rn,<label>`	If Rn {== | !=} 0 then PC := label	label must be within +4 to +130 bytes of current instruction.
	Unconditional branch		`B <label>`	PC := label	label must be within ±2KB of current instruction.
	Long branch with link		`BL <label>`	LR := address of next instruction, PC := label	This is a 32-bit instruction. label must be within ±4MB of current instruction (T2: ±16MB).
	Branch and exchange		`BX Rm`	PC := Rm AND 0xFFFFFFFE	Change to ARM state if Rm[0] = 0.
	Branch with link and exchange	5T	`BLX <label>`	LR := address of next instruction, PC := label Change to ARM	This is a 32-bit instruction. label must be within ±4MB of current instruction (T2: ±16MB).
	Branch with link and exchange	5T	`BLX Rm`	LR := address of next instruction, PC := Rm AND 0xFFFFFFFE	Change to ARM state if Rm[0] = 0.
Extend	Signed, halfword to word	6	`SXTH Rd, Rm`	Rd[31:0] := SignExtend(Rm[15:0])	
	Signed, byte to word	6	`SXTB Rd, Rm`	Rd[31:0] := SignExtend(Rm[7:0])	
	Unsigned, halfword to word	6	`UXTH Rd, Rm`	Rd[31:0] := ZeroExtend(Rm[15:0])	
	Unsigned, byte to word	6	`UXTB Rd, Rm`	Rd[31:0] := ZeroExtend(Rm[7:0])	
Reverse	Bytes in word	6	`REV Rd, Rm`	Rd[31:24] := Rm[7:0], Rd[23:16] := Rm[15:8], Rd[15:8] := Rm[23:16], Rd[7:0] := Rm[31:24]	
	Bytes in both halfwords	6	`REV16 Rd, Rm`	Rd[15:8] := Rm[7:0], Rd[7:0] := Rm[15:8], Rd[31:24] := Rm[23:16], Rd[23:16] := Rm[31:24]	
	Bytes in low halfword, sign extend	6	`REVSH Rd, Rm`	Rd[15:8] := Rm[7:0], Rd[7:0] := Rm[15:8], Rd[31:16] := Rm[7] * &FFFF	

Thumb 16-bit Instruction Set
Quick Reference Card

Operation		§	Assembler	Action	Notes
Processor state change	Supervisor Call		`SVC <immed_8>`	Supervisor Call processor exception	8-bit immediate value encoded in instruction. Formerly SWI.
	Change processor state	6	`CPSID <iflags>`	Disable specified interrupts	
		6	`CPSIE <iflags>`	Enable specified interrupts	
	Set endianness	6	`SETEND <endianness>`	Sets endianness for loads and saves.	`<endianness>` can be `BE` (Big Endian) or `LE` (Little Endian).
	Breakpoint	5T	`BKPT <immed_8>`	Prefetch abort *or* enter debug state	8-bit immediate value encoded in instruction.
No Op	No operation		`NOP`	None, might not even consume any time.	Real NOP available in ARM v6K and above.
Hint	Set event	T2	`SEV`	Signal event in multiprocessor system.	Executes as NOP in Thumb-2. Functionally available in ARM v7.
	Wait for event	T2	`WFE`	Wait for event, IRQ, FIQ, Imprecise abort, or Debug entry request.	Executes as NOP in Thumb-2. Functionally available in ARM v7.
	Wait for interrupt	T2	`WFI`	Wait for IRQ, FIQ, Imprecise abort, or Debug entry request.	Executes as NOP in Thumb-2. Functionally available in ARM v7.
	Yield	T2	`YIELD`	Yield control to alternative thread.	Executes as NOP in Thumb-2. Functionally available in ARM v7.

Condition Field	
Mnemonic	**Description**
`EQ`	Equal
`NE`	Not equal
`CS / HS`	Carry Set / Unsigned higher or same
`CC / LO`	Carry Clear / Unsigned lower
`MI`	Negative
`PL`	Positive or zero
`VS`	Overflow
`VC`	No overflow
`HI`	Unsigned higher
`LS`	Unsigned lower or same
`GE`	Signed greater than or equal
`LT`	Signed less than
`GT`	Signed greater than
`LE`	Signed less than or equal
`AL`	Always. Do not use in `B{cond}`

In Thumb code for processors earlier than ARMv6T2, cond must not appear anywhere except in Conditional Branch (`B{cond}`) instructions.

In Thumb-2 code, cond can appear in any of these instructions (except `CBZ`, `CBNZ`, `CPSID`, `CPSIE`, `IT`, and `SETEND`).

The condition is encoded in a preceding `IT` instruction (except in the case of `B{cond}` instructions).

If `IT` instructions are explicitly provided in the Assembly language source file, the conditions in the instructions must match the corresponding `IT` instructions.

