



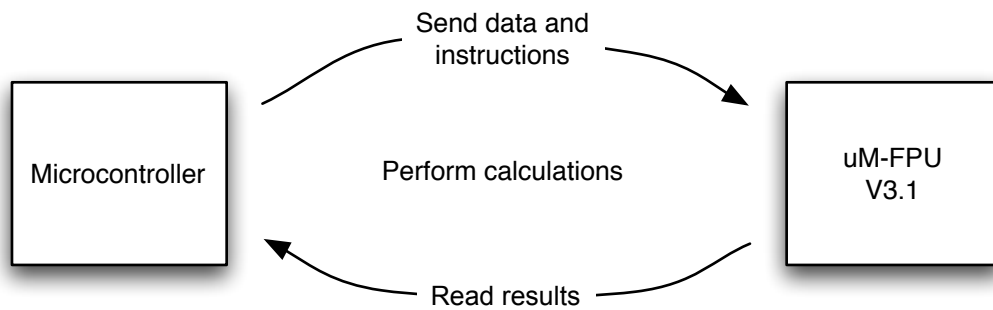
Micromega Corporation

uM-FPU V3.1 Instruction Set

32-bit Floating Point Coprocessor

Introduction

The uM-FPU V3.1 floating point coprocessor provides instructions for working with 32-bit IEEE 754 compatible floating point numbers and 32-bit long integer. A typical calculation involves sending instructions and data from the microcontroller to the uM-FPU, performing the calculation, and transferring the result back to the microcontroller.



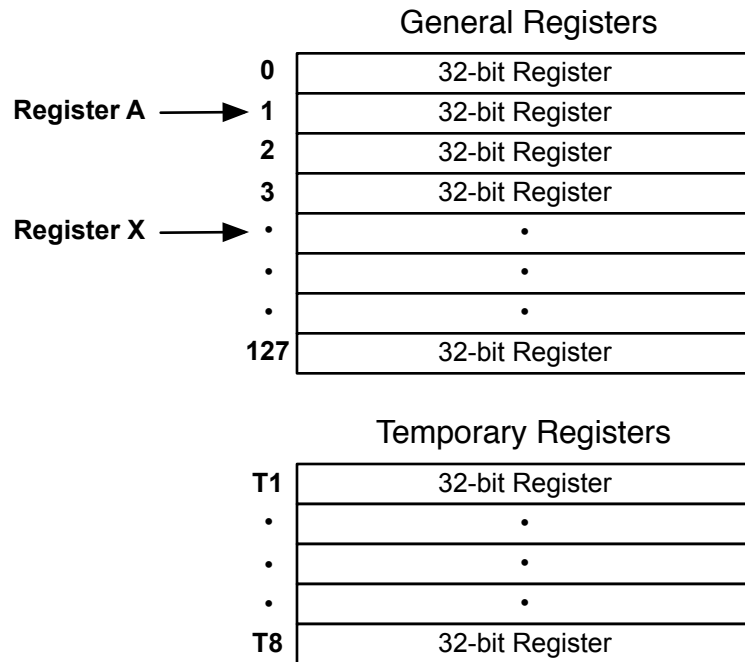
Instructions and data are sent to the uM-FPU using either a SPI or I²C interface. The uM-FPU V3.1 chip has a 256 byte instruction buffer which allows for multiple instructions to be sent. This improves the transfer times and allows the microcontroller to perform other tasks while the uM-FPU is performing a series of calculations. Prior to issuing any instruction that reads data from the uM-FPU, the Busy/Ready status must be checked to ensure that all instructions have been executed. If more than 256 bytes are required to specify a sequence of operations, the Busy/Ready status must be checked at least every 256 bytes to ensure that the instruction buffer does not overflow. See the datasheet for more detail regarding the SPI or I²C interfaces.

Instructions consist of a single opcode byte, optionally followed by additional data bytes. A detailed description of each instruction is provided later in this document, and a summary table is provided in Appendix A.

For instruction timing, see Appendix B of the uM-FPU V3.1 Datasheet.

uM-FPU Registers

The uM-FPU V3.1 contains 128 general purpose registers, and 8 temporary registers. All registers are 32-bits and can be used to store either floating point or long integer values. The general purpose registers are numbered 0 to 127, and can be directly accessed by the instruction set. The eight temporary registers are used by the `LEFT` and `RIGHT` parenthesis instructions to store temporary results and can't be accessed directly. Register 0 is normally only used to store temporary values, since it is modified by many instructions.



Register A

To perform arithmetic operations, one of the uM-FPU registers is selected as register A. Register A can be regarded as the accumulator or working register. Arithmetic instructions use the value in register A as an operand and store the results of an operation in register A. Any register can be selected as register A using the `SELECTA` instruction. For example,

```
SELECTA, 5    select register 5 as register A
```

Arithmetic instructions that only involve one register implicitly refer to register A. For example,

```
FNEG          negate the value in register A
```

Arithmetic instructions that use two registers will specify the second register as part of the instruction. For example,

```
FADD, 4       add the value of register 4 to register A
```

Register X

Register X is used to reference a series of sequential registers. The register X selection is automatically incremented to the next register in sequence by all instructions that use register X. Any register can be selected as register X using the `SELECTX` instruction. For example,

```
SELECTX, 16  select register 16 as register X
CLR X       clear register 16 (and increment register X)
CLR X       clear register 17 (and increment register X)
CLR X       clear register 18 (and increment register X)
```

Another example would be to use the `FWRITE X` and `READ X` instructions to store and retrieve blocks of data.

In this document the following abbreviations are used to refer to registers:

<code>reg[0]</code>	register 0
<code>reg[A]</code>	register A
<code>reg[X]</code>	register X
<code>reg[nn]</code>	any one of the 128 general purpose registers

Floating Point Instructions

The following descriptions provide a quick summary of the floating point instructions. Detailed descriptions are provided in the next section.

Basic Floating Point Instructions

Each of the basic floating point arithmetic instructions are provided in three different forms as shown in the table below. The FADD instruction will be used as an example to describe the three different forms of the instructions. The FADD, nn instruction allows any general purpose register to be added to register A. The register to be added to register A is specified by the byte following the opcode. The FADD0 instruction adds register 0 to register A and only requires the opcode. The FADDI instruction adds a small integer value the register A. The signed byte (-128 to 127) following the opcode is converted to floating point and added to register A. The FADD, nn instruction is most general, but the FADD0 and FADDI, bb instructions are more efficient for many common operations.

Register nn	Register 0	Immediate value	Description
FSET, nn	FSET0	FSETI, bb	Set
FADD, nn	FADD0	FADDI, bb	Add
FSUB, nn	FSUB0	FSUBI, bb	Subtract
FSUBR, nn	FSUBR0	FSUBRI, bb	Subtract Reverse
FMUL, nn	FMUL0	FMULI, bb	Multiply
FDIV, nn	FDIV0	FDIVI, bb	Divide
FDIVR, nn	FDIVR0	FDIVRI, bb	Divide Reverse
FPOW, nn	FPOW0	FPOWI, bb	Power
FCMP, nn	FCMP0	FCMPI, bb	Compare

Loading Floating Point Values

The following instructions are used to load data from the microprocessor and store it on the uM-FPU as 32-bit floating point values.

FWRITE, nn, b1, b2, b3, b4	Write 32-bit floating point value to reg[nn]
FWRITEA, b1, b2, b3, b4	Write 32-bit floating point value to reg[A]
FWRITEX, b1, b2, b3, b4	Write 32-bit floating point value to reg[X]
FWRITE0, b1, b2, b3, b4	Write 32-bit floating point value to reg[0]
WRBLK, tc, t1...tn	Write multiple 32-bit values
ATOF, aa...00	Convert ASCII string to floating point value and store in reg[0]
LOADBYTE, bb	Convert signed byte to floating point and store in reg[0]
LOADUBYTE, bb	Convert unsigned byte to floating point and store in reg[0]
LOADWORD, b1, b2	Convert signed 16-bit value to floating point and store in reg[0]
LOADUWORD, b1, b2	Convert unsigned 16-bit value to floating point and store in reg[0]
LOADE	Load the value of e (2.7182818) to reg[0]
LOADPI	Load the value of pi (3.1415927) to reg[0]

Reading Floating Point Values

The following instructions are used to read floating point values from the uM-FPU.

FREAD, nn [b1, b2, b3, b4]	Return 32-bit floating point value from reg[nn]
FREADA [b1, b2, b3, b4]	Return 32-bit floating point value from reg[A]
FREADX [b1, b2, b3, b4]	Return 32-bit floating point value from reg[X]
FREAD0 [b1, b2, b3, b4]	Return 32-bit floating point value from reg[0]
RDBLK, tc [t1...tn]	Read multiple 32-bit values
FTOA, bb	Convert floating point to ASCII string (use READSTR to read string)

Additional Floating Point Instructions

FSTATUS, nn	LOG	ACOS	ROUND
FSTATUSA	LOG10	ATAN	FMIN, nn
FCMP2, nn, mm	EXP	ATAN2, nn	FMAX, nn
FNEG	EXP10	DEGREES	FCNV, bb
FABS	SIN	RADIANS	FMAC, nn, mm
FINV	COS	FMOD	FMSC, nn, mm
SQRT	TAN	FLOOR	FRACTION
ROOT, nn	ASIN	CEIL	

Matrix Instructions

SELECTMA, nn, b1, b2	Select matrix A at register nn of size b1 rows x b2 columns
SELECTMB, nn, b1, b2	Select matrix B at register nn of size b1 rows x b2 columns
SELECTMC, nn, b1, b2	Select matrix C at register nn of size b1 rows x b2 columns
LOADMA, b1, b2	Load reg[0] with value from matrix A row b1, column b2
LOADMB, b1, b2	Load reg[0] with value from matrix B row b1, column b2
LOADMC, b1, b2	Load reg[0] with value from matrix C row b1, column b2
SAVEMA, b1, b2	Store reg[0] value to matrix A row b1, column b2
SAVEMB, b1, b2	Store reg[0] value to matrix A row b1, column b2
SAVEMC, b1, b2	Store reg[0] value to matrix A row b1, column b2
MOP, bb	Perform matrix operation

Fast Fourier Transform Instruction

FFT, action	Perform Fast Fourier Transform operation
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Conversion Instructions

FLOAT	Convert reg[A] from long integer to floating point
FIX	Convert reg[A] from floating point to long integer
FIXR	Convert reg[A] from floating point to long integer (with rounding)
FSPLIT	reg[A] = integer value, reg[0] = fractional value

Long Integer Instructions

The following descriptions provide a quick summary of the long integer instructions. Detailed descriptions are provided in the next section.

Basic Long Integer Instructions

Each of the basic long integer arithmetic instructions are provided in three different forms as shown in the table below. The LADD instruction will be used as an example to describe the three different forms of the instructions. The LADD, nn instruction allows any general purpose register to be added to register A. The register to be added to register A is specified by the byte following the opcode. The LADD0 instruction adds register 0 to register A and only requires the opcode. The LADDI instruction adds a small integer value the register A. The signed byte (-128 to 127) following the opcode is converted to a long integer and added to register A. The LADD, nn instruction is most general, but the LADD0 and LADDI, bb instructions are more efficient for many common operations.

Register nn	Register 0	Immediate value	Description
LSET, nn	LSET0	LSETI, bb	Set
LADD, nn	LADD0	LADDI, bb	Add
LSUB, nn	LSUB0	LSUBI, bb	Subtract
LMUL, nn	LMUL0	LMULI, bb	Multiply
LDIV, nn	LDIV0	LDIVI, bb	Divide
LCMP, nn	LCMP0	LCMPI, bb	Compare
LUDIV, nn	LUDIV0	LUDIVI, bb	Unsigned Divide
LUCMP, nn	LUCMP0	LUCMPI, bb	Unsigned Compare
LTST, nn	LTST0	LTSTI, bb	Test Bits

Loading Long Integer Values

The following instructions are used to load data from the microprocessor and store it on the uM-FPU as 32-bit long integer values.

LWRITE, nn, b1, b2, b3, b4	Write 32-bit long integer value to reg[nn]
LWRITEA, b1, b2, b3, b4	Write 32-bit long integer value to reg[A]
LWRITEX, b1, b2, b3, b4	Write 32-bit long integer value to reg[X]
LWRITE0, b1, b2, b3, b4	Write 32-bit long integer value to reg[0]
WRBLK, tc, t1...tn	Write multiple 32-bit values
ATOL, aa...00	Convert ASCII string to long integer value and store in reg[0]
LONGBYTE, bb	Convert signed byte to long integer and store in reg[0]
LONGUBYTE, bb	Convert unsigned byte to long integer and store in reg[0]
LONGWORD, b1, b2	Convert signed 16-bit value to long integer and store in reg[0]
LONGUWORD, b1, b2	Convert unsigned 16-bit value to long integer and store in reg[0]

Reading Long Integer Values

The following instructions are used to read long integer values from the uM-FPU.

LREAD, nn [b1, b2, b3, b4]	Returns 32-bit long integer value from reg[nn]
LREADA [b1, b2, b3, b4]	Returns 32-bit long integer value from reg[A]
LREADX [b1, b2, b3, b4]	Returns 32-bit long integer value from reg[X]
LREAD0 [b1, b2, b3, b4]	Returns 32-bit long integer value from reg[0]
RDBLK, tc [t1...tn]	Read multiple 32-bit values
LREADBYTE [b1]	Returns 8-bit byte from reg[A]
LREADWORD [b1, b2]	Returns 16-bit value from reg[A]
LTOA, bb	Convert long integer to ASCII string (use READSTR to read string)

Additional Long Integer Instructions

LSTATUS, nn	LNEG	LNOT	LSHIFT, nn
LSTATUSA	LABS	LAND, nn	LMIN, nn
LCMP2, nn, mm	LINC, nn	LOR, nn	LMAX, nn
LUCMP2, nn, mm	LDEC, nn	LXOR, nn	

General Purpose Instructions

RESET	COPYI, bb, nn	LOADIND, nn	SYNC
NOP	COPYA, nn	SAVEIND, nn	READSTATUS
SELECTA, nn	COPYX, nn	INDA	READSTR
SELECTX, nn	LOAD, nn	INDX	VERSION
CLR, nn	LOADA	SWAP, nn, mm	IEEEMODE
CLRA	LOADX	SWAPA, nn	PICMODE
CLRX	ALOADX	LEFT	CHECKSUM
COPY, mm, nn	XSAVE, nn	RIGHT	READVAR, bb
COPY0, nn	XSAVEA	SETOUT, bb	SETSTATUS, bb

Special Purpose Instructions

Stored Function Instructions

FCALL, fn	Call Flash user-defined function
EECALL, fn	Call EPROM user-defined function
RET	Return from user-defined function
RET, cc	Conditional return from user-defined function
BRA, bb	Unconditional branch inside user-defined function
BRA, cc, bb	Conditional branch inside user-defined function
JMP, b1, b2	Unconditional jump inside user-defined function
JMP, cc, b1, b2	Conditional jump inside user-defined function
GOTO, nn	Computed goto
TABLE, tc, t1...tn	Table lookup
FTABLE, cc, tc, t1...tn	Floating point reverse table lookup
LTABLE, cc, tc, t1...tn	Long integer reverse table lookup
POLY, tc, t1...tn	N th order polynomial

Analog to Digital Conversion Instructions

ADCMODE, bb	Select A/D trigger mode
ADCTRIG	Manual A/D trigger
ADCSCALE, bb	Set A/D floating point scale factor
ADCLONG, bb	Get raw long integer A/D reading
ADCLOAD, bb	Get scaled floating point A/D reading
ADCWAIT	Wait for A/D conversion to complete