ARM architecture versions	
4T	All Thumb versions of ARM v4 and above.
5T	All Thumb versions of ARM v5 and above.
6	All Thumb versions of ARM v6 and above.
T2	All Thumb-2 versions of ARM v6 and above.

Document Number

ARM QRC 0006E

Change Log

Issue	Date	Change
A	Nov 2004	First Release
B	May 2005	RVCT 2.2 SP1
C	March 2006	RVCT 3.0
D	March 2007	RVCT 3.1
E	Sept 2008	RVCT 4.0

ARM® Thumb® Cortex-M0/M1 Instruction Set ordered by machine code

This card lists all Thumb instructions ordered by machine code to ease manually disassemble Thumb code.
See the respective ***Thumb® 16-bit Instruction Set Quick Reference Card*** for details on the individual instructions.

Version 1.3, 2019-08-20, Andreas Gieriet

Zürcher Hochschule für Angewandte Wissenschaften
zhaw School of Engineering
InES Institute of Embedded Systems

```
0000 – 0x0xxx Instructions
0000 0000 00mm mddd    MOVS  Rddd, Rmmm          ; Rddd  = Rmmm              --> alias for LSLS Rddd,Rmmm,#0
0000 0iii iimm mddd    LSLS  Rddd, Rmmm, #0biiiii; Rddd  = Rmmm LSL #0b0iiiii
0000 1iii iimm mddd    LSRS  Rddd, Rmmm, #0biiiii; Rddd  = Rmmm LSR #0b0iiiii

0001 – 0x1xxx Instructions
0001 0iii iimm mddd    ASRS  Rddd, Rmmm, #0biiiii; Rddd  = Rmmm ASR #0b0iiiii
0001 100m mnnn nddd    ADDS  Rddd, Rnnn, Rmmm    ; Rddd  = Rnnn  +  Rmmm
0001 101m mnnn nddd    SUBS  Rddd, Rnnn, Rmmm    ; Rddd  = Rnnn  -  Rmmm
0001 110i iinn nddd    ADDS  Rddd, Rnnn, #0biii  ; Rddd  = Rnnn  +  #0b0iii
0001 111i iinn nddd    SUBS  Rddd, Rnnn, #0biii  ; Rddd  = Rnnn  -  #0b0iii

0010 – 0x2xxx Instructions
0010 0ddd iiii iiii    MOVS  Rddd, #0biiiiiiii   ; Rddd  =          #0b0iiiiiiii
0010 1nnn iiii iiii    CMP   Rnnn, #0biiiiiiii   ; flags = Rnnn  -  #0b0iiiiiiii

0011 – 0x3xxx Instructions
0011 0ddd iiii iiii    ADDS  Rddd, #0biiiiiiii   ; Rddd  = Rddd  +  #0b0iiiiiiii
0011 1ddd iiii iiii    SUBS  Rddd, #0biiiiiiii   ; Rddd  = Rddd  -  #0b0iiiiiiii

0100 – 0x4xxx Instructions
0100 0000 00mm mddd    ANDS  Rddd,  Rmmm         ; Rddd  = Rddd  &  Rmmm
0100 0000 01mm mddd    EORS  Rddd,  Rmmm         ; Rddd  = Rddd  ^  Rmmm
0100 0000 10mm mddd    LSLS  Rddd,  Rmmm         ; Rddd  = Rddd LSL Rmmm
0100 0000 11mm mddd    LSRS  Rddd,  Rmmm         ; Rddd  = Rddd LSR Rmmm
0100 0001 00mm mddd    ASRS  Rddd,  Rmmm         ; Rddd  = Rddd ASR Rmmm
0100 0001 01mm mddd    ADCS  Rddd,  Rmmm         ; Rddd  = Rddd  +  Rmmm +  carry
0100 0001 10mm mddd    SBCS  Rddd,  Rmmm         ; Rddd  = Rddd  -  Rmmm - ~carry
0100 0001 11mm mddd    RORS  Rddd,  Rmmm         ; Rddd  = Rddd ROR Rmmm
0100 0010 00mm mddd    TST   Rddd,  Rmmm         ; flags : Rddd  &  Rmmm
0100 0010 01mm mddd    RSBS  Rddd,  Rmmm, #0     ; Rddd  = 0     -  Rmmm   --> alias for NEGS Rddd, Rmmm
0100 0010 10mm mnnn    CMP   Rnnn,  Rmmm         ; flags : Rnnn  -  Rmmm
0100 0010 11mm mnnn    CMN   Rnnn,  Rmmm         ; flags : Rnnn  +  Rmmm
0100 0011 00mm mddd    ORRS  Rddd,  Rmmm         ; Rddd  = Rddd  |  Rmmm
0100 0011 01mm mddd    MULS  Rddd,  Rmmm, Rddd   ; Rddd  = Rddd  *  Rmmm
0100 0011 10mm mddd    BICS  Rddd,  Rmmm         ; Rddd  = Rddd  & ~Rmmm   --> bit clear
0100 0011 11mm mddd    MVNS  Rddd,  Rmmm         ; Rddd  =        ~Rmmm
0100 0100 dmmm mddd    ADD   Rdddd, Rmmmm        ; Rdddd = Rdddd + Rmmmm
0100 0101 nmmm mnnn    CMP   Rnnnn, Rmmmm        ; flags : Rnnnn - Rmmmm
0100 0110 dmmm mddd    MOV   Rdddd, Rmmmm        ; Rdddd =         Rmmmm
0100 0111 0mmm m...    BX    Rmmmm               ;           PC=Rmmmm  (mmmm==0b1111: unpredictable)
0100 0111 1mmm m...    BLX   Rmmmm               ; LR = IPC+2,PC=Rmmmm  (mmmm==0b1111: unpredictable)
0100 1ttt iiii iiii    LDR   Rttt, [PC, #off]    ; Rttt = [((IPC+4)&~0b011)+0b0iiiiiiii00] --> +1020 max
                       LDR   Rttt, label         ; --> the assembler calculates the above from the label