Timer Instructions

TIMESSET	Set timers
TIMELONG	Get time in seconds
TICKLONG	Get time in milliseconds

EEPROM Instructions

EESAVE, mm, nn	Save reg[nn] value to EEPROM
EESAVEA, nn	Save reg[A] to EEPROM
EELOAD, mm, nn	Load reg[nn] with EEPROM value
EELOADA, nn	Load reg[A] with EEPROM value
EEWRITE, nn, bc, b1..bn	Write byte string to EEPROM

External Input Instructions

EXTSET	Set external input counter
EXTLONG	Get external input counter
EXTWAIT	Wait for next external input pulse

String Manipulation Instructions

STRSET, aa...00	Copy string to string buffer
STRSEL, bb, bb	Set string selection point
STRINC	Increment string selection point
STRDEC	Decrement string selection point
STRINS, aa...00	Insert string at selection point
STRBYTE	Insert byte at selection point
STRCMP, aa...00	Compare string with string selection
STRFIND, aa...00	Find string
STRFCHR, aa...00	Set field delimiters
STRFIELD, bb	Find field
STRTOF	Convert string selection to floating point
STRTOL	Convert string selection to long integer
FTOA, bb	Convert floating point value to string
LTOA, bb	Convert long integer value to string
READSTR	Read entire string buffer
READSEL	Read string selection

Serial Input/Output

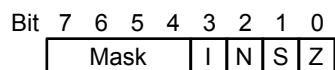
SEROUT, bb	Serial Output
SEROUT, bb, bd	Serial Output
SEROUT, bb, aa...00	Serial Output
SERIN, bb	Serial Input

Debugging Instructions

BREAK	Debug breakpoint
TRACEOFF	Turn debug trace off
TRACEON	Turn debug trace on
TRACESTR, aa...00	Display string in debug trace
TRACEREG, nn	Display contents of register in debug trace

Test Conditions

Several of the stored function instructions use a test condition byte. The test condition is an 8-bit byte that defines the expected state of the internal status byte. The upper nibble is used as a mask to determine which status bits to check. A status bit will only be checked if the corresponding mask bit is set to 1. The lower nibble specifies the expected value for each of the corresponding status bits in the internal status byte. A test condition is considered to be true if all of the masked test bits have the same value as the corresponding bits in the internal status byte. There are two special cases: 0x60 evaluates as greater than or equal, and 0x62 evaluates as less than or equal.



Bits 7:4 Mask bits

- Bit 7 Mask bit for Infinity
- Bit 6 Mask bit for NaN
- Bit 5 Mask bit for Sign
- Bit 4 Mask bit for Zero

Bits 3:0 Test bits

- Bit 3 Expected state of Infinity status bit
- Bit 2 Expected state of NaN status bit
- Bit 1 Expected state of Sign status bit
- Bit 0 Expected state of Zero status bit

The uM-FPU V3 IDE assembler has built-in symbols for the most common test conditions. They are as follows:

<i>Assembler Symbol</i>	<i>Test Condition</i>	<i>Description</i>
Z	0x51	Zero
EQ	0x51	Equal
NZ	0x50	Not Zero
NE	0x50	Not Equal
LT	0x72	Less Than
LE	0x62	Less Than or Equal
GT	0x70	Greater Than
GE	0x60	Greater Than or Equal
PZ	0x71	Positive Zero
MZ	0x73	Negative Zero
INF	0xC8	Infinity
FIN	0xC0	Finite
PINF	0xE8	Positive Infinity
MINF	0xEA	Minus infinity
NAN	0x44	Not-a-Number (NaN)
TRUE	0x00	True
FALSE	0xFF	False

uM-FPU V3.1 Instruction Reference

ACOS **Arc Cosine**

Opcode: 4B

Description: $\text{reg}[A] = \text{acos}(\text{reg}[A])$
Calculates the arc cosine (inverse cosine) of an angle in the range 0.0 through pi. The initial value is contained in register A, and the result is stored in register A.

Special Cases: • if $\text{reg}[A]$ is NaN or its absolute value is greater than 1, then the result is NaN

ADCLOAD **Load scaled A/D value**

Opcode: D5 nn where: nn is the A/D channel number

Description: $\text{reg}[0] = \text{float}(\text{ADCchannel}[\text{nn}]) * \text{ADCscale}[\text{nn}]$
Wait until the A/D conversion is complete, then load register 0 with the reading from channel nn of the A/D converter. The 12-bit value is converted to floating point, multiplied by a scale value, and stored in register 0. The instruction buffer should be empty when this instruction is executed. If there are other instructions in the instruction buffer, or another instruction is sent before the ADCLOAD instruction has been completed, the wait will terminate and the previous value for the selected channel will be used.

ADCLONG **Load raw A/D value**

Opcode: D4 nn where: nn is the A/D channel number

Description: $\text{reg}[0] = \text{ADCchannel}[\text{nn}], \text{status} = \text{longstatus}(\text{reg}[0])$
Wait until the A/D conversion is complete, then load register 0 with the reading from channel nn of the A/D converter. The 12-bit value is converted to a long integer and stored in register 0. The instruction buffer should be empty when this instruction is executed. If there are other instructions in the instruction buffer, or another instruction is sent before the ADCLONG instruction has been completed, the wait will terminate and the previous value for the selected channel will be used.

ADCMODE **Set ADC trigger mode**

Opcode: D1 nn where: nn is the trigger mode

Description: Set the trigger mode of the A/D converter. The value nn is interpreted as follows:

Bit 7 6 5 4 3 2 1 0

7	6	5	4	3	2	1	0
Trigger				Repeat			

Bits 7:4 Trigger Type

- 0 - disable A/D conversions
- 1 - manual trigger
- 2 - external input trigger
- 3 - timer trigger, the value in register 0 specifies the period in microseconds (the minimum period is 100 microseconds)

Bits 3:0 Repeat Count

The number of samples taken for each trigger is equal to the repeat count plus one. (e.g. a value of 0 will result in one sample per trigger)

Examples:	ADCMODE, 0x10	set manual trigger with 1 sample per trigger
	ADCMODE, 0x24	set external trigger with 5 samples per trigger
	LOADWORD, 1000 ADCMODE, 0x30	set timer trigger every 1000 usec, with 1 sample per trigger
	ADCMODE, 0	disable A/D conversions

ADCSCALE Set scale multiplier for ADC

Opcode: D3 nn where: nn is the A/D channel number

Description: ADCscale[nn] = reg[0]
Set the scale value for channel nn to the floating point value in register 0. The scale value for all channels is set to 1.0 at device reset or when the ADCMODE mode is set to disable A/D conversions.

ADCTRIG Trigger an A/D conversion

Opcode: D2

Description: Trigger an A/D conversion. If a conversion is already in progress the trigger is ignored. This is normally used only when the ADCMODE is set for manual trigger.

ADCWAIT Wait for next A/D sample

Opcode: D6

Description: Wait until the next A/D sample is ready. When ADCMODE is set for manual trigger, this instruction can be used to wait until the conversion started by the last ADCTRIG is done. ADCLONG and ADCLOAD automatically wait until the next sample is ready. If the ADCMODE is set for timer trigger or external input trigger, this instruction will wait until the next full conversion is completed. The instruction buffer should be empty when this instruction is executed. If there are other instructions in the instruction buffer, or another instruction is sent before the ADCWAIT instruction has completed, the wait will terminate.

ALOADX Load register A from register X

Opcode: 0D

Description: reg[A] = reg[X], X = X + 1
Set register A to the value of register X, and increment X to select the next register in sequence.

Special Cases: • the X register will not increment past the maximum register value of 127

ASIN Arc Sine

Opcode: 4A

Description: reg[A] = asin(reg[A])
Calculates the arc sine (inverse sine) of an angle in the range of $-\pi/2$ through $\pi/2$. The initial

value is contained in register A, and the result is stored in register A.

- Special Cases:
- if reg[A] is NaN or its absolute value is greater than 1, then the result is NaN
 - if reg[A] is 0.0, then the result is a 0.0
 - if reg[A] is -0.0, then the result is -0.0

ATAN **Arc Tangent**

Opcode: 4C

Description: $\text{reg}[A] = \text{atan}(\text{reg}[A])$
Calculates the arc tangent (inverse tangent) of an angle in the range of $-\pi/2$ through $\pi/2$. The initial value is contained in register A, and the result is stored in register A.

- Special Cases:
- if reg[A] is NaN, then the result is NaN
 - if reg[A] is 0.0, then the result is a 0.0
 - if reg[A] is -0.0, then the result is -0.0

ATAN2 **Arc Tangent (two arguments)**

Opcode: 4D nn where: nn is a register number

Description: $\text{reg}[A] = \text{atan}(\text{reg}[A] / \text{reg}[nn])$
Calculates the arc tangent of an angle in the range of $-\pi/2$ through $\pi/2$. The initial value is determined by dividing the value in register A by the value in register nn, and the result is returned in register A. This instruction is used to convert rectangular coordinates (reg[A], reg[nn]) to polar coordinates (r, theta). The value of theta is returned in register A.

- Special Cases:
- if reg[A] or reg[nn] is NaN, then the result is NaN
 - if reg[A] is 0.0 and reg[nn] > 0, then the result is 0.0
 - if reg[A] > 0 and finite, and reg[nn] is +inf, then the result is 0.0
 - if reg[A] is -0.0 and reg[nn] > 0, then the result is -0.0
 - if reg[A] < 0 and finite, and reg[nn] is +inf, then the result is -0.0
 - if reg[A] is 0.0 and reg[nn] < 0, then the result is pi
 - if reg[A] > 0 and finite, and reg[nn] is -inf, then the result is pi
 - if reg[A] is -0.0, and reg[nn] < 0, then the result is -pi
 - if reg[A] < 0 and finite, and reg[nn] is -inf, then the result is -pi
 - if reg[A] > 0, and reg[nn] is 0.0 or -0.0, then the result is pi/2
 - if reg[A] is +inf, and reg[nn] is finite, then the result is pi/2
 - if reg[A] < 0, and reg[nn] is 0.0 or -0.0, then the result is -pi/2
 - if reg[A] is -inf, and reg[nn] is finite, then the result is -pi/2
 - if reg[A] is +inf, and reg[nn] is +inf, then the result is pi/4
 - if reg[A] is +inf, and reg[nn] is -inf, then the result is 3*pi/4
 - if reg[A] is -inf, and reg[nn] is +inf, then the result is -pi/4
 - if reg[A] is -inf, and reg[nn] is -inf, then the result is -3*pi/4

ATOF **Convert ASCII string to floating point**

Opcode: 1E aa...00 where: aa...00 is a zero-terminated ASCII string

Description: Converts a zero terminated ASCII string to a 32-bit floating point number and stores the result in register 0. The string to convert is sent immediately following the opcode. The string can be

- Special Cases:
- if is NaN, then the result is NaN
 - if reg[A] is +infinity or -infinity, then the result is +infinity or -infinity
 - if reg[A] is 0.0 or -0.0, then the result is 0.0 or -0.0
 - if reg[A] is less than zero but greater than -1.0, then the result is -0.0

CHECKSUM Calculate checksum for uM-FPU code

Opcode: F6

Description: A checksum is calculated for the uM-FPU code and user-defined functions stored in Flash. The checksum value is stored in register 0. This can be used as a diagnostic test for confirming the state of a uM-FPU chip.

CLR Clear register

Opcode: 03 nn where: nn is a register number

Description: reg[nn] = 0, status = longstatus(reg[nn])
Set the value of register nn to zero.

CLR0 Clear register 0

Opcode: 06

Description: reg[0] = 0, status = longstatus(reg[0])
Set the value of register 0 to zero.

CLRA Clear register A

Opcode: 04

Description: reg[A] = 0, status = longstatus(reg[A])
Set the value of register A to zero.

CLR X Clear register X

Opcode: 05

Description: reg[X] = 0, status = longstatus(reg[X]), X = X + 1
Set the value of register A to zero, and increment X to select the next register in sequence.

Special Cases: • the X register will not increment past the maximum register value of 127

COPY Copy registers

Opcode: 07 mm nn where: mm and nn are register numbers

Description: reg[nn] = reg[mm], status = longstatus(reg[nn])
The value of register mm is copied to register nn.

COPYA Copy register A

Opcode: 08 nn where: nn is a register number

Description: reg[nn] = reg[A], status = longstatus(reg[A])
Set register nn to the value of register A.

EELoad **Load register nn with value from EEPROM**

Opcode: DC nn ee where: nn is a register number
 ee is the EEPROM address slot.

Description: $reg[nn] = EEPROM[ee]$, status = longstatus(reg[nn])
Register nn is set to the value in EEPROM at the address slot specified by ee. EEPROM address slots are 4 bytes in length (32-bits).

EELoada **Load register A with value from EEPROM**

Opcode: DD ee where: ee is the EEPROM address slot

Description: $reg[A] = EEPROM[ee]$, status = longstatus(reg[A])
Register A is set to the value in EEPROM at the address slot specified by ee. EEPROM address slots are 4 bytes in length (32-bits).

EESave **Save register nn to EEPROM**

Opcode: DA nn ee where: nn is a register number
 ee is the EEPROM address slot

Description: $EEPROM[ee] = reg[nn]$
The value in register nn is stored in EEPROM at the address slot specified by ee. EEPROM address slots are 4 bytes in length (32-bits).

EESaveA **Save register A to EEPROM**

Opcode: DB ee where: ee is the EEPROM address slot

Description: $EEPROM[ee] = reg[A]$
The value in register A is stored in EEPROM at the address slot specified by ee. EEPROM address slots are 4 bytes in length (32-bits).

EEWrite **Write bytes to EEPROM**

Opcode: DE ee bc bb...bb
 where: ee is the EEPROM address slot
 bc is the number of bytes
 bb...bb is a string of bytes

Description: Bytes are stored sequentially in EEPROM starting at the EEPROM[ee] address slot. The number of bytes specified by bc are copied to the EEPROM starting at address slot ee. Address slots are 4 bytes in length (32-bits). Consecutive address slots are used to store the specified number of bytes. This instruction can be used to store multiple values to the EEPROM address slots or to dynamically store a user-defined function.

EXP **The value e raised to a power**

Opcode: 45

Description: $reg[A] = exp(reg[A])$
Calculates the value of e (2.7182818) raised to the power of the floating point value in register A. The result is stored in register A.

Special Cases: • if reg[A] is NaN, then the result is NaN
 • if reg[A] is +infinity or greater than 88, then the result is +infinity

- if reg[A] is $-\infty$ or less than -88, then the result is 0.0

EXP10 The value 10 raised to a power

Opcode: 46

Description: $\text{reg}[A] = \exp_{10}(\text{reg}[A])$
 Calculates the value of 10 raised to the power of the floating point value in register A. The result is stored in A.

Special Cases: • if reg[A] is NaN, then the result is NaN
 • if reg[A] is $+\infty$ or greater than 38, then the result is $+\infty$
 • if reg[A] is $-\infty$ or less than -38, then the result is 0.0

EXTLONG Load value of external input counter

Opcode: E1

Description: $\text{reg}[0] = \text{external input count}$, $\text{status} = \text{longstatus}(\text{reg}[0])$
 Load register 0 with the external input count.