                       LDR   Rttt, =lab          ; --> pseudo instruction: the assembler stores the lab/lit
                       LDR   Rttt, =lit          ;     in litpool, access PC relative with LDR Rttt,litpool

0101 – 0x5xxx Instructions
0101 000m mnnn nttt    STR   Rttt, [Rnnn, Rmmm]  ; [Rnnn + Rmmm] = Rttt
0101 001m mnnn nttt    STRH  Rttt, [Rnnn, Rmmm]  ; [Rnnn + Rmmm] = Rttt                --> low half
0101 010m mnnn nttt    STRB  Rttt, [Rnnn, Rmmm]  ; [Rnnn + Rmmm] = Rttt                --> low byte
0101 011m mnnn nttt    LDRSB Rttt, [Rnnn, Rmmm]  ; Rttt<sss1> = [Rnnn + Rmmm]<1>       --> low byte
0101 100m mnnn nttt    LDR   Rttt, [Rnnn, Rmmm]  ; Rttt = [Rnnn + Rmmm]
0101 101m mnnn nttt    LDRH  Rttt, [Rnnn, Rmmm]  ; Rttt<0021> = [Rnnn + Rmmm]<21>      --> low half
0101 110m mnnn nttt    LDRB  Rttt, [Rnnn, Rmmm]  ; Rttt<0001> = [Rnnn + Rmmm]<1>       --> low byte
0101 111m mnnn nttt    LDRSH Rttt, [Rnnn, Rmmm]  ; Rttt<ss21> = [Rnnn + Rmmm]<21>      --> low half

0110 – 0x6xxx Instructions
0110 0iii iinn nttt    STR   Rttt, [Rnnn, #off]  ; [Rnnn + 0b0iiiii00] = Rttt          --> +124 max
0110 1iii iinn nttt    LDR   Rttt, [Rnnn, #off]  ; Rttt = [Rnnn + 0x0iiiii00]          --> +124 max

0111 – 0x7xxx Instructions
0111 0iii iinn nttt    STRB  Rttt, [Rnnn, #off]  ; [Rnnn + 0b0iiiii] = Rttt            --> +31 max, low byte
0111 1iii iinn nttt    LDRB  Rttt, [Rnnn, #off]  ; Rttt<0001> = [Rnnn + 0x0iiiii]<1>   --> +31 max, low byte

1000 – 0x8xxx Instructions
1000 0iii iinn nttt    STRH  Rttt, [Rnnn, #off]  ; [Rnnn + 0x0iiiii0] = Rttt           --> +62 max, low half
1000 1iii iinn nttt    LDRH  Rttt, [Rnnn, #off]  ; Rttt<0021> = [Rnnn + 0x0iiiii0]<21> --> +62 max, low half

1001 – 0x9xxx Instructions
1001 0ttt iiii iiii    STR   Rttt, [SP, #off]    ; [SP + 0b0iiiiiiii00] = Rttt             --> +1020 max
1001 1ttt iiii iiii    LDR   Rttt, [SP, #off]    ; Rttt = [SP + 0b0iiiiiiii00]             --> +1020 max
```

```
1010 – 0xAxxx Instructions
1010 0ddd iiii iiii    ADR   Rddd, label     ; Rddd = ((IPC+4)&~0b011)+0b0iiiiiiii00   --> +1020 max
1010 1ddd iiii iiii    ADD   Rddd, SP, #off  ; Rddd = SP + 0b0iiiiiiii00              --> +1020 max

1011 – 0xBxxx Instructions
1011 0000 0iii iiii    ADD   SP, SP, #off    ; SP = SP + 0b0iiiiiii00                 --> +508 max
1011 0000 1iii iiii    SUB   SP, SP, #off    ; SP = SP - 0b0iiiiiii00                 --> +508 max
1011 00i1 iiii innn    CBZ   Rnnn, label     ; if Rnnn==zero, PC = IPC+4 + 0x0iiiiii0  --> +126 max
1011 0010 00mm mddd    SXTH Rddd, Rmmm       ; Rddd<ss21> = Rmmm<4321> --> low half
1011 0010 01mm mddd    SXTB Rddd, Rmmm       ; Rddd<sss1> = Rmmm<4321> --> low byte
1011 0010 10mm mddd    UXTH Rddd, Rmmm       ; Rddd<0021> = Rmmm<4321> --> low half
1011 0010 11mm mddd    UXTB Rddd, Rmmm       ; Rddd<0001> = Rmmm<4321> --> low byte
1011 0100 rrrr rrrr    PUSH {reg0-7}         ; rrrrrrrr = Lo reg-mask --> pushes regs to SP (decrements SP)
1011 0101 rrrr rrrr    PUSH {LR,reg0-7]      ; rrrrrrrr = Lo reg-mask --> pushes regs to SP (decrements SP)
1011 0110 0100 xxxx    -                     ; unpredictable
1011 0110 0101 0...    SETEND LE             ; sets little-endian mode in CPSR
1011 0110 0101 1...    SETEND BE             ; sets big-endian mode in CPSR
1011 0110 0110 0aif    CPSIE aif             ; Enable Processor State  --> a=imprecise-abort, i=IRQ, f=FIQ
1011 0110 0111 0aif    CPSID aif             ; Disable Processor State --> a=imprecise-abort, i=IRQ, f=FIQ
1011 0110 011x 1xxx    -                     ; unpredictable
1011 10i1 iiii innn    CBNZ Rnnn, label      ; if Rnnn!=zero, PC = IPC+4 + 0x0iiiii0   --> +126 max
1011 1010 00mm mddd    REV   Rddd, Rmmm      ; Rddd<4321> = Rmmm<1234> --> reverse all
1011 1010 01mm mddd    REV16 Rddd, Rmmm      ; Rddd<4321> = Rmmm<3412> --> reverse low half, rev. upper half