EXTSET Set value of external input counter

Opcode: E0

Description: $\text{external input count} = \text{reg}[0]$
 The external input count is set to the value in register 0. If the value is -1 (0xFFFFFFFF) the external input counter is disabled.

EXTWAIT Wait for next external input pulse

Opcode: E2

Description: Wait for the next external input to occur. The instruction buffer should be empty when this instruction is executed. If there are other instructions in the instruction buffer, or another instruction is sent before the EXTWAIT instruction has completed, the wait will terminate.

FABS Floating point absolute value

Opcode: 3F

Description: $\text{reg}[A] = |\text{reg}[A]|$
 Sets the floating value in register A to the absolute value.

Special Cases: • if reg[A] is NaN, then the result is NaN

FADD Floating point add

Opcode: 21 nn where: nn is a register number

Description: $\text{reg}[A] = \text{reg}[A] + \text{reg}[nn]$
 The floating point value in register nn is added to the floating point value in register A and the result is stored in register A.

Special Cases: • if either value is NaN, then the result is NaN

- if one value is +infinity and the other is -infinity, then the result is NaN
- if one value is +infinity and the other is not -infinity, then the result is +infinity
- if one value is -infinity and the other is not +infinity, then the result is -infinity

FADD0 Floating point add register 0

Opcode: 2A

Description: $reg[A] = reg[A] + reg[0]$
 The floating point value in register 0 is added to the floating point value in register A and the result is stored in register A.

- Special Cases:
- if either value is NaN, then the result is NaN
 - if one value is +infinity and the other is -infinity, then the result is NaN
 - if one value is +infinity and the other is not -infinity, then the result is +infinity
 - if one value is -infinity and the other is not +infinity, then the result is -infinity

FADDI Floating point add immediate value

Opcode: 33 bb where: bb is a signed byte value (-128 to 127)

Description: $reg[A] = reg[A] + float(bb)$
 The signed byte value is converted to floating point and added to the value in register A and the result is stored in register A.

- Special Cases:
- if reg[A] is NaN, then the result is NaN
 - if reg[A] is +infinity, then the result is +infinity
 - if reg[A] is -infinity, then the result is -infinity

FCALL Call Flash memory user defined function

Opcode: 7E fn where: fn is the function number

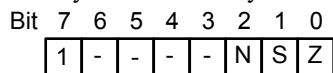
Description: The user defined function nn, stored in Flash memory, is executed. Up to 16 levels of nesting is supported for function calls. The uM-FPU IDE provides support for programming user defined functions in Flash memory using the serial debug monitor (see datasheet).

Special Cases: If the selected user function is not defined, register 0 is set to NaN, and execution continues.

FCMP Floating point compare

Opcode: 28 nn where: nn is a register number

Description: $status = compare(reg[A] - reg[nn])$
 Compares the floating point value in register A with the value in register nn and sets the internal status byte. The status byte can be read with the READSTATUS instruction. It is set as follows:



- Bit 2 Not-a-Number Set if either value is not a valid number
- Bit 1 Sign Set if $reg[A] < reg[nn]$
- Bit 0 Zero Set if $reg[A] = reg[nn]$
 If neither Bit 0 or Bit 1 is set, $reg[A] > reg[nn]$

FCMP0 Floating point compare register 0

Opcode: 31

Description: $status = compare(reg[A] - reg[0])$

Compares the floating point value in register A with the value in register 0 and sets the internal status byte. The status byte can be read with the READSTATUS instruction. It is set as follows:

Bit 7	6	5	4	3	2	1	0
1	-	-	-	-	N	S	Z

Bit 2 Not-a-Number Set if either value is not a valid number

Bit 1 Sign Set if $reg[A] < reg[0]$ Bit 0 Zero Set if $reg[A] = reg[0]$ If neither Bit 0 or Bit 1 is set, $reg[A] > reg[0]$ **FCMP2 Floating point compare**

Opcode: 3D nn mm where: nn and mm are register numbers

Description: $status = compare(reg[nn] - reg[mm])$

Compares the floating point value in register nn with the value in register mm and sets the internal status byte. The status byte can be read with the READSTATUS instruction. It is set as follows:

Bit 7	6	5	4	3	2	1	0
1	-	-	-	-	N	S	Z

Bit 2 Not-a-Number Set if either value is not a valid number

Bit 1 Sign Set if $reg[mm] < reg[nn]$ Bit 0 Zero Set if $reg[mm] = reg[nn]$ If neither Bit 0 or Bit 1 is set, $reg[mm] > reg[nn]$ **FCMPI Floating point compare immediate value**

Opcode: 3A bb where: bb is a signed byte value (-128 to 127)

Description: $status = compare(reg[A] - float(bb))$

The signed byte value is converted to floating point and compared to the floating point value in register A. The status byte can be read with the READSTATUS instruction. It is set as follows:

Bit 7	6	5	4	3	2	1	0
1	-	-	-	-	N	S	Z

Bit 2 Not-a-Number Set if either value is not a valid number

Bit 1 Sign Set if $reg[A] < float(bb)$ Bit 0 Zero Set if $reg[A] = float(bb)$ If neither Bit 0 or Bit 1 is set, $reg[A] > float(bb)$ **FCNV Floating point conversion**

Opcode: 56 bb where: bb is an unsigned byte value (0 to 255)

Description: $reg[A] = \text{the converted value of } reg[A]$

Convert the value in register A using the conversion specified by the byte bb and store the result in register A. The conversions are as follows:

0 Fahrenheit to Celsius

1 Celsius to Fahrenheit

2 inches to millimeters

3	millimeters to inches
4	inches to centimeters
5	centimeters to inches
6	inches to meters
7	meters to inches
8	feet to meters
9	meters to feet
10	yards to meters
11	meters to yards
12	miles to kilometers
13	kilometers to miles
14	nautical miles to meters
15	meters to nautical miles
16	acres to meters ²
17	meters ² to acres
18	ounces to grams
19	grams to ounces
20	pounds to kilograms
21	kilograms to pounds
22	US gallons to liters
23	liters to US gallons
24	UK gallons to liters
25	liters to UK gallons
26	US fluid ounces to milliliters
27	milliliters to US fluid ounces
28	UK fluid ounces to milliliters
29	milliliters to UK fluid ounces
30	calories to Joules
31	Joules to calories
32	horsepower to watts
33	watts to horsepower
34	atmospheres to kilopascals
35	kilopascals to atmospheres
36	mmHg to kilopascals
37	kilopascals to mmHg
38	degrees to radians
39	radians to degrees

Special Cases: • if the byte value *bb* is greater than 39, the value of register *A* is unchanged.

FDIV Floating point divide

Opcode: 25 *nn* where: *nn* is a register number

Description: $\text{reg}[A] = \text{reg}[A] / \text{reg}[nn]$
 The floating point value in register *A* is divided by the floating point value in register *nn* and the result is stored in register *A*.

Special Cases: • if either value is NaN, then the result is NaN
 • if both values are zero or both values are infinity, then the result is NaN

- if reg[nn] is zero and reg[A] is not zero, then the result is infinity
- if reg[nn] is infinity, then the result is zero

FDIV0 Floating point divide by register 0

Opcode: 2E

Description: $\text{reg}[A] = \text{reg}[A] / \text{reg}[0]$
 The floating point value in register A is divided by the floating point value in register 0 and the result is stored in register A.

- Special Cases:
- if either value is NaN, then the result is NaN
 - if both values are zero or both values are infinity, then the result is NaN
 - if reg[0] is zero and reg[A] is not zero, then the result is infinity
 - if reg[0] is infinity, then the result is zero

FDIVI Floating point divide by immediate value

Opcode: 37 bb where: bb is a signed byte value (-128 to 127)

Description: $\text{reg}[A] = \text{reg}[A] / \text{float}(\text{bb})$
 The signed byte value is converted to floating point and the value in register A is divided by the converted value and the result is stored in register A.

- Special Cases:
- if reg[A] is NaN, then the result is NaN
 - if both values are zero, then the result is NaN
 - if the value bb is zero and reg[A] is not zero, then the result is infinity

FDIVR Floating point divide (reversed)

Opcode: 26 nn where: nn is a register number

Description: $\text{reg}[A] = \text{reg}[\text{nn}] / \text{reg}[A]$
 The floating point value in register nn is divided by the floating point value in register A and the result is stored in register A.

- Special Cases:
- if either value is NaN, then the result is NaN
 - if both values are zero or both values are infinity, then the result is NaN
 - if reg[A] is zero and reg[nn] is not zero, then the result is infinity
 - if reg[A] is infinity, then the result is zero

FDIVR0 Floating point divide register 0 (reversed)

Opcode: 2F

Description: $\text{reg}[A] = \text{reg}[0] / \text{reg}[A]$
 The floating point value in register 0 is divided by the floating point value in register A and the result is stored in register A.

- Special Cases:
- if either value is NaN, then the result is NaN
 - if both values are zero or both values are infinity, then the result is NaN
 - if reg[A] is zero and reg[0] is not zero, then the result is infinity
 - if reg[A] is infinity, then the result is zero
-

FDIVRI Floating point divide by immediate value (reversed)

Opcode: 38 bb where: bb is a signed byte value (-128 to 127)

Description: $\text{reg}[A] = \text{float}(\text{bb}) / \text{reg}[A]$
The signed byte value is converted to floating point and divided by the value in register A. The result is stored in register A.Special Cases:

- if $\text{reg}[A]$ is NaN, then the result is NaN
- if both values are zero, then the result is NaN
- if the value $\text{reg}[A]$ is zero and $\text{float}(\text{bb})$ is not zero, then the result is infinity

FFT Fast Fourier Transform

Opcode: 6F bb where: bb specifies the type of operation

Description: The type of operation is specified as follows:
0 first stage
1 next stage
2 next level
3 next block
+4 pre-processing bit reverse sort
+8 pre-processing for inverse FFT
+16 post-processing for inverse FFT

The data for the FFT instruction is stored in matrix A as a Nx2 matrix, where N must be a power of two. The data points are specified as complex numbers, with the real part stored in the first column and the imaginary part stored in the second column. If all data points can be stored in the matrix (maximum of 64 points if all 128 registers are used), the Fast Fourier Transform can be calculated with a single instruction. If more data points are required than will fit in the matrix, the calculation must be done in blocks. The algorithm iteratively writes the next block of data, executes the FFT instruction for the appropriate stage of the FFT calculation, and reads the data back to the microcontroller. This proceeds in stages until all data points have been processed. See application notes for more details.

FINV Floating point inverse

Opcode: 40

Description: $\text{reg}[A] = 1 / \text{reg}[A]$
The inverse of the floating point value in register A is stored in register A.Special Cases:

- if $\text{reg}[A]$ is NaN, then the result is NaN
- if $\text{reg}[A]$ is zero, then the result is infinity
- if $\text{reg}[A]$ is infinity, then the result is zero

FIX Convert floating point to long integer

Opcode: 61

Description: $\text{reg}[A] = \text{fix}(\text{reg}[A])$
Converts the floating point value in register A to a long integer value.

Special Cases:

- if reg[A] is NaN, then the result is zero
- if reg[A] is +infinity or greater than the maximum signed long integer, then the result is the maximum signed long integer (decimal: 2147483647, hex: \$7FFFFFFF)
- if reg[A] is -infinity or less than the minimum signed long integer, then the result is the minimum signed long integer (decimal: -2147483648, hex: \$80000000)

FIXR Convert floating point to long integer with rounding

Opcode: 62

Description: $\text{reg}[A] = \text{fix}(\text{round}(\text{reg}[A]))$
 Converts the floating point value in register A to a long integer value with rounding.

Special Cases:

- if reg[A] is NaN, then the result is zero
- if reg[A] is +infinity or greater than the maximum signed long integer, then the result is the maximum signed long integer (decimal: 2147483647, hex: \$7FFFFFFF)
- if reg[A] is -infinity or less than the minimum signed long integer, then the result is the minimum signed long integer (decimal: -2147483648, hex: \$80000000)

FLOAT Convert long integer to floating point

Opcode: 60

Description: $\text{reg}[A] = \text{float}(\text{reg}[A])$
 Converts the long integer value in register A to a floating point value.

FLOOR Floor

Opcode: 51

Description: $\text{reg}[A] = \text{floor}(\text{reg}[A])$
 Calculates the floating point value equal to the nearest integer that is less than or equal to the floating point value in register A. The result is stored in register A.

Special Cases:

- if reg[A] is NaN, then the result is NaN
- if reg[A] is +infinity or -infinity, then the result is +infinity or -infinity
- if reg[A] is 0.0 or -0.0, then the result is 0.0 or -0.0

FMAC Multiply and add to accumulator

Opcode: 57 nn mm where: nn and mm are a register numbers

Description: $\text{reg}[A] = \text{reg}[A] + (\text{reg}[nn] * \text{reg}[mm])$
 The floating point value in register nn is multiplied by the value in register mm and the result is added to register A.

Special Cases:

- if either value is NaN, or one value is zero and the other is infinity, then the result is NaN
- if either values is infinity and the other is nonzero, then the result is infinity

FMAX Floating point maximum

Opcode: 55 nn where: nn is a register number

Description: $\text{reg}[A] = \text{max}(\text{reg}[A], \text{reg}[nn])$
 The maximum floating point value of registers A and register nn is stored in register A.

Special Cases: • if either value is NaN, then the result is NaN

FMIN Floating point minimum

Opcode: 54 nn where: nn is a register number

Description: $\text{reg}[A] = \min(\text{reg}[A], \text{reg}[nn])$
The minimum floating point value of registers A and register nn is stored in register A.

Special Cases: • if either value is NaN, then the result is NaN

FMOD Floating point remainder

Opcode: 50 nn where: nn is a register number

Description: $\text{reg}[A] = \text{remainder of } \text{reg}[A] / (\text{reg}[nn])$
The floating point remainder of the floating point value in register A divided by register nn is stored in register A.

FMSC Multiply and subtract from accumulator

Opcode: 58 nn mm where: nn and mm are a register numbers

Description: $\text{reg}[A] = \text{reg}[A] - (\text{reg}[nn] * \text{reg}[mm])$
The floating point value in register nn is multiplied by the value in register mm and the result is subtracted from register A.

Special Cases: • if either value is NaN, or one value is zero and the other is infinity, then the result is NaN
• if either values is infinity and the other is nonzero, then the result is infinity

FMUL Floating point multiply

Opcode: 24 nn where: nn is a register number

Description: $\text{reg}[A] = \text{reg}[A] * \text{reg}[nn]$
The floating point value in register A is multiplied by the value in register nn and the result is stored in register A.

Special Cases: • if either value is NaN, or one value is zero and the other is infinity, then the result is NaN
• if either values is infinity and the other is nonzero, then the result is infinity

FMULO Floating point multiply by register 0

Opcode: 2D

Description: $\text{reg}[A] = \text{reg}[A] * \text{reg}[0]$
The floating point value in register 0 is multiplied by the value in register nn and the result is stored in register A.

Special Cases: • if either value is NaN, or one value is zero and the other is infinity, then the result is NaN
• if either values is infinity and the other is nonzero, then the result is infinity

FMULI Floating point multiply by immediate value

Opcode: 36 bb where: bb is a signed byte value (-128 to 127)

Description: $\text{reg}[A] = \text{reg}[A] * \text{float}[bb]$

The signed byte value is converted to floating point and the value in register A is multiplied by the converted value and the result is stored in register A.

- Special Cases:
- if $\text{reg}[A]$ is NaN, then the result is NaN
 - if the signed byte is zero and $\text{reg}[A]$ is infinity, then the result is NaN

FNEG Floating point negate

Opcode: 3E

Description: $\text{reg}[A] = -\text{reg}[A]$

The negative of the floating point value in register A is stored in register A.