1011 1010 10xx xxxx    -                     ; undefined
1011 1010 11mm mddd    REVSH Rddd, Rmmm      ; Rddd<4321> = Rmmm<ss12> --> reverse low half, sign extended
1011 1100 rrrr rrrr    POP  {reg0-7}         ; rrrrrrrr = Lo reg-mask  --> pops regs from SP (increments SP)
1011 1101 rrrr rrrr    POP  {PC,reg0-7]      ; rrrrrrrr = Lo reg-mask  --> pops regs from SP (increments SP)
1011 1110 iiii iiii    BKPT #0biiiiiiii      ; breakpoint, arg ignored by HW
1011 1111 0000 0000    NOP                   ; do nothing
1011 1111 0001 0000    YIELD                 ; do nothing, NOP-Hint: signal to HW to suspend/resume threads
1011 1111 0010 0000    WFE                   ; do nothing, NOP-Hint, wait for event
1011 1111 0011 0000    WFI                   ; do nothing, NOP-Hint: wait for interrupt
1011 1111 0100 0000    SEV                   ; do nothing, NOP-Hint: signal event to multi-processor system
1011 1111 cccc mmmm    ITsel cond            ; if-then: sel=mmmm: T=then/E=else, cond=cccc: as for Bcc<11:8>

1100 – 0xCxxx Instructions
1100 0nnn rrrr rrrr    STMIA Rnnn! {reg0-7}  ; rrrrrrrr = Lo reg-mask, inc Rnnn
1100 1nnn rrrr rrrr    LDMIA Rnnn! {reg0-7}  ; rrrrrrrr = Lo reg-mask, inc Rnnn if Rnnn not in mask
                       LDMIA Rnnn  {reg0-7}  ; rrrrrrrr = Lo reg-mask, load Rnnn if Rnnn in mask

1101 – 0xDxxx Instructions
1101 0000 iiii iiii    BEQ label             ; if true, PC = IPC+4 + 0biiiiiiii0 --> -256/+254 max
1101 0001 iiii iiii    BNE label             ; if true, PC = IPC+4 + 0biiiiiiii0 --> -256/+254 max
1101 0010 iiii iiii    BHS/BCS label         ; if true, PC = IPC+4 + 0biiiiiiii0 --> -256/+254 max
1101 0011 iiii iiii    BLO/BCC label         ; if true, PC = IPC+4 + 0biiiiiiii0 --> -256/+254 max
1101 0100 iiii iiii    BPL label             ; if true, PC = IPC+4 + 0biiiiiiii0 --> -256/+254 max
1101 0101 iiii iiii    BMI label             ; if true, PC = IPC+4 + 0biiiiiiii0 --> -256/+254 max
1101 0110 iiii iiii    BVS label             ; if true, PC = IPC+4 + 0biiiiiiii0 --> -256/+254 max
1101 0111 iiii iiii    BVC label             ; if true, PC = IPC+4 + 0biiiiiiii0 --> -256/+254 max
1101 1000 iiii iiii    BHI label             ; if true, PC = IPC+4 + 0biiiiiiii0 --> -256/+254 max
1101 1001 iiii iiii    BLS label             ; if true, PC = IPC+4 + 0biiiiiiii0 --> -256/+254 max
1101 1010 iiii iiii    BGE label             ; if true, PC = IPC+4 + 0biiiiiiii0 --> -256/+254 max
1101 1011 iiii iiii    BLT label             ; if true, PC = IPC+4 + 0biiiiiiii0 --> -256/+254 max
1101 1100 iiii iiii    BGT label             ; if true, PC = IPC+4 + 0biiiiiiii0 --> -256/+254 max
1101 1101 iiii iiii    BLE label             ; if true, PC = IPC+4 + 0biiiiiiii0 --> -256/+254 max
1101 1110 xxxx xxxx    -                     ; undefined --> can be used for instruction emulation
1101 1111 iiii iiii    SVC #0biiiiiiii       ; supervisor call (formerly called SWI), arg ignored by HW

1110 – 0xExxx Instructions
1110 0iii iiii iiii    B label               ; PC = IPC+4 + 0biiiiiiiiiii0       --> -2048/+2046 max
1110 1xxx xxxx xxxx    -                     ; 32 bit instructions

1111 – 0xFxxx Instructions
1111 0xii iiii iiii 11y1 ziii iiii iiii BL  label  ; LR=IPC+4,PC=IPC+4+0bXYZii...ii0,X,Y,Z=f(x,y,z), +/-16M
1111 0011 1110 1111 1000 dddd ssss ssss MRS Rdddd,S; Rdddd = special register S (encoded as 0bssssssss)
1111 0011 1000 mmmm 1000 1000 ssss ssss MSR S,Rmmmm; special register S (encoded as 0bssssssss) = Rmmmm
1111 0011 1011 1111 1000 1111 0100 1111 DSB       ; data synchronization barrier
1111 0011 1011 1111 1000 1111 0101 1111 DMB       ; data memory barrier
1111 0011 1011 1111 1000 1111 0110 1111 ISB       ; instruction synchronization barrier
1111 xxxx xxxx xxxx xxxx xxxx xxxx xxxx -          ; other 32 bit instructions
```

1) IPC is the PC of the current instruction (IPC+4 is given by the pipeline, IPC+2/+4 is the return address in the LR)
2) a dot means don't care, but must be set to 0.
3) <4321>: word, <21>: low half word, <1>: low byte, <0001>: zero extend byte, <sss1>: sign extend byte, etc.
4) Undefined instructions can be used to emulate instructions (they trigger the undefined exception).
5) Unpredictable instructions do any unpredictable actions and are therefore illegal instructions.
6) Unallocated codes are undefined unless they are explicitly marked as unpredictable.
7) CBZ, CBNZ, IT are the only 16 bit instructions which are not part of Cortex-M0/M1 Thumb code.
8) BL, DMB, DSB, ISB, MRS, MSR are the only 32 bit instructions as part of the Cortex-M0/M1 instruction set.

ARM Cond. Jumps

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Flag- Dependent

Symbol	Condition	Flag
EQ	Equal	Z == 1
NE	Not equal	Z == 0
CS	Carry set	C == 1
CC	Carry clear	C == 0
MI	Minus/negative	N == 1
PL	Plus/positive or zero	N == 0
VS	Overflow	V == 1
VC	No overflow	V == 0

Arithmetic - unsigned: higher and lower

Symbol	Condition	Flag
EQ	Equal	Z == 1
NE	Not equal	Z == 0
HS (=CS)	Unsigned higher or same	C == 1
LO (=CC)	Unsigned lower	C == 0
HI	Unsigned higher	C == 1 and Z == 0
LS	Unsigned lower or same	C == 0 or Z == 1

Arithmetic - signed: greater and less

Symbol	Condition	Flag
EQ	Equal	Z == 1
NE	Not equal	Z == 0
MI	Minus/negative	N == 1
PL	Plus/positive or zero	N == 0
VS	Overflow	V == 1
VC	No overflow	V == 0
GE	Signed greater than or equal	N == V
LT	Signed less than	N != V
GT	Signed greater than	Z == 0 and N == V
LE	Signed less than or equal	Z == 1 or N != V

C Reference Card (ANSI)