- Special Cases:
- if the value is NaN, then the result is NaN

FPOW Floating point power

Opcode: 27 nn where: nn is a register number

Description: $\text{reg}[A] = \text{reg}[A] ** \text{reg}[nn]$

The floating point value in register A is raised to the power of the floating point value in register nn and stored in register A.

- Special Cases:
- if $\text{reg}[nn]$ is 0.0 or -0.0, then the result is 1.0
 - if $\text{reg}[nn]$ is 1.0, then the result is the same as the A value
 - if $\text{reg}[nn]$ is NaN, then the result is NaN
 - if $\text{reg}[A]$ is NaN and $\text{reg}[nn]$ is nonzero, then the result is NaN
 - if $|\text{reg}[A]| > 1$ and $\text{reg}[nn]$ is +infinite, then the result is +infinity
 - if $|\text{reg}[A]| < 1$ and $\text{reg}[nn]$ is -infinite, then the result is +infinity
 - if $|\text{reg}[A]| > 1$ and $\text{reg}[nn]$ is -infinite, then the result is 0.0
 - if $|\text{reg}[A]| < 1$ and $\text{reg}[nn]$ is +infinite, then the result is 0.0
 - if $|\text{reg}[A]| = 1$ and $\text{reg}[nn]$ is infinite, then the result is NaN
 - if $\text{reg}[A]$ is 0.0 and $\text{reg}[nn] > 0$, then the result is 0.0
 - if $\text{reg}[A]$ is +infinity and $\text{reg}[nn] < 0$, then the result is 0.0
 - if $\text{reg}[A]$ is 0.0 and $\text{reg}[nn] < 0$, then the result is +infinity
 - if $\text{reg}[A]$ is +infinity and $\text{reg}[nn] > 0$, then the result is +infinity
 - if $\text{reg}[A]$ is -0.0 and $\text{reg}[nn] > 0$ but not a finite odd integer, then the result is 0.0
 - if the $\text{reg}[A]$ is -infinity and $\text{reg}[nn] < 0$ but not a finite odd integer, then the result is 0.0
 - if $\text{reg}[A]$ is -0.0 and the $\text{reg}[nn]$ is a positive finite odd integer, then the result is -0.0
 - if $\text{reg}[A]$ is -infinity and $\text{reg}[nn]$ is a negative finite odd integer, then the result is -0.0
 - if $\text{reg}[A]$ is -0.0 and $\text{reg}[nn] < 0$ but not a finite odd integer, then the result is +infinity
 - if $\text{reg}[A]$ is -infinity and $\text{reg}[nn] > 0$ but not a finite odd integer, then the result is +infinity
 - if $\text{reg}[A]$ is -0.0 and $\text{reg}[nn]$ is a negative finite odd integer, then the result is -infinity
 - if $\text{reg}[A]$ is -infinity and $\text{reg}[nn]$ is a positive finite odd integer, then the result is -infinity
 - if $\text{reg}[A] < 0$ and $\text{reg}[nn]$ is a finite even integer,

then the result is equal to $| \text{reg}[A] |$ to the power of $\text{reg}[\text{nn}]$

- if $\text{reg}[A] < 0$ and $\text{reg}[\text{nn}]$ is a finite odd integer,

then the result is equal to the negative of $| \text{reg}[A] |$ to the power of $\text{reg}[\text{nn}]$

- if $\text{reg}[A] < 0$ and finite and $\text{reg}[\text{nn}]$ is finite and not an integer, then the result is NaN

FPOW0 Floating point power by register 0

Opcode: 30

Description: $\text{reg}[A] = \text{reg}[A] ** \text{reg}[0]$

The floating point value in register A is raised to the power of the floating point value in register 0 and stored in register A.

- Special Cases:
- if $\text{reg}[0]$ is 0.0 or -0.0, then the result is 1.0
 - if $\text{reg}[0]$ is 1.0, then the result is the same as the A value
 - if $\text{reg}[0]$ is NaN, then the result is Nan
 - if $\text{reg}[A]$ is NaN and $\text{reg}[0]$ is nonzero, then the result is NaN
 - if $| \text{reg}[A] | > 1$ and $\text{reg}[0]$ is +infinite, then the result is +infinity
 - if $| \text{reg}[A] | < 1$ and $\text{reg}[0]$ is -infinite, then the result is +infinity
 - if $| \text{reg}[A] | > 1$ and $\text{reg}[0]$ is -infinite, then the result is 0.0
 - if $| \text{reg}[A] | < 1$ and $\text{reg}[0]$ is +infinite, then the result is 0.0
 - if $| \text{reg}[A] | = 1$ and $\text{reg}[0]$ is infinite, then the result is NaN
 - if $\text{reg}[A]$ is 0.0 and $\text{reg}[0] > 0$, then the result is 0.0
 - if $\text{reg}[A]$ is +infinity and $\text{reg}[0] < 0$, then the result is 0.0
 - if $\text{reg}[A]$ is 0.0 and $\text{reg}[0] < 0$, then the result is +infinity
 - if $\text{reg}[A]$ is +infinity and $\text{reg}[0] > 0$, then the result is +infinity
 - if $\text{reg}[A]$ is -0.0 and $\text{reg}[0] > 0$ but not a finite odd integer, then the result is 0.0
 - if the $\text{reg}[A]$ is -infinity and $\text{reg}[0] < 0$ but not a finite odd integer, then the result is 0.0
 - if $\text{reg}[A]$ is -0.0 and the $\text{reg}[0]$ is a positive finite odd integer, then the result is -0.0
 - if $\text{reg}[A]$ is -infinity and $\text{reg}[0]$ is a negative finite odd integer, then the result is -0.0
 - if $\text{reg}[A]$ is -0.0 and $\text{reg}[0] < 0$ but not a finite odd integer, then the result is +infinity
 - if $\text{reg}[A]$ is -infinity and $\text{reg}[0] > 0$ but not a finite odd integer, then the result is +infinity
 - if $\text{reg}[A]$ is -0.0 and $\text{reg}[0]$ is a negative finite odd integer, then the result is -infinity
 - if $\text{reg}[A]$ is -infinity and $\text{reg}[0]$ is a positive finite odd integer, then the result is -infinity
 - if $\text{reg}[A] < 0$ and $\text{reg}[0]$ is a finite even integer, then the result is equal to $| \text{reg}[A] |$ to the power of $\text{reg}[0]$
 - if $\text{reg}[A] < 0$ and $\text{reg}[0]$ is a finite odd integer, then the result is equal to the negative of $| \text{reg}[A] |$ to the power of $\text{reg}[0]$
 - if $\text{reg}[A] < 0$ and finite and $\text{reg}[0]$ is finite and not an integer, then the result is NaN

FPOWI Floating point power by immediate value

Opcode: 39 bb where: bb is a signed byte value (-128 to 127)

Description: $\text{reg}[A] = \text{reg}[A] ** \text{float}[\text{bb}]$

The signed byte value is converted to floating point and the value in register A is raised to the power of the converted value. The result is stored in register A.

- Special Cases:
- if bb is 0, then the result is 1.0
 - if bb is 1, then the result is the same as the A value
 - if reg[A] is NaN and bb is nonzero, then the result is NaN
 - if reg[A] is 0.0 and bb > 0, then the result is 0.0
 - if reg[A] is +infinity and bb < 0, then the result is 0.0
 - if reg[A] is 0.0 and bb < 0, then the result is +infinity
 - if reg[A] is +infinity and bb > 0, then the result is +infinity
 - if reg[A] is -0.0 and bb > 0 but not an odd integer, then the result is 0.0
 - if the reg[A] is -infinity and bb < 0 but not an odd integer, then the result is 0.0
 - if reg[A] is -0.0 and bb is a positive odd integer, then the result is -0.0
 - if reg[A] is -infinity and bb is a negative odd integer, then the result is -0.0
 - if reg[A] is -0.0 and bb < 0 but not an odd integer, then the result is +infinity
 - if reg[A] is -infinity and bb > 0 but not an odd integer, then the result is +infinity
 - if reg[A] is -0.0 and bb is a negative odd integer, then the result is -infinity
 - if reg[A] is -infinity and bb is a positive odd integer, then the result is -infinity
 - if reg[A] < 0 and bb is an even integer,
then the result is equal to | reg[A] | to the power of bb
 - if reg[A] < 0 and bb is an odd integer,
then the result is equal to the negative of | reg[A] | to the power of bb

FRAC Get fractional part of floating point value

Opcode: 63

Description: Register A is loaded with the fractional part the floating point value in register A. The sign of the fraction is the same as the sign of the original value.

Special Cases: • if register A is NaN or infinity, then the result is NaN

FREAD Read floating point value

Opcode: 1A nn where: nn is a register number

Returns: b1, b2, b3, b4 where: b1, b2, b3, b4 is floating point value (b1 is MSB)

Description: Return 32-bit floating point value from reg[nn]
The floating point value of register nn is returned. The four bytes of the 32-bit floating point value must be read immediately following this instruction. If the PIC data format has been selected (using the PICMODE instruction), the IEEE 754 format floating point value is converted to PIC format before being sent.

FREAD0 Read floating point value from register 0

Opcode: 1D

Returns: b1, b2, b3, b4 where: b1, b2, b3, b4 is floating point value (b1 is MSB)

Description: Return 32-bit floating point value from reg[0]
The floating point value from register 0 is returned. The four bytes of the 32-bit floating point value must be read immediately following this instruction. If the PIC data format has been selected (using the PICMODE instruction), the IEEE 754 format floating point value is converted to PIC format before being sent.

FREADA Read floating point value from register A

Opcode: 1B

Returns: b1, b2, b3, b4 where: b1, b2, b3, b4 is floating point value (b1 is MSB)

Description: Return 32-bit floating point value from reg[A]

The floating point value of register A is returned. The four bytes of the 32-bit floating point value must be read immediately following this instruction. If the PIC data format has been selected (using the PICMODE instruction), the IEEE 754 format floating point value is converted to PIC format before being sent.

FREADX Read floating point value from register X

Opcode: 1C

Returns: b1, b2, b3, b4 where: b1, b2, b3, b4 is floating point value (b1 is MSB)

Description: Return 32-bit floating point value from reg[X], X = X + 1

The floating point value from register X is returned, and X is incremented to the next register. The four bytes of the 32-bit floating point value must be read immediately following this instruction. If the PIC data format has been selected (using the PICMODE instruction), the IEEE 754 format floating point value is converted to PIC format before being sent.

FSET Set register A

Opcode: 20 nn where: nn is a register number

Description: reg[A] = reg[nn]

Set register A to the value of register nn.

FSET0 Set register A from register 0

Opcode: 29

Description: reg[A] = reg[0]

Set register A to the value of register 0.

FSETI Set register from immediate value

Opcode: 32 bb where: bb is a signed byte value (-128 to 127)

Description: reg[A] = float(bb)

The signed byte value is converted to floating point and stored in register A.

FSPLIT Split integer and fractional portions of floating point value

Opcode: 64

Description: reg[A] = integer portion of reg[A], reg[0] = fractional portion of reg[A]

The integer portion of the original value in register A is stored in register A, and the fractional portion is stored in register 0. Both values are stored as floating point values.

Special Cases: • if the original value is NaN or Infinity, reg[A] is set to zero and reg[0] is set to NaN

FSTATUS **Get floating point status**
Opcode: 3B nn where: nn is a register number

Description: $status = floatstatus(reg[nn])$
Set the internal status byte to the floating point status of the value in register nn. The status byte can be read with the READSTATUS instruction. It is set as follows:

Bit 7 6 5 4 3 2 1 0

1	-	-	-	I	N	S	Z
---	---	---	---	---	---	---	---

Bit 3 Infinity Set if the value is an infinity
Bit 2 Not-a-Number Set if the value is not a valid number
Bit 1 Sign Set if the value is negative
Bit 0 Zero Set if the value is zero

FSTATUSA **Get floating point status of register A**
Opcode: 3C

Description: $status = floatstatus(reg[A])$
Set the internal status byte to the floating point status of the value in register A. The status byte can be read with the READSTATUS instruction. It is set as follows:

Bit 7 6 5 4 3 2 1 0

1	-	-	-	I	N	S	Z
---	---	---	---	---	---	---	---

Bit 3 Infinity Set if the value is an infinity
Bit 2 Not-a-Number Set if the value is not a valid number
Bit 1 Sign Set if the value is negative
Bit 0 Zero Set if the value is zero

FSUB **Floating point subtract**
Opcode: 22 nn where: nn is a register number

Description: $reg[A] = reg[A] - reg[nn]$
The floating point value in register nn is subtracted from the floating point value in register A.

Special Cases: • if either value is NaN, then the result is NaN
 • if both values are infinity and the same sign, then the result is NaN
 • if reg[A] is +infinity and reg[nn] is not +infinity, then the result is +infinity
 • if reg[A] is -infinity and reg[nn] is not -infinity, then the result is -infinity
 • if reg[A] is not an infinity and reg[nn] is an infinity, then the result is an infinity of the opposite sign as reg[nn]

FSUB0 **Floating point subtract register 0**
Opcode: 2B

Description: $reg[A] = reg[A] - reg[0]$
The floating point value in register 0 is subtracted from the floating point value in register A.

Special Cases: • if either value is NaN, then the result is NaN
 • if both values are infinity and the same sign, then the result is NaN
 • if reg[A] is +infinity and reg[0] is not +infinity, then the result is +infinity
 • if reg[A] is -infinity and reg[0] is not -infinity, then the result is -infinity

- if reg[A] is not an infinity and reg[0] is an infinity, then the result is an infinity of the opposite sign as reg[0]

FSUBI Floating point subtract immediate value

Opcode: 34 bb where: bb is a signed byte value (-128 to 127)

Description: $\text{reg}[A] = \text{reg}[A] - \text{float}[\text{bb}]$
 The signed byte value is converted to floating point and subtracted from the value in register A.

- Special Cases:
- if reg[A] is NaN, then the result is NaN
 - if reg[A] is +infinity, then the result is +infinity
 - if reg[A] is -infinity, then the result is -infinity

FSUBR Floating point subtract (reversed)

Opcode: 23 nn where: nn is a register number

Description: $\text{reg}[A] = \text{reg}[\text{nn}] - \text{reg}[A]$
 The floating point value in register A is subtracted from the floating point value in register nn and the result is stored in register A.

- Special Cases:
- if either value is NaN, then the result is NaN
 - if both values are infinity and the same sign, then the result is NaN
 - if reg[nn] is +infinity and reg[A] is not +infinity, then the result is +infinity
 - if reg[nn] is -infinity and reg[A] is not -infinity, then the result is -infinity
 - if reg[nn] is not an infinity and reg[A] is an infinity, then the result is an infinity of the opposite sign as reg[A]

FSUBR0 Floating point subtract register 0 (reversed)

Opcode: 2C

Description: $\text{reg}[A] = \text{reg}[0] - \text{reg}[A]$
 The floating point value in register A is subtracted from the floating point value in register 0 and the result is stored in register A.