Program Structure/Functions

type fnc(*type*$_1$, ...);	function prototype
type name;	variable declaration
`int main(void) {`	main routine
declarations	local variable declarations
statements	
`}`	
type fnc(*arg*$_1$, ...) {	function definition
declarations	local variable declarations
statements	
`return` *value*;	
`}`	
`/* */`	comments
`int main(int argc, char *argv[])`	main with args
`exit(`*arg*`);`	terminate execution

C Preprocessor

include library file	`#include <`*filename*`>`
include user file	`#include "`*filename*`"`
replacement text	`#define` *name text*
replacement macro	`#define` *name*`(`*var*`)` *text*
Example. `#define max(A,B) ((A)>(B) ? (A) : (B))`	
undefine	`#undef` *name*
quoted string in replace	`#`
Example. `#define msg(A) printf("%s = %d", #A, (A))`	
concatenate args and rescan	`##`
conditional execution	`#if, #else, #elif, #endif`
is *name* defined, not defined?	`#ifdef, #ifndef`
name defined?	`defined(`*name*`)`
line continuation char	`\`

Data Types/Declarations

character (1 byte)	`char`
integer	`int`
real number (single, double precision)	`float, double`
short (16 bit integer)	`short`
long (32 bit integer)	`long`
double long (64 bit integer)	`long long`
positive or negative	`signed`
non-negative modulo 2^m	`unsigned`
pointer to `int`, `float`,...	`int*, float*`,...
enumeration constant	`enum` *tag* {*name*$_1$`=`*value*$_1$,...};
constant (read-only) value	*type* `const` *name*;
declare external variable	`extern`
internal to source file	`static`
local persistent between calls	`static`
no value	`void`
structure	`struct` *tag* {...};
create new name for data type	`typedef` *type name*;
size of an object (type is `size_t`)	`sizeof` *object*
size of a data type (type is `size_t`)	`sizeof(`*type*`)`

Initialization

initialize variable	*type name*`=`*value*;
initialize array	*type name*`[]={`*value*$_1$,...};
initialize char string	`char` *name*`[]="`*string*`"`;

Constants

suffix: long, unsigned, float	`65536L, -1U, 3.0F`
exponential form	`4.2e1`
prefix: octal, hexadecimal	`0, 0x` or `0X`
Example. `031` is 25, `0x31` is 49 decimal	
character constant (char, octal, hex)	`'a', '\`*ooo*`', '\x`*hh*`'`
newline, cr, tab, backspace	`\n, \r, \t, \b`
special characters	`\\, \?, \', \"`
string constant (ends with `'\0'`)	`"abc...de"`

Pointers, Arrays & Structures

declare pointer to *type*	*type* `*`*name*;
declare function returning pointer to *type*	*type* `*f();`
declare pointer to function returning *type*	*type* `(*pf)();`
generic pointer type	`void *`
null pointer constant	`NULL`
object pointed to by *pointer*	`*`*pointer*
address of object *name*	`&`*name*
array	*name*`[`*dim*`]`
multi-dim array	*name*`[`*dim*$_1$`][`*dim*$_2$`]`...

Structures

`struct` *tag* `{`	structure template
declarations	declaration of members
`};`	

create structure	`struct` *tag name*
member of structure from template	*name*`.`*member*
member of pointed-to structure	*pointer* `->` *member*
Example. `(*p).x` and `p->x` are the same	
single object, multiple possible types	`union`
bit field with *b* bits	`unsigned` *member*`:` *b*;

Operators (grouped by precedence)

struct member operator	*name*`.`*member*
struct member through pointer	*pointer*`->`*member*
increment, decrement	`++, --`
plus, minus, logical not, bitwise not	`+, -, !, ~`
indirection via pointer, address of object	`*`*pointer*`, &`*name*
cast expression to type	`(`*type*`)` *expr*
size of an object	`sizeof`
multiply, divide, modulus (remainder)	`*, /, %`
add, subtract	`+, -`
left, right shift [bit ops]	`<<, >>`
relational comparisons	`>, >=, <, <=`
equality comparisons	`==, !=`
and [bit op]	`&`
exclusive or [bit op]	`^`
or (inclusive) [bit op]	`|`
logical and	`&&`
logical or	`||`
conditional expression	*expr*$_1$ `?` *expr*$_2$ `:` *expr*$_3$
assignment operators	`+=, -=, *=,` ...
expression evaluation separator	`,`

Unary operators, conditional expression and assignment operators group right to left; all others group left to right.