- Special Cases:
- if either value is NaN, then the result is NaN
 - if both values are infinity and the same sign, then the result is NaN
 - if reg[nn] is +infinity and reg[0] is not +infinity, then the result is +infinity
 - if reg[nn] is -infinity and reg[A] is not -infinity, then the result is -infinity
 - if reg[nn] is not an infinity and reg[A] is an infinity, then the result is an infinity of the opposite sign as reg[A]

FSUBRI Floating point subtract immediate value (reversed)

Opcode: 35 bb where: bb is a signed byte value (-128 to 127)

Description: $\text{reg}[A] = \text{float}[\text{bb}] - \text{reg}[A]$
 The signed byte value is converted to floating point and the value in register A is subtracted from it and the result is stored in register A.

- Special Cases:
- if reg[A] is NaN, then the result is NaN
 - if reg[A] is +infinity, then the result is +infinity

- if reg[A] is -infinity, then the result is -infinity

FTABLE Floating point reverse table lookup

Opcode: 85 cc tc t1...tn where: cc is the test condition
 tc is the size of the table
 t1...tn are 32-bit floating point values

Description: reg[0] = index of table entry that matches the test condition for reg[A]
 This instruction is only valid in a user-defined function in Flash memory or EEPROM memory. It performs a reverse table lookup on a floating point value. The value in register A is compared to the values in the table using the test condition. The index number of the first table entry that satisfies the test condition is stored in register 0. If no entry is found, register 0 is unchanged. The index number for the first table entry is zero.

FTOA Convert floating point value to ASCII string

Opcode: 1F bb where: bb is the format byte

Description: The floating point value in register A is converted to an ASCII string and stored in the string buffer at the current selection point. The selection point is updated to point immediately after the inserted string, so multiple insertions can be appended. The byte immediately following the FTOA opcode is the format byte and determines the format of the converted value.

If the format byte is zero, as many digits as necessary will be used to represent the number with up to eight significant digits. Very large or very small numbers are represented in exponential notation. The length of the displayed value is variable and can be from 3 to 12 characters in length. The special cases of NaN (Not a Number), +infinity, -infinity, and -0.0 are handled. Examples of the ASCII strings produced are as follows:

1.0	NaN	0.0
10e20	Infinity	-0.0
3.1415927	-Infinity	1.0
-52.333334	-3.5e-5	0.01

If the format byte is non-zero, it is interpreted as a decimal number. The tens digit specifies the maximum length of the converted string, and the ones digit specifies the number of decimal points. The maximum number of digits for the formatted conversion is 9, and the maximum number of decimal points is 6. If the floating point value is too large for the format specified, asterisks will be stored. If the number of decimal points is zero, no decimal point will be displayed. Examples of the display format are as follows: (note: leading spaces are shown where applicable)

<i>Value in register A</i>	<i>Format byte</i>	<i>Display format</i>
123.567	61 (6.1)	[123.6]
123.567	62 (6.2)	[123.57]
123.567	42 (4.2)	[*.**]
0.9999	20 (2.0)	[1]
0.9999	31 (3.1)	[1.0]

This instruction is usually followed by a READSTR instruction to read the string.

LADDI Long integer add immediate value

Opcode: AF bb where: bb is a signed byte value (-128 to 127)

Description: $\text{reg}[A] = \text{reg}[A] + \text{long}(\text{bb})$, status = longstatus(reg[A])
The signed byte value is converted to a long integer and added to register A.

LAND Long integer AND

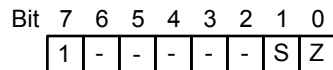
Opcode: C0 nn where: nn is a register number

Description: $\text{reg}[A] = \text{reg}[A] \text{ AND } \text{reg}[\text{nn}]$, status = longstatus(reg[A])
The bitwise AND of the values in register A and register nn is stored in register A.

LCMP Long integer compare

Opcode: A1 nn where: nn is a register number

Description: status = longstatus(reg[A] - reg[nn])
Compares the signed long integer value in register A with the value in register nn and sets the internal status byte. The status byte can be read with the READSTATUS instruction. It is set as follows:

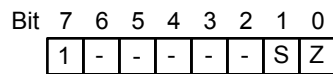


Bit 1	Sign	Set if $\text{reg}[A] < \text{reg}[\text{nn}]$
Bit 0	Zero	Set if $\text{reg}[A] = \text{reg}[\text{nn}]$
		If neither Bit 0 or Bit 1 is set, $\text{reg}[A] > \text{reg}[\text{nn}]$

LCMP0 Long integer compare register 0

Opcode: AA

Description: status = longstatus(reg[A] - reg[0])
Compares the signed long integer value in register A with the value in register 0 and sets the internal status byte. The status byte can be read with the READSTATUS instruction. It is set as follows:

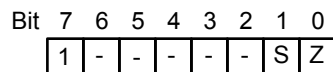


Bit 1	Sign	Set if $\text{reg}[A] < \text{reg}[0]$
Bit 0	Zero	Set if $\text{reg}[A] = \text{reg}[0]$
		If neither Bit 0 or Bit 1 is set, $\text{reg}[A] > \text{reg}[0]$

LCMP2 Long integer compare

Opcode: B9 nn mm where: nn and mm are register numbers

Description: status = longstatus(reg[nn] - reg[mm])
Compares the signed long integer value in register nn with the value in register mm and sets the internal status byte. The status byte can be read with the READSTATUS instruction. It is set as follows:



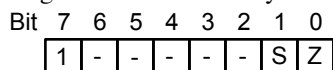
Bit 1	Sign	Set if $\text{reg}[\text{nn}] < \text{reg}[\text{mm}]$
-------	------	--

Bit 0 Zero Set if $\text{reg}[\text{nn}] = \text{reg}[\text{mm}]$
 If neither Bit 0 or Bit 1 is set, $\text{reg}[\text{nn}] > \text{reg}[\text{mm}]$

LCMPI Long integer compare immediate value

Opcode: B3 bb where: bb is a signed byte value (-128 to 127)

Description: $\text{status} = \text{longstatus}(\text{reg}[\text{A}] - \text{long}(\text{bb}))$
 The signed byte value is converted to long integer and compared to the signed long integer value in register A. The status byte can be read with the READSTATUS instruction. It is set as follows:



Bit 1 Sign Set if $\text{reg}[\text{A}] < \text{long}(\text{bb})$
 Bit 0 Zero Set if $\text{reg}[\text{A}] = \text{long}(\text{bb})$
 If neither Bit 0 or Bit 1 is set, $\text{reg}[\text{A}] > \text{long}(\text{bb})$

LDEC Long integer decrement

Opcode: BE nn where: nn is a register number

Description: $\text{reg}[\text{nn}] = \text{reg}[\text{nn}] - 1$, $\text{status} = \text{longstatus}(\text{reg}[\text{nn}])$
 The long integer value in register nn is decremented by one. The long integer status is stored in the status byte.

LDIV Long integer divide

Opcode: A0 nn where: nn is a register number

Description: $\text{reg}[\text{A}] = \text{reg}[\text{A}] / \text{reg}[\text{nn}]$, $\text{reg}[0] = \text{remainder}$, $\text{status} = \text{longstatus}(\text{reg}[\text{A}])$
 The long integer value in register A is divided by the signed value in register nn, and the result is stored in register A. The remainder is stored in register 0.

Special Cases: • if $\text{reg}[\text{nn}]$ is zero, the result is the largest positive long integer (\$7FFFFFFF)

LDIV0 Long integer divide by register 0

Opcode: A9

Description: $\text{reg}[\text{A}] = \text{reg}[\text{A}] / \text{reg}[0]$, $\text{reg}[0] = \text{remainder}$, $\text{status} = \text{longstatus}(\text{reg}[\text{A}])$
 The long integer value in register A is divided by the signed value in register 0, and the result is stored in register A. The remainder is stored in register 0.

Special Cases: • if $\text{reg}[0]$ is zero, the result is the largest positive long integer (\$7FFFFFFF)

LDIVI Long integer divide by immediate value

Opcode: B2 bb where: bb is a signed byte value (-128 to 127)

Description: $\text{reg}[\text{A}] = \text{reg}[\text{A}] / \text{long}(\text{bb})$, $\text{reg}[0] = \text{remainder}$, $\text{status} = \text{longstatus}(\text{reg}[\text{A}])$
 The signed byte value is converted to a long integer and register A is divided by the converted value. The result is stored in register A. The remainder is stored in register 0.

Special Cases: • if the signed byte value is zero, the result is the largest positive long integer (\$7FFFFFFF)

LEFT Left Parenthesis*(modified V3.1)*

Opcode: 14

Description: The LEFT instruction saves the current register A selection, allocates the next temporary register, sets the value of the temporary register to the current register A value, then selects the temporary register as register A. The RIGHT instruction is used to restore previous values. When used together, these instructions are like parentheses in an equation, and can be used to allocate temporary registers, and change the order of a calculation. Parentheses can be nested up to eight levels.

Special Cases: • If the maximum number of temporary register is exceeded, the value of register A is set to NaN (\$7FFFFFFF).

LINC Long integer increment

Opcode: BD nn where: nn is a register number

Description: $\text{reg}[nn] = \text{reg}[nn] + 1$, status = longstatus(reg[nn])
The long integer value in register nn is incremented by one. The long integer status is stored in the status byte.

LMAX Long integer maximum

Opcode: C5 nn where: nn is a register number

Description: $\text{reg}[A] = \max(\text{reg}[A], \text{reg}[nn])$, status = longstatus(reg[A])
The maximum signed long integer value of registers A and register nn is stored in register A.

Special Cases: • if either value is NaN, then the result is NaN

LMIN Long integer minimum

Opcode: C4 nn where: nn is a register number

Description: $\text{reg}[A] = \min(\text{reg}[A], \text{reg}[nn])$, status = longstatus(reg[A])
The minimum signed long integer value of registers A and register nn is stored in register A.

Special Cases: • if either value is NaN, then the result is NaN

LMUL Long integer multiply

Opcode: 9F nn where: nn is a register number

Description: $\text{reg}[A] = \text{reg}[A] * \text{reg}[nn]$, status = longstatus(reg[A])
The long integer value in register A is multiplied by register nn and the result is stored in register A.

LMULO Long integer multiply by register 0

Opcode: A8

Description: $\text{reg}[A] = \text{reg}[A] * \text{reg}[0]$, status = longstatus(reg[A])
The long integer value in register A is multiplied by register 0 and the result is stored in register A.

LMULI Long integer multiply by immediate value

Opcode: B1 bb where: bb is a signed byte value (-128 to 127)

Description: $\text{reg}[A] = \text{reg}[A] * \text{long}(\text{bb})$, status = longstatus(reg[A])
The signed byte value is converted to a long integer and the long integer value in register A is multiplied by the converted value. The result is stored in register A.

LNEG Long integer negate

Opcode: BB

Description: $\text{reg}[A] = -\text{reg}[A]$, status = longstatus(reg[A])
The negative of the long integer value in register A is stored in register A.

LNOT A = NOT A

Opcode: BF

Description: $\text{reg}[A] = \text{NOT } \text{reg}[A]$, status = longstatus(reg[A])
The bitwise complement of the value in register A is stored in register A.

LOAD reg[0] = reg[nn]

Opcode: 0A nn where: nn is a register number

Description: $\text{reg}[0] = \text{reg}[\text{nn}]$, status = longstatus(reg[0])
Load register 0 with the value in register nn.

LOADA Load register 0 with the value of register A

Opcode: 0B

Description: $\text{reg}[0] = \text{reg}[A]$, status = longstatus(reg[0])
Load register 0 with the value of register A.

LOADBYTE Load register 0 with 8-bit signed value

Opcode: 59 bb where: bb is a signed byte value (-128 to 127)

Description: $\text{reg}[0] = \text{float}(\text{signed } \text{bb})$
Loads register 0 with the 8-bit signed integer value converted to floating point value.

LOADCON Load register 0 with floating point constant

Opcode: 5F bb where: bb selects the constant

Description: This instruction is defined for version 3.0.0 to V3.1.3 of the uM-FPU V3 chip, but will be removed in future versions. Use of this instruction is not recommended. Constant values can easily be loaded using the FWRITE0 instruction.

 $\text{reg}[0] = \text{constant}[\text{bb}]$

Loads register 0 with the floating point constant specified by bb as follows:

0	1.0	10^0
1	10.0	10^1
2	100.0	10^2
3	1000.0	10^3

4	10000.0	10 ⁴
5	100000.0	10 ⁵
6	1000000.0	10 ⁶
7	10000000.0	10 ⁷
8	100000000.0	10 ⁸
9	1000000000.0	10 ⁹
10	$\approx 3.4028235 \times 10^{38}$	largest positive finite 32-bit floating point value
11	$\approx 1.4012985 \times 10^{-45}$	smallest positive non-zero 32-bit floating point value
12	299792458.0	speed of light in vacuum (m/s)
13	6.6742e-11	Newtonian constant of gravitation (m ³ /kg*s ²)
14	9.80665	acceleration of gravity
15	9.1093826e-31	electron mass (kg)
16	1.67262171e-27	proton mass (kg)
17	1.67492728e-27	neutron mass (kg)
18	6.0221415e23	Avogadro constant (/mol)
19	1.60217653e-19	elementary charge, electron volt
20	101.325	standard atmosphere (kPa)

Special Cases: • if the byte value bb is greater than 20, register A is set to NaN.

LOADE Load register 0 with floating point value of e (2.7182818)

Opcode: 5D

Description: reg[0] = 2.7182818
Loads register 0 with the floating point value of e (2.7182818).

LOADIND Load Indirect

Opcode: 7A nn where: nn is a register number

Description: reg[0] = reg[reg[nn]], status = longstatus(reg[0])
Load register 0 with the value of the register number contained in register nn. The value in register nn is assumed to be a long integer value.

Special Cases: If the value in register nn > 127, register 127 is used.

LOADMA Load register 0 with the value from matrix A

Opcode: 68 bb bb where: bb, bb selects the row, column of matrix A

Description: reg[0] = matrix A [bb, bb]
Load register 0 with a value from matrix A. Row and column numbers start from 0.

Special Cases: If the row or column is out of range, register 0 is set to NaN.

LOADMB Load register 0 with the value from matrix B

Opcode: 69 bb bb where: bb, bb selects the row, column of matrix B

Description: reg[0] = matrix B [bb, bb]
Load register 0 with a value from matrix B. Row and column numbers start from 0.

Special Cases: If the row or column is out of range, register 0 is set to NaN.

LOADMC Load register 0 with the value from matrix A

Opcode: 6A bb bb where: bb, bb selects the row, column of matrix C

Description: $\text{reg}[0] = \text{matrix C}[\text{bb}, \text{bb}]$
Load register 0 with a value from matrix C. Row and column numbers start from 0.

Special Cases: If the row or column is out of range, register 0 is set to NaN.

LOADPI Load register 0 with value of Pi

Opcode: 5E

Description: $\text{reg}[0] = 3.1415927$
Loads register 0 with the floating point value of pi (3.1415927).

LOADUBYTE Load register 0 with 8-bit unsigned value

Opcode: 5A bb where: bb is an unsigned byte value (0 to 255)

Description: $\text{reg}[0] = \text{float}(\text{unsigned bb})$
The 8-bit unsigned value is converted to floating point and stored in register 0.

LOADUWORD Load register 0 with 16-bit unsigned value

Opcode: 5C b1, b2 where: b1, b2 is an unsigned word value (0 to 65535)

Description: $\text{reg}[0] = \text{float}(\text{unsigned}(b1*256 + b2))$
The 16-bit unsigned value is converted to floating point and stored in register 0.

LOADWORD Load register 0 with 16-bit signed value

Opcode: 5B b1, b2 where: b1, b2 is a signed word value (-32768 to 32767)

Description: $\text{reg}[0] = \text{float}(\text{signed}(b1*256 + b2))$
The 16-bit signed value is converted to floating point and stored in register 0.