Flow of Control

statement terminator	`;`
block delimiters	`{ }`
exit from `switch`, `while`, `do`, `for`	`break;`
next iteration of `while`, `do`, `for`	`continue;`
go to	`goto` *label*;
label	*label*`:` `statement`
return value from function	`return` *expr*

Flow Constructions

`if` statement	`if (`*expr*$_1$`)` *statement*$_1$ `else if (`*expr*$_2$`)` *statement*$_2$ `else` *statement*$_3$
`while` statement	`while (`*expr*`)` *statement*
`for` statement	`for (`*expr*$_1$`;` *expr*$_2$`;` *expr*$_3$`)` *statement*
`do` statement	`do` *statement* `while(`*expr*`);`

`switch` statement	`switch (`*expr*`) {`
	`case` *const*$_1$`:` *statement*$_1$ `break;`
	`case` *const*$_2$`:` *statement*$_2$ `break;`
	`default:` *statement*
	`}`

ANSI Standard Libraries

`<assert.h>`	`<ctype.h>`	`<errno.h>`	`<float.h>`	`<limits.h>`
`<locale.h>`	`<math.h>`	`<setjmp.h>`	`<signal.h>`	`<stdarg.h>`
`<stddef.h>`	`<stdio.h>`	`<stdlib.h>`	`<string.h>`	`<time.h>`

Character Class Tests `<ctype.h>`

alphanumeric?	`isalnum(c)`
alphabetic?	`isalpha(c)`
control character?	`iscntrl(c)`
decimal digit?	`isdigit(c)`
printing character (not incl space)?	`isgraph(c)`
lower case letter?	`islower(c)`
printing character (incl space)?	`isprint(c)`
printing char except space, letter, digit?	`ispunct(c)`
space, formfeed, newline, cr, tab, vtab?	`isspace(c)`
upper case letter?	`isupper(c)`
hexadecimal digit?	`isxdigit(c)`
convert to lower case	`tolower(c)`
convert to upper case	`toupper(c)`

String Operations `<string.h>`

`s` is a string; `cs`, `ct` are constant strings

length of `s`	`strlen(s)`
copy `ct` to `s`	`strcpy(s,ct)`
concatenate `ct` after `s`	`strcat(s,ct)`
compare `cs` to `ct`	`strcmp(cs,ct)`
only first `n` chars	`strncmp(cs,ct,n)`
pointer to first `c` in `cs`	`strchr(cs,c)`
pointer to last `c` in `cs`	`strrchr(cs,c)`
copy `n` chars from `ct` to `s`	`memcpy(s,ct,n)`
copy `n` chars from `ct` to `s` (may overlap)	`memmove(s,ct,n)`
compare `n` chars of `cs` with `ct`	`memcmp(cs,ct,n)`
pointer to first `c` in first `n` chars of `cs`	`memchr(cs,c,n)`
put `c` into first `n` chars of `s`	`memset(s,c,n)`

C Reference Card (ANSI)

Input/Output <stdio.h>

Standard I/O

standard input stream	stdin
standard output stream	stdout
standard error stream	stderr
end of file (type is int)	EOF
get a character	getchar()
print a character	putchar(*chr*)
print formatted data	printf("*format*",arg_1,...)
print to string s	sprintf(s,"*format*",arg_1,...)
read formatted data	scanf("*format*",&$name_1$,...)
read from string s	sscanf(s,"*format*",&$name_1$,...)
print string s	puts(s)

File I/O

declare file pointer	FILE *fp;
pointer to named file	fopen("*name*","*mode*")
modes: r (read), w (write), a (append), b (binary)	
get a character	getc(*fp*)
write a character	putc(*chr*,*fp*)
write to file	fprintf(*fp*,"*format*",arg_1,...)
read from file	fscanf(*fp*,"*format*",arg_1,...)
read and store n elts to *ptr	fread(*ptr,eltsize,n,*fp*)
write n elts from *ptr to file	fwrite(*ptr,eltsize,n,*fp*)
close file	fclose(*fp*)
non-zero if error	ferror(*fp*)
non-zero if already reached EOF	feof(*fp*)
read line to string s (< max chars)	fgets(s,max,*fp*)
write string s	fputs(s,*fp*)

Codes for Formatted I/O: "%-+ 0*w.pmc*"

-	left justify
+	print with sign
space	print space if no sign
0	pad with leading zeros
w	min field width
p	precision
m	conversion character: h short, l long, L long double
c	conversion character:

d,i	integer	u	unsigned
c	single char	s	char string
f	double (printf)	e,E	exponential
f	float (scanf)	lf	double (scanf)
o	octal	x,X	hexadecimal
p	pointer	n	number of chars written
g,G	same as f or e,E depending on exponent		

Variable Argument Lists <stdarg.h>

declaration of pointer to arguments	va_list *ap*;
initialization of argument pointer	va_start(*ap*,*lastarg*);
lastarg is last named parameter of the function	
access next unnamed arg, update pointer	va_arg(*ap*,*type*)
call before exiting function	va_end(*ap*);