LOADX Load register 0 with the value of register X

Opcode: 0C

Description: $\text{reg}[0] = \text{reg}[X]$, $\text{status} = \text{longstatus}(\text{reg}[0])$, $X = X + 1$
Load register 0 with the value of register X, and increment X to select the next register in sequence.

Special Cases: • the X register will not increment past the maximum register value of 127

LOG Logarithm (base e)

Opcode: 43

Description: $\text{reg}[A] = \log(\text{reg}[A])$
Calculates the natural log of the floating point value in register A. The result is stored in register A. The number e (2.7182818) is the base of the natural system of logarithms.

Special Cases:

- if the value is NaN or less than zero, then the result is NaN
- if the value is +infinity, then the result is +infinity
- if the value is 0.0 or -0.0, then the result is -infinity

LOG10 **Logarithm (base 10)**

Opcode: 44

Description: $\text{reg}[A] = \log_{10}(\text{reg}[A])$
Calculates the base 10 logarithm of the floating point value in register A. The result is stored in register A.

Special Cases:

- if the value is NaN or less than zero, then the result is NaN
- if the value is +infinity, then the result is +infinity
- if the value is 0.0 or -0.0, then the result is -infinity

LONGBYTE **Load register 0 with 8-bit signed value**

Opcode: C6 bb where: bb is a signed byte value (-128 to 127)

Description: $\text{reg}[0] = \text{long}(\text{signed}(bb))$, status = longstatus(reg[0])
The 8-bit signed value is converted to a long integer and stored in register 0.

LONGUBYTE **Load register 0 with 8-bit unsigned value**

Opcode: C7 bb where: bb is an unsigned byte value (0 to 255)

Description: $\text{reg}[0] = \text{long}(\text{unsigned}(bb))$, status = longstatus(reg[0])
The 8-bit unsigned value is converted to a long integer and stored in register 0.

LONGUWORD **Load register 0 with 16-bit unsigned value**

Opcode: C9 b1, b2 where: b1, b2 is an unsigned word value (0 to 65535)

Description: $\text{reg}[0] = \text{long}(\text{unsigned}(b1*256 + b2))$, status = longstatus(reg[0])
The 16-bit unsigned value is converted to a long integer and stored in register 0.

LONGWORD **Load register 0 with 16-bit signed value**

Opcode: C8 b1, b2 where: b1, b2 is a signed word value (-32768 to 32767)

Description: $\text{reg}[0] = \text{long}(\text{signed}(b1*256 + b2))$, status = longstatus(reg[0])
The 16-bit signed value is converted to a long integer and stored in register 0.

LOR **Long integer OR**

Opcode: C1 nn where: nn is a register number

Description: $\text{reg}[A] = \text{reg}[A] \text{ OR } \text{reg}[nn]$, status = longstatus(reg[A])
The bitwise OR of the values in register A and register nn is stored in register A.

LREAD **Read long integer value**

Opcode: 94 nn where: nn is a register number

Returns: b1, b2, b3, b4 where: b1, b2, b3, b4 is integer value (b1 is MSB)

Description: Return 32-bit integer value from reg[nn]

The long integer value of register nn is returned. The four bytes of the 32-bit integer value must be read immediately following this instruction.

LREAD0 Read long integer value from register 0

Opcode: 97

Returns: $b1, b2, b3, b4$ where: $b1, b2, b3, b4$ is integer value (b1 is MSB)

Description: Return 32-bit integer value from $reg[0]$
The long integer value of register 0 is returned. The four bytes of the 32-bit integer value must be read immediately following this instruction.

LREADA Read long integer value from register A

Opcode: 95

Returns: $b1, b2, b3, b4$ where: $b1, b2, b3, b4$ is integer value (b1 is MSB)

Description: Return 32-bit integer value from $reg[A]$
The long integer value of register A is returned. The four bytes of the 32-bit integer value must be read immediately following this instruction.

LREADBYTE Read the lower 8-bits of register A

Opcode: 98

Returns: bb where: bb is 8-bit integer value

Description: Return 8-bit integer value from $reg[A]$
Returns the lower 8 bits of register A. The byte containing the 8-bit integer value must be read immediately following the instruction.

LREADWORD Read the lower 16-bits of register A

Opcode: 99

Returns: $b1, b2$ where: $b1, b2$ is 16-bit integer value (b1 is MSB)

Description: Return 16-bit integer value from $reg[A]$
Returns the lower 16 bits of register A. The two bytes containing the 16-bit integer value must be read immediately following this instruction.

LREADX Read long integer value from register X

Opcode: 96

Returns: $b1, b2, b3, b4$ where: $b1, b2, b3, b4$ is integer value (b1 is MSB)

Description: Return 32-bit integer value from $reg[X]$, $X = X + 1$
The long integer value from register X is returned, and X is incremented to the next register. The four bytes of the 32-bit integer value must be read immediately following this instruction.

LSET Set register A

Opcode: $9C\ nn$ where: nn is a register number

Description: $reg[A] = reg[nn]$, $status = longstatus(reg[A])$
Set register A to the value of register nn .

LSET0 **Set register A from register 0**
 Opcode: A5
 Description: $\text{reg}[A] = \text{reg}[0]$, $\text{status} = \text{longstatus}(\text{reg}[A])$
 Set register A to the value of register 0.

LSETI **Set register from immediate value**
 Opcode: AE bb where: bb is a signed byte value (-128 to 127)
 Description: $\text{reg}[A] = \text{long}(bb)$, $\text{status} = \text{longstatus}(\text{reg}[A])$
 The signed byte value is converted to a long integer and stored in register A.

LSHIFT **Long integer shift**
 Opcode: C3 nn where: nn is a register number
 Description: if $\text{reg}[nn] > 0$, then $\text{reg}[A] = \text{reg}[A]$ shifted left by $\text{reg}[nn]$ bits
 if $\text{reg}[nn] < 0$, then $\text{reg}[A] = \text{reg}[A]$ shifted right by $-\text{reg}[nn]$ bits
 $\text{status} = \text{longstatus}(\text{reg}[A])$
 The value in register A is shifted by the number of bit positions specified by the long integer value in register nn. Register A is shifted left if the value in register nn is positive, and right if the value is negative. Zero bits are loaded into bit 0 during a left shift, and into bit 31 during a right shift.
 Special Cases: • if $\text{reg}[nn] = 0$, no shift occurs
 • if $\text{reg}[nn] > 32$ or $\text{reg}[nn] < -32$, then $\text{reg}[A] = 0$

LSTATUS **Get long integer status**
 Opcode: B7 nn where: nn is a register number
 Description: $\text{status} = \text{longstatus}(\text{reg}[nn])$
 Set the internal status byte to the long integer status of the value in register nn. The status byte can be read with the READSTATUS instruction. It is set as follows:

Bit	7	6	5	4	3	2	1	0
	1	-	-	-	-	-	S	Z
Bit 1	Sign		Set if the value is negative					
Bit 0	Zero		Set if the value is zero					

LSTATUSA **Get long integer status of register A**
 Opcode: B8
 Description: $\text{status} = \text{longstatus}(\text{reg}[A])$
 Set the internal status byte to the long integer status of the value in register A. The status byte can be read with the READSTATUS instruction. It is set as follows:

Bit	7	6	5	4	3	2	1	0
	1	-	-	-	-	-	S	Z
Bit 1	Sign		Set if the value is negative					
Bit 0	Zero		Set if the value is zero					

LSUB Long integer subtract

Opcode: 9E nn where: nn is a register number

Description: $\text{reg}[A] = \text{reg}[A] - \text{reg}[nn]$, status = longstatus(reg[A])
The long integer value in register nn is subtracted from register A.

LSUB0 Long integer subtract register 0

Opcode: A7

Description: $\text{reg}[A] = \text{reg}[A] - \text{reg}[0]$, status = longstatus(reg[A])
The long integer value in register 0 is subtracted from register A.

LSUBI Long integer subtract immediate value

Opcode: B0 bb where: bb is a signed byte value (-128 to 127)

Description: $\text{reg}[A] = \text{reg}[A] - \text{long}(bb)$, status = longstatus(reg[A])
The signed byte value is converted to a long integer and subtracted from register A.

LTABLE Long integer reverse table lookupOpcode: 87 cc tc t1...tn where: cc is the test condition
tc is the size of the table
t1...tn are 32-bit long integer valuesDescription: $\text{reg}[0] = \text{index of table entry that matches the test condition for reg}[A]$
status = longstatus(reg[0])
This instruction is only valid in a user-defined function in Flash memory or EEPROM memory. It performs a reverse table lookup on a long integer value. The value in register A is compared to the values in the table using the specified test condition. The index number of the first table entry that satisfied the test condition is stored in register 0. If no entry is found, register 0 is unchanged. The index number for the first table entry is zero.

LTOA Convert long integer value to ASCII string and store in string buffer

Opcode: 9B bb where: bb is the format byte

Description: stringbuffer = converted string
The long integer value in register A is converted to an ASCII string and stored in the string buffer at the current selection point. The selection point is updated to point immediately after the inserted string, so multiple insertions can be appended. The byte immediately following the LTOA opcode is the format byte and determines the format of the converted value.

If the format byte is zero, the length of the converted string is variable and can range from 1 to 11 characters in length. Examples of the converted string are as follows:

1
500000
-3598390

If the format byte is non-zero, a value between 0 and 15 specifies the length of the converted string. The converted string is right justified. If the format byte is positive, leading spaces are used. If the format byte is negative, its absolute value specifies the length of the converted string, and leading zeros are used. If 100 is added to the format value the value is converted as an unsigned

long integer, otherwise it is converted as an signed long integer. If the converted string is longer than the specified length, asterisks are stored. If the length is specified as zero, the string will be as long as necessary to represent the number. Examples of the converted string are as follows: (note: leading spaces are shown where applicable)

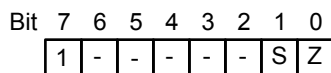
<i>Value in register A</i>	<i>Format byte</i>	<i>Description</i>	<i>Display format</i>
-1	10	(signed 10)	[-1]
-1	110	(unsigned 10)	[4294967295]
-1	4	(signed 4)	[-1]
-1	104	(unsigned 4)	[****]
0	4	(signed 4)	[0]
0	0	(unformatted)	[0]
1000	6	(signed 6)	[1000]
1000	-6	(signed 6, zero fill)	[001000]

The maximum length of the string is 15. This instruction is usually followed by a READSTR instruction to read the string.

LTST Long integer bit test

Opcode: A4 nn where: nn is a register number

Description: status = longstatus(reg[A] AND reg[nn])
Sets the internal status byte based on the result of a bitwise AND of the values in register A and register nn. The values of register A and register nn are not changed. The status byte can be read with the READSTATUS instruction. It is set as follows:

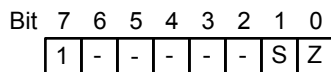


Bit 1 Sign Set if the MSB of the result is set
Bit 0 Zero Set the result is zero

LTST0 Long integer bit test register 0

Opcode: AD

Description: status = longstatus(reg[A] AND reg[0])
Sets the internal status byte based on the result of a bitwise AND of the value in register A and register 0. The values of register A and register 0 are not changed. The status byte can be read with the READSTATUS instruction. It is set as follows:

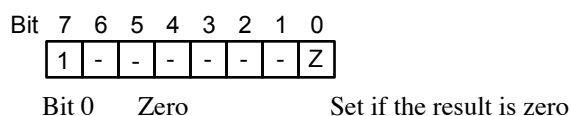


Bit 1 Sign Set if the MSB of the result is set
Bit 0 Zero Set the result is zero

LTSTI Long integer bit test using immediate value

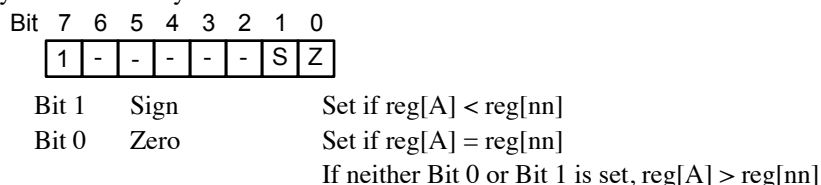
Opcode: B6 bb where: bb is an unsigned byte value (0 to 255)

Description: status = longstatus(reg[A] AND long(bb))
The unsigned byte value is converted to long integer and the internal status byte is set based on the result of a bitwise AND of the converted value and register A. The value of register A is not changed. The status byte can be read with the READSTATUS instruction. It is set as follows:



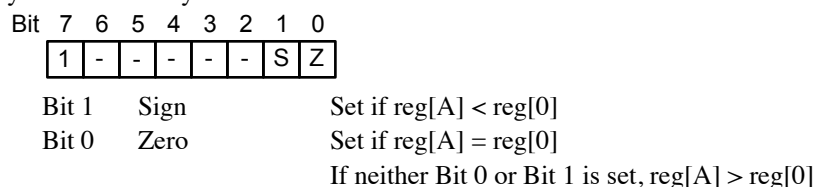
LUCMP Unsigned long integer compare
 Opcode: A3 nn where: nn is a register number

Description: status = longstatus(reg[A] - reg[nn])
 Compares the unsigned long integer value in register A with register nn and sets the internal status byte. The status byte can be read with the READSTATUS instruction. It is set as follows:



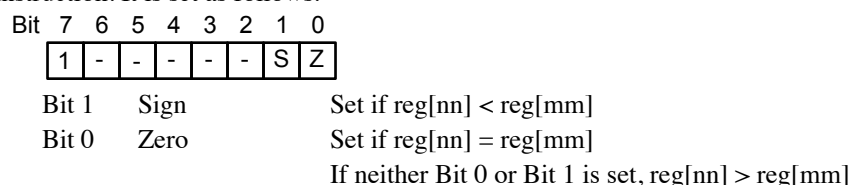
LUCMP0 Unsigned long integer compare register 0
 Opcode: AC

Description: status = longstatus(reg[A] - reg[0])
 Compares the unsigned long integer value in register A with register 0 and sets the internal status byte. The status byte can be read with the READSTATUS instruction. It is set as follows:



LUCMP2 Unsigned long integer compare
 Opcode: BA nn mm where: nn and mm are register numbers

Description: status = longstatus(reg[nn] - reg[mm])
 Compares the unsigned long integer value in register nn with the signed long integer value in register mm and sets the internal status byte. The status byte can be read with the READSTATUS instruction. It is set as follows:



LUCMPI Unsigned long integer compare immediate value
 Opcode: B5 bb where: bb is an unsigned byte value (0 to 255)

Description: status = longstatus(reg[A] - long(bb))
 The unsigned byte value is converted to long integer and compared to register A. The status byte can be read with the READSTATUS instruction. It is set as follows:

the polynomial is:

$$y = A_0 + A_1x^1 + A_2x^2 + \dots A_nx^n$$

The value of x is the initial value of register A . An n^{th} order polynomial will have $n+1$ coefficients stored in the table. The coefficient values A_0, A_1, A_2, \dots are stored as a series of 32-bit floating point values (4 bytes) stored in order from A_n to A_0 . If a given term in the polynomial is not needed, a zero must be stored for that value.

Example: The polynomial $3x + 5$ would be represented as follows:

88 02 40 A0 00 00 40 40 00 00

Where: 88 opcode
02 size of the table (order of the polynomial + 1)
40 40 00 00 floating point constant 3.0
40 A0 00 00 floating point constant 5.0

RADIANS Convert degrees to radians

Opcode: 4F

Description: $\text{reg}[A] = \text{radians}(\text{reg}[A])$

The floating point value in register A is converted from degrees to radians and the result is stored in register A .

Special Cases: • if the value is NaN, then the result is NaN

RDBLK Read multiple 32-bit point values (new V3.1)

Opcode: 71 τc where: τc is the number of 32-bit values to read

Description: Return τc 32-bit values from $\text{reg}[X]$, $X = X+1$

This instruction is used to read multiple 32-bit values from the uM-FPU registers. The byte immediately following the opcode is the transfer count, and bits 6:0 specify the number of 32-bit values that follow (a value of zero specifies a transfer count of 128). If bit 7 of the transfer count is set, the bytes are reversed for each 32-bit value that follows. This allows for efficient data transfers when the native storage format of the microcontroller is the reverse of the uM-FPU format. The X register specifies the register to read from, and it is incremented after each 32-bit value is read.

Special Cases: • the X register will not increment past the maximum register value of 127
• if PICMODE is enabled, the 32-bit values are assumed to be floating point values

READSEL Read string selection

Opcode: EC

Returns: $aa\dots 00$ where: $aa\dots 00$ is a zero-terminated string

Description: Returns the current string selection. Data bytes must be read immediately following this instruction and continue until a zero byte is read. This instruction is typically used after STRSEL or STRFIELD instructions.

READSTATUS Return the last status byte

Opcode: F1

Returns: `ss` where: `ss` is the status byteDescription: The 8-bit internal status byte is returned.

READSTR Read string

Opcode: F2

Returns: `aa...00` where: `aa...00` is a zero-terminated stringDescription: Returns the zero terminated string in the string buffer. Data bytes must be read immediately following this instruction and continue until a zero byte is read. This instruction is used after instructions that load the string buffer (e.g. `FTOA`, `LTOA`, `VERSION`). On completion of the `READSTR` instruction the string selection is set to select the entire string.

READVAR Read internal variable*(modified V3.1)*Opcode: `FC bb` where: `bb` is index of internal valueDescription: `reg[0]` = internal value, `status = longstatus(reg[0])`
Sets register 0 to the current value of one of the internal registers (based on index value passed).

0	A register
1	X register
2	Matrix A register
3	Matrix A rows
4	Matrix A columns
5	Matrix B register
6	Matrix B rows
7	Matrix B columns
8	Matrix C register
9	Matrix C rows
10	Matrix C columns
11	internal mode word
12	last status byte
13	clock ticks per millisecond
14	current length of string buffer
15	string selection starting point
16	string selection length
17	8-bit character at string selection point
18	number of bytes in instruction buffer

RESET ResetOpcode: `FF`Description: Nine consecutive `FF` bytes will cause the uM-FPU to reset. If less than nine consecutive `FF` bytes are received, they are treated as NOPs.

characters can be read using the `SERIN, 3` instruction.

SERIN, 2

Get character mode serial input status. The status byte is set to zero (Z) if the input buffer is empty, or non-zero (NZ) if the input buffer is not empty.

Bit	7	6	5	4	3	2	1	0
	1	-	-	-	-	-	-	Z

Bit 0 Zero Set if receive buffer is empty.
 Clear if receive buffer is not empty.

SERIN, 3

Get serial input character. The serial input character is stored in register 0. If this instruction is the last instruction in the instruction buffer, it will wait for the next available input character. If there are other instructions in the instruction buffer, or another instruction is sent before the `SERIN, 3` instruction has completed, it will terminate and store a zero value in register 0. Note: A known problem in V3.1 is that carriage return (0x0D) characters are returned as zero bytes.

SERIN, 4

Enable NMEA serial input. Serial input is enabled, and the serial input data is scanned for NMEA sentences which are then stored in a 200 byte buffer. Additional NMEA sentences can be buffered while the current sentence is being processed. The sentence prefix character (\$), trailing checksum characters (if specified), and the terminator (CR,LF) are not stored in the buffer. NMEA sentences are transferred to the string buffer for processing using the `SERIN, 6` instruction, and the NMEA input status can be checked with the `SERIN, 5` instruction.

SERIN, 5

Get the NMEA input status. The status byte is set to zero (Z) if the buffer is empty, or non-zero (NZ) if at least one NMEA sentence is available in the buffer.

Bit	7	6	5	4	3	2	1	0
	1	-	-	-	-	-	-	Z

Bit 0 Zero Set if NMEA buffer is empty.
 Clear if at least one NMEA sentence is available in the buffer.

SERIN, 6

Transfer NMEA sentence to string buffer. This instruction transfers the next NMEA sentence to the string buffer, and selects the first field of the string so that a `STRCMP` instruction can be used to check the sentence type. If the sentence is valid, the status byte is set to 0x80 and the greater-than (GT) test condition will be true. If an error occurs, the status byte will be set to 0x82, 0x92, 0xA2, or 0xB2. Bit 4 of the status byte is set if an overrun error occurred. Bit 5 of the status byte is set if a checksum error occurred. The less-than (LT) test condition will be true for all errors. If this instruction is the last instruction in the instruction buffer, it will wait for the next available NMEA sentence. If there are other instructions in the instruction buffer, or another instruction is sent before the `SERIN, 6` instruction has completed, it will terminate and return an empty sentence.

Bit	7	6	5	4	3	2	1	0
	1	-	C	V	-	-	S	-

Bit 5 Checksum error Set if checksum error occurred
 Bit 4 Overrun Set if overrun occurred
 Bit 1 Sign Set if error occurred

SEROUT**Serial Output***(new V3.1)*

Opcode:

CE bb

where: bb specifies the type of operation

CE bb bd

bd specifies the I/O mode and baud rate

CE bb aa...00

aa...00 is a zero-terminated string

Description:

This instruction is used to set the serial input/output mode and baud rate, and to send serial data to the SEROUT pin. The operation to be performed is specified by the byte immediately following the opcode:

- 0 Set serial I/O mode and baud rate
- 1 Send text string to serial output
- 2 Send string buffer to serial output
- 3 Send string selection to serial output
- 4 Send lower 8 bits of register 0 to serial output
- 5 Send text string and zero terminator to serial output

SEROUT, 0, bb

This instruction sets the baud rate for serial input/output, and enables or disables Debug Mode.

The mode is specified by the byte immediately following the operation type:

- 0 57,600 baud, Debug Mode enabled
- 1 300 baud, Debug Mode disabled
- 2 600 baud, Debug Mode disabled
- 3 1200 baud, Debug Mode disabled
- 4 2400 baud, Debug Mode disabled
- 5 4800 baud, Debug Mode disabled
- 6 9600 baud, Debug Mode disabled
- 7 19200 baud, Debug Mode disabled
- 8 38400 baud, Debug Mode disabled
- 9 57600 baud, Debug Mode disabled
- 10 115200 baud, Debug Mode disabled

For mode 0, a {DEBUG ON} message is sent to the serial output and the baud rate is changed.

For modes 1 to 10, if the debug mode is enabled, a {DEBUG OFF} message is sent to the serial output before the baud rate is changed.

SEROUT, 1, aa...00

The text string specified by the instruction (not including the zero-terminator) is sent to the serial output. The instruction is ignored if Debug Mode is enabled.

SEROUT, 2

The contents of the string buffer are sent to the serial output. The instruction is ignored if Debug Mode is enabled.

SEROUT, 3

The current string selection is sent to the serial port. The instruction is ignored if Debug Mode is enabled.

SEROUT, 4

The lower 8 bits of register 0 are sent to the serial port as an 8-bit character. The instruction is ignored if Debug Mode is enabled.

SEROUT, 5, aa. . 00

The text string specified by the instruction (including the zero-terminator) is sent to the serial output. The instruction is ignored if Debug Mode is enabled.

SETOUT Set output

Opcode: D0 nn where: nn is a command byte

Description: Set the OUT0 or OUT1 output pin according to the command byte nn as follows:

Bit 7 6 5 4 3 2 1 0

Pin	Action
-----	--------

Bits 7:4 Output pin (upper nibble)

0 - OUT 0

1 - OUT 1

Bits 3:0 Action (lower nibble)

0 - set output low

1 - set output high

2 - toggle the output to opposite level

3 - set output to high impedance

SETSTATUS Set status byte

(new V3.1)

Opcode: CD bb where: ss is status value

Description: status = bb

The internal status byte is set to the 8-bit value specified.

SIN Sine

Opcode: 47

Description: $\text{reg}[A] = \sin(\text{reg}[A])$

Calculates the sine of the angle (in radians) in register A and stores the result in register A.

Special Cases: • if A is NaN or an infinity, then the result is NaN

• if A is 0.0, then the result is 0.0

• if A is -0.0, then the result is -0.0

SQRT Square root

Opcode: 41

Description: $\text{reg}[A] = \text{sqrt}(\text{reg}[A])$

Calculates the square root of the floating point value in register A and stores the result in register A.

Special Cases: • if the value is NaN or less than zero, then the result is NaN

• if the value is +infinity, then the result is +infinity

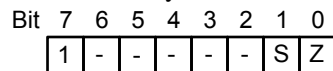
• if the value is 0.0 or -0.0, then the result is 0.0 or -0.0

STRBYTE **Insert byte at string selection** *(new V3.1)*
Opcode: ED

Description: The lower 8 bits of register 0 are stored as an 8-bit character in the string buffer at the current selection point. The selection point is updated to point immediately after the stored byte, so multiple bytes can be appended.

STRCMP **Compare string with string selection**
Opcode: E6 aa...00 where: aa...00 is a zero-terminated string

Description: status = longstatus of string compare
The string is compared with the string at the current selection point and the internal status byte is set. The status byte can be read with the READSTATUS instruction. It is set as follows:



Bit 1 Sign Set if string selection < specified string
Bit 0 Zero Set if string selection = specified string
If neither Bit 0 or Bit 1 is set, string selection > specified string

STRDEC **Decrement string selection point** *(new V3.1)*
Opcode: EF

Description: The string selection point is decremented and the selection length is set to zero.

Special Cases: • the selection point will not decrement past the beginning of the string

STRFCHR **Set field separator characters**
Opcode: E8 aa...00 where: aa...00 is a zero-terminated string

Description: The string specifies a list of characters (maximum of 6) to be used as field separators. The default field separator is a comma.

STRFIELD **Find field in string** *(modified V3.1)*
Opcode: E9 bb where: bb is the field number

Description: The selection point is set to the specified field. Fields are numbered from 1 to n, and are separated by the characters specified by the last STRFCHR instruction. If no STRFCHR instruction has been executed, the default field separator is a comma. If bit 7 of bb is set, then bits 6:0 of bb specify a register number, and the lower 8 bits of the register specify the field number.

Special Cases: • if bb = 0, selection point is set to the start of the string buffer
• if bb > number of fields, selection point is set to the end of the string buffer

STRFIND **Find string in the string selection** *(modified V3.1)*
Opcode: E7 aa...00 where: aa...00 is a zero-terminated string

Description: Search the string selection for the first occurrence of the specified string. If the string is found, the

selection point is set to the matching substring. If the string is not found, the selection point is set to the end of the string selection.

STRINC **Increment string selection point** *(new V3.1)*

Opcode: EE

Description: The string selection point is incremented and the selection length is set to zero.

Special Cases: • the selection point will not increment past the end of the string

STRINS **Insert string**

Opcode: E5 aa...00 where: aa...00 is a zero-terminated string

Description: Insert the string in the string buffer at the current selection point. The selection point is updated to point immediately after the inserted string, so multiple insertions can be appended.

STRSEL **Set string selection point** *(modified V3.1)*

Opcode: E4 nn mm where: nn is the start of the selection
 mm is the length of the selection

Description: Set the start of the string selection to character nn and the length of the selection to mm characters. Characters are numbered from 0 to n. If bit 7 of nn is set, then bits 6:0 of nn specify a register number, and the lower 8 bits of the register specify the start of the selection. If bit 7 of mm is set, then bits 6:0 of mm specify a register number, and the lower 8 bits of the register specify the length of the selection.

Special Cases: • if nn > string length, start of selection is set to end of string
 • if nn+mm > string length, selection is adjusted for the end of string

STRSET **Copy string to string buffer**

Opcode: E3 aa...00 where: aa...00 is a zero-terminated string

Description: Copy the string to the string buffer and set the selection point to the end of the string.

Special Cases: • if nn > string length, only the first 127 characters will be stored in string buffer.

STRTOF **Convert string selection to floating point**

Opcode: EA

Description: Convert the string at the current selection point to a floating point value and store the result in register 0.

STRTOL **Convert string selection to long integer**

Opcode: EB

Description: Convert the string at the current selection point to a long integer value and store the result in register 0.

SWAP	Swap registers	
Opcode:	12 nn mm	where: nn and mm are register numbers
Description:	tmp = reg[nn], reg[nn] = reg[mm], reg[mm] = tmp The values of register nn and register mm are swapped.	

SWAPA	Swap register A	
Opcode:	13 nn	where: nn is a register number
Description:	tmp = reg[nn], reg[nn] = reg[A], reg[A] = tmp The values of register nn and register A are swapped.	

SYNC	Synchronization	
Opcode:	F0	
Returns:	5C	
Description:	A sync character (0x5C) is sent in reply. This instruction is typically used after a reset to verify communications.	

TABLE	Table lookup	
Opcode:	85 tc t1...tn	where: tc is the size of the table t1...tn are 32-bit floating point or integer values
Description:	reg[A] = value from table indexed by reg[0] This opcode is only valid within a user function stored in the uM-FPU Flash memory or EEPROM memory. The value of the item in the table, indexed by register 0, is stored in register A. The first byte after the opcode specifies the size of the table, followed by groups of four bytes representing the 32-bit values for each item in the table. This instruction can be used to load either floating point values or long integer values. The long integer value in register 0 is used as an index into the table. The index number for the first table entry is zero.	
Special Cases:	<ul style="list-style-type: none"> • if reg[0] <= 0, then the result is item 0 • if reg[0] > maximum size of table, then the result is the last item in the table 	

TAN	Tangent	
Opcode:	49	
Description:	reg[A] = tan(reg[A]) Calculates the tangent of the angle (in radians) in register A and stores the result in register A.	
Special Cases:	<ul style="list-style-type: none"> • if reg[A] is NaN or an infinity, then the result is NaN • if reg[A] is 0.0, then the result is 0.0 • if reg[A] is -0.0, then the result is -0.0 	

TICKLONG	Load register 0 with millisecond ticks	
Opcode:	D9	
Description:	reg[0] = ticks, status = longstatus(reg[0]) Load register 0 with the ticks (in milliseconds).	

TIMELONG Load register 0 with time value in seconds

Opcode: D8

Operation: reg[0] = time, status = longstatus(reg[0])

Description: Load register 0 with the time (in seconds).

TIMESET Set time value in seconds

Opcode: D7

Description: time = reg[0], ticks = 0

The time (in seconds) is set from the value in register 0. The ticks (in milliseconds) is set to zero.

Special Cases: • if reg[0] is -1, the timer is turned off.

TRACEOFF Turn debug trace off

Opcode: F8

Description: Used with the built-in debugger. If the debugger is not enabled, this instruction is ignored. Debug tracing is turned off, and a {TRACE OFF} message is sent to the serial output.

TRACEON Turn debug trace on

Opcode: F9

Description: Used with the built-in debugger. If the debugger is not enabled, this instruction is ignored. Debug tracing is turned on, and a {TRACE ON} message is sent to the serial output. The debug terminal will display a trace of all instructions executed until tracing is turned off.