Standard Utility Functions <stdlib.h>

absolute value of int n	abs(n)
absolute value of long n	labs(n)
quotient and remainder of ints n,d	div(n,d)
returns structure with div_t.quot and div_t.rem	
quotient and remainder of longs n,d	ldiv(n,d)
returns structure with ldiv_t.quot and ldiv_t.rem	
pseudo-random integer [0,RAND_MAX]	rand()
set random seed to n	srand(n)
terminate program execution	exit(status)
pass string s to system for execution	system(s)

Conversions

convert string s to double	atof(s)
convert string s to integer	atoi(s)
convert string s to long	atol(s)
convert prefix of s to double	strtod(s,&endp)
convert prefix of s (base b) to long	strtol(s,&endp,b)
same, but unsigned long	strtoul(s,&endp,b)

Storage Allocation

allocate storage	malloc(size), calloc(nobj,size)
change size of storage	newptr = realloc(ptr,size);
deallocate storage	free(ptr);

Array Functions

search array for key	bsearch(key,array,n,size,cmpf)
sort array ascending order	qsort(array,n,size,cmpf)

Time and Date Functions <time.h>

processor time used by program	clock()
Example. clock()/CLOCKS_PER_SEC is time in seconds	
current calendar time	time()
$time_2$-$time_1$ in seconds (double)	difftime($time_2$,$time_1$)
arithmetic types representing times	clock_t,time_t
structure type for calendar time comps	struct tm

tm_sec	seconds after minute
tm_min	minutes after hour
tm_hour	hours since midnight
tm_mday	day of month
tm_mon	months since January
tm_year	years since 1900
tm_wday	days since Sunday
tm_yday	days since January 1
tm_isdst	Daylight Savings Time flag

convert local time to calendar time	mktime(tp)
convert time in tp to string	asctime(tp)
convert calendar time in tp to local time	ctime(tp)
convert calendar time to GMT	gmtime(tp)
convert calendar time to local time	localtime(tp)
format date and time info	strftime(s,smax,"*format*",tp)
tp is a pointer to a structure of type tm	

Mathematical Functions <math.h>

Arguments and returned values are double

trig functions	sin(x), cos(x), tan(x)
inverse trig functions	asin(x), acos(x), atan(x)
arctan(y/x)	atan2(y,x)
hyperbolic trig functions	sinh(x), cosh(x), tanh(x)
exponentials & logs	exp(x), log(x), log10(x)
exponentials & logs (2 power)	ldexp(x,n), frexp(x,&e)
division & remainder	modf(x,ip), fmod(x,y)
powers	pow(x,y), sqrt(x)
rounding	ceil(x), floor(x), fabs(x)

Integer Type Limits <limits.h>

The numbers given in parentheses are typical values for the constants on a 32-bit Unix system, followed by minimum required values (if significantly different).

CHAR_BIT	bits in char	(8)
CHAR_MAX	max value of char	(SCHAR_MAX or UCHAR_MAX)
CHAR_MIN	min value of char	(SCHAR_MIN or 0)
SCHAR_MAX	max signed char	(+127)
SCHAR_MIN	min signed char	(−128)
SHRT_MAX	max value of short	(+32,767)
SHRT_MIN	min value of short	(−32,768)
INT_MAX	max value of int	(+2,147,483,647) (+32,767)
INT_MIN	min value of int	(−2,147,483,648) (−32,767)
LONG_MAX	max value of long	(+2,147,483,647)
LONG_MIN	min value of long	(−2,147,483,648)
UCHAR_MAX	max unsigned char	(255)
USHRT_MAX	max unsigned short	(65,535)
UINT_MAX	max unsigned int	(4,294,967,295) (65,535)
ULONG_MAX	max unsigned long	(4,294,967,295)

Float Type Limits <float.h>

The numbers given in parentheses are typical values for the constants on a 32-bit Unix system.

FLT_RADIX	radix of exponent rep	(2)
FLT_ROUNDS	floating point rounding mode	
FLT_DIG	decimal digits of precision	(6)
FLT_EPSILON	smallest x so $1.0\text{f} + x \neq 1.0\text{f}$	($1.1\text{E}-7$)
FLT_MANT_DIG	number of digits in mantissa	
FLT_MAX	maximum float number	($3.4\text{E}38$)
FLT_MAX_EXP	maximum exponent	
FLT_MIN	minimum float number	($1.2\text{E}-38$)
FLT_MIN_EXP	minimum exponent	
DBL_DIG	decimal digits of precision	(15)
DBL_EPSILON	smallest x so $1.0 + x \neq 1.0$	($2.2\text{E}-16$)
DBL_MANT_DIG	number of digits in mantissa	
DBL_MAX	max double number	($1.8\text{E}308$)
DBL_MAX_EXP	maximum exponent	
DBL_MIN	min double number	($2.2\text{E}-308$)
DBL_MIN_EXP	minimum exponent	

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