TRACEREG Display register value in debug trace

Opcode: FB nn where: nn is a register number

Description: Used with the built-in debugger. If the debugger is not enabled, this instruction is ignored. If the debugger is enabled, the value of register nn will be displayed on the debug terminal.

TRACESTR Display debug trace message

Opcode: FA aa...00 where: aa...00 is a zero-terminated string

Description: Used with the built-in debugger. If the debugger is not enabled, this instruction is ignored. If the debugger is enabled, a message will be displayed on the debug terminal. The zero terminated ASCII string to be displayed is sent immediately following the opcode.

VERSION Copy the version string to the string buffer*(modified V3.1)*

Opcode: F3

Description: The uM-FPU V3.1 version string is copied to the string buffer at the current selection point, and the version code is copied to register 0. The version code is represented as follows:

Bit 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0

3	Major	Minor	Beta
---	-------	-------	------

Bits 15:12 Chip Version (always set to 3)

Bits 11:8 Major Version

Appendix A

uM-FPU V3.1 Instruction Summary

Instruction	Opcode	Arguments	Returns	Description
NOP	00			No Operation
SELECTA	01	nn		Select register A
SELECTX	02	nn		Select register X
CLR	03	nn		reg[nn] = 0
CLRA	04			reg[A] = 0
CLR _X	05			reg[X] = 0, X = X + 1
CLR ₀	06			reg[0] = 0
COPY	07	mm, nn		reg[nn] = reg[mm]
COPYA	08	nn		reg[nn] = reg[A]
COPYX	09	nn		reg[nn] = reg[X], X = X + 1
LOAD	0A	nn		reg[0] = reg[nn]
LOADA	0B			reg[0] = reg[A]
LOADX	0C			reg[0] = reg[X], X = X + 1
ALOADX	0D			reg[A] = reg[X], X = X + 1
XSAVE	0E	nn		reg[X] = reg[nn], X = X + 1
XSAVEA	0F			reg[X] = reg[A], X = X + 1
COPY ₀	10	nn		reg[nn] = reg[0]
COPY _I	11	bb, nn		reg[nn] = long(unsigned byte bb)
SWAP	12	nn, mm		Swap reg[nn] and reg[mm]
SWAPA	13	nn		Swap reg[nn] and reg[A]
LEFT	14			Left parenthesis
RIGHT	15			Right parenthesis
FWRITE	16	nn, b1, b2, b3, b4		Write 32-bit floating point to reg[nn]
FWRITEA	17	b1, b2, b3, b4		Write 32-bit floating point to reg[A]
FWRITE _X	18	b1, b2, b3, b4		Write 32-bit floating point to reg[X]
FWRITE ₀	19	b1, b2, b3, b4		Write 32-bit floating point to reg[0]
FREAD	1A	nn	b1, b2, b3, b4	Read 32-bit floating point from reg[nn]
FREADA	1B		b1, b2, b3, b4	Read 32-bit floating point from reg[A]
FREADX	1C		b1, b2, b3, b4	Read 32-bit floating point from reg[X]
FREAD ₀	1D		b1, b2, b3, b4	Read 32-bit floating point from reg[0]
A _{TOF}	1E	aa...00		Convert ASCII to floating point
F _{TOA}	1F	bb		Convert floating point to ASCII
FSET	20	nn		reg[A] = reg[nn]
FADD	21	nn		reg[A] = reg[A] + reg[nn]
F _{SUB}	22	nn		reg[A] = reg[A] - reg[nn]
F _{SUBR}	23	nn		reg[A] = reg[nn] - reg[A]
F _{MUL}	24	nn		reg[A] = reg[A] * reg[nn]
F _{DIV}	25	nn		reg[A] = reg[A] / reg[nn]
F _{DIVR}	26	nn		reg[A] = reg[nn] / reg[A]
F _{POW}	27	nn		reg[A] = reg[A] ** reg[nn]
F _{CMP}	28	nn		Compare reg[A], reg[nn], Set floating point status
F _{SET0}	29			reg[A] = reg[0]
F _{ADD0}	2A			reg[A] = reg[A] + reg[0]
F _{SUB0}	2B			reg[A] = reg[A] - reg[0]

FSUBR0	2C			$\text{reg}[A] = \text{reg}[0] - \text{reg}[A]$
FMUL0	2D			$\text{reg}[A] = \text{reg}[A] * \text{reg}[0]$
FDIV0	2E			$\text{reg}[A] = \text{reg}[A] / \text{reg}[0]$
FDIVR0	2F			$\text{reg}[A] = \text{reg}[0] / \text{reg}[A]$
FPOW0	30			$\text{reg}[A] = \text{reg}[A] ** \text{reg}[0]$
FCMP0	31			Compare $\text{reg}[A]$, $\text{reg}[0]$, Set floating point status
FSETI	32	bb		$\text{reg}[A] = \text{float}(bb)$
FADDI	33	bb		$\text{reg}[A] = \text{reg}[A] - \text{float}(bb)$
FSUBI	34	bb		$\text{reg}[A] = \text{reg}[A] - \text{float}(bb)$
FSUBRI	35	bb		$\text{reg}[A] = \text{float}(bb) - \text{reg}[A]$
FMULI	36	bb		$\text{reg}[A] = \text{reg}[A] * \text{float}(bb)$
FDIVI	37	bb		$\text{reg}[A] = \text{reg}[A] / \text{float}(bb)$
FDIVRI	38	bb		$\text{reg}[A] = \text{float}(bb) / \text{reg}[A]$
FPOWI	39	bb		$\text{reg}[A] = \text{reg}[A] ** bb$
FCMPI	3A	bb		Compare $\text{reg}[A]$, $\text{float}(bb)$, Set floating point status
FSTATUS	3B	nn		Set floating point status for $\text{reg}[nn]$
FSTATUSA	3C			Set floating point status for $\text{reg}[A]$
FCMP2	3D	nn, mm		Compare $\text{reg}[nn]$, $\text{reg}[mm]$ Set floating point status
FNEG	3E			$\text{reg}[A] = -\text{reg}[A]$
FABS	3F			$\text{reg}[A] = \text{reg}[A] $
FINV	40			$\text{reg}[A] = 1 / \text{reg}[A]$
SQRT	41			$\text{reg}[A] = \text{sqrt}(\text{reg}[A])$
ROOT	42	nn		$\text{reg}[A] = \text{root}(\text{reg}[A], \text{reg}[nn])$
LOG	43			$\text{reg}[A] = \text{log}(\text{reg}[A])$
LOG10	44			$\text{reg}[A] = \text{log}_{10}(\text{reg}[A])$
EXP	45			$\text{reg}[A] = \text{exp}(\text{reg}[A])$
EXP10	46			$\text{reg}[A] = \text{exp}_{10}(\text{reg}[A])$
SIN	47			$\text{reg}[A] = \text{sin}(\text{reg}[A])$
COS	48			$\text{reg}[A] = \text{cos}(\text{reg}[A])$
TAN	49			$\text{reg}[A] = \text{tan}(\text{reg}[A])$
ASIN	4A			$\text{reg}[A] = \text{asin}(\text{reg}[A])$
ACOS	4B			$\text{reg}[A] = \text{acos}(\text{reg}[A])$
ATAN	4C			$\text{reg}[A] = \text{atan}(\text{reg}[A])$
ATAN2	4D	nn		$\text{reg}[A] = \text{atan}_{2}(\text{reg}[A], \text{reg}[nn])$
DEGREES	4E			$\text{reg}[A] = \text{degrees}(\text{reg}[A])$
RADIANS	4F			$\text{reg}[A] = \text{radians}(\text{reg}[A])$
FMOD	50	nn		$\text{reg}[A] = \text{reg}[A] \text{ MOD } \text{reg}[nn]$
FLOOR	51			$\text{reg}[A] = \text{floor}(\text{reg}[A])$
CEIL	52			$\text{reg}[A] = \text{ceil}(\text{reg}[A])$
ROUND	53			$\text{reg}[A] = \text{round}(\text{reg}[A])$
FMIN	54	nn		$\text{reg}[A] = \text{min}(\text{reg}[A], \text{reg}[nn])$
FMAX	55	nn		$\text{reg}[A] = \text{max}(\text{reg}[A], \text{reg}[nn])$
FCNV	56	bb		$\text{reg}[A] = \text{conversion}(bb, \text{reg}[A])$
FMAC	57	nn, mm		$\text{reg}[A] = \text{reg}[A] + (\text{reg}[nn] * \text{reg}[mm])$
FMSC	58	nn, mm		$\text{reg}[A] = \text{reg}[A] - (\text{reg}[nn] * \text{reg}[mm])$
LOADBYTE	59	bb		$\text{reg}[0] = \text{float}(\text{signed } bb)$
LOADUBYTE	5A	bb		$\text{reg}[0] = \text{float}(\text{unsigned byte})$

LOADWORD	5B	b1, b2		reg[0] = float(signed b1*256 + b2)
LOADUWORD	5C	b1, b2		reg[0] = float(unsigned b1*256 + b2)
LOADE	5D			reg[0] = 2.7182818
LOADPI	5E			reg[0] = 3.1415927
LOADCON	5F	bb		reg[0] = float constant(bb)
FLOAT	60			reg[A] = float(reg[A])
FIX	61			reg[A] = fix(reg[A])
FIXR	62			reg[A] = fix(round(reg[A]))
FRAC	63			reg[A] = fraction(reg[A])
FSPLIT	64			reg[A] = integer(reg[A]), reg[0] = fraction(reg[A])
SELECTMA	65	nn, bb, bb		Select matrix A
SELECTMB	66	nn, bb, bb		Select matrix B
SELECTMC	67	nn, bb, bb		Select matrix C
LOADMA	68	bb, bb		reg[0] = Matrix A[bb, bb]
LOADMB	69	bb, bb		reg[0] = Matrix B[bb, bb]
LOADMC	6A	bb, bb		reg[0] = Matrix C[bb, bb]
SAVEMA	6B	bb, bb		Matrix A[bb, bb] = reg[0]
SAVEMB	6C	bb, bb		Matrix B[bb, bb] = reg[0]
SAVEMC	6D	bb, bb		Matrix C[bb, bb] = reg[0]
MOP	6E	bb		Matrix/Vector operation
FFT	6F	bb		Fast Fourier Transform
WRBLK	70	tc, t1...tn		Write multiple 32-bit values
RDBLK	71	tc	t1...tn	Read multiple 32-bit values
LOADIND	7A	nn		reg[0] = reg[reg[nn]]
SAVEIND	7B	nn		reg[reg[nn]] = reg[A]
INDA	7C	nn		Select register A using value in reg[nn]
INDX	7D	nn		Select register X using value in reg[nn]
FCALL	7E	fn		Call user-defined function in Flash
EECALL	7F	fn		Call user-defined function in EEPROM
RET	80			Return from user-defined function
BRA	81	bb		Unconditional branch
BRA, cc	82	cc, bb		Conditional branch
JMP	83	b1, b2		Unconditional jump
JMP, cc	84	cc, b1, b2		Conditional jump
TABLE	85	tc, t1...tn		Table lookup
FTABLE	86	cc, tc, t1...tn		Floating point reverse table lookup
LTABLE	87	cc, tc, t1...tn		Long integer reverse table lookup
POLY	88	tc, t1...tn		reg[A] = nth order polynomial
GOTO	89	nn		Computed GOTO
RET, cc	8A	cc		Conditional return from user-defined function
LWRITE	90	nn, b1, b2, b3, b4		Write 32-bit long integer to reg[nn]
LWRITEA	91	b1, b2, b3, b4		Write 32-bit long integer to reg[A]
LWRITEX	92	b1, b2, b3, b4		Write 32-bit long integer to reg[X], X = X + 1
LWRITE0	93	b1, b2, b3, b4		Write 32-bit long integer to reg[0]
LREAD	94	nn	b1, b2, b3, b4	Read 32-bit long integer from reg[nn]
LREADA	95		b1, b2, b3, b4	Read 32-bit long value from reg[A]

LREADX	96		b1 , b2 , b3 , b4	Read 32-bit long integer from reg[X], X = X + 1
LREAD0	97		b1 , b2 , b3 , b4	Read 32-bit long integer from reg[0]
LREADBYTE	98		bb	Read lower 8 bits of reg[A]
LREADWORD	99		b1 , b2	Read lower 16 bits reg[A]
ATOL	9A	aa...00		Convert ASCII to long integer
LTOA	9B	bb		Convert long integer to ASCII
LSET	9C	nn		reg[A] = reg[nn]
LADD	9D	nn		reg[A] = reg[A] + reg[nn]
LSUB	9E	nn		reg[A] = reg[A] - reg[nn]
LMUL	9F	nn		reg[A] = reg[A] * reg[nn]
LDIV	A0	nn		reg[A] = reg[A] / reg[nn] reg[0] = remainder
LCMP	A1	nn		Signed compare reg[A] and reg[nn], Set long integer status
LUDIV	A2	nn		reg[A] = reg[A] / reg[nn] reg[0] = remainder
LUCMP	A3	nn		Unsigned compare reg[A] and reg[nn], Set long integer status
LTST	A4	nn		Test reg[A] AND reg[nn], Set long integer status
LSET0	A5			reg[A] = reg[0]
LADD0	A6			reg[A] = reg[A] + reg[0]
LSUB0	A7			reg[A] = reg[A] - reg[0]
LMUL0	A8			reg[A] = reg[A] * reg[0]
LDIV0	A9			reg[A] = reg[A] / reg[0] reg[0] = remainder
LCMP0	AA			Signed compare reg[A] and reg[0], set long integer status
LUDIV0	AB			reg[A] = reg[A] / reg[0] reg[0] = remainder
LUCMP0	AC			Unsigned compare reg[A] and reg[0], Set long integer status
LTST0	AD			Test reg[A] AND reg[0], Set long integer status
LSETI	AE	bb		reg[A] = long(bb)
LADDI	AF	bb		reg[A] = reg[A] + long(bb)
LSUBI	B0	bb		reg[A] = reg[A] - long(bb)
LMULI	B1	bb		reg[A] = reg[A] * long(bb)
LDIVI	B2	bb		reg[A] = reg[A] / long(bb) reg[0] = remainder
LCMPI	B3	bb		Signed compare reg[A] - long(bb), Set long integer status
LUDIVI	B4	bb		reg[A] = reg[A] / unsigned long(bb) reg[0] = remainder
LUCMPI	B5	bb		Unsigned compare reg[A] and long(bb), Set long integer status
LTSTI	B6	bb		Test reg[A] AND long(bb), Set long integer status
LSTATUS	B7	nn		Set long integer status for reg[nn]
LSTATUSA	B8			Set long integer status for reg[A]

LCMP2	B9	nn, mm		Signed long compare reg[nn], reg[mm] Set long integer status
LUCMP2	BA	nn, mm		Unsigned long compare reg[nn], reg[mm] Set long integer status
LNEG	BB			reg[A] = -reg[A]
LABS	BC			reg[A] = reg[A]
LINC	BD	nn		reg[nn] = reg[nn] + 1, set status
LDEC	BE	nn		reg[nn] = reg[nn] - 1, set status
LNOT	BF			reg[A] = NOT reg[A]
LAND	C0	nn		reg[A] = reg[A] AND reg[nn]
LOR	C1	nn		reg[A] = reg[A] OR reg[nn]
LXOR	C2	nn		reg[A] = reg[A] XOR reg[nn]
LSHIFT	C3	nn		reg[A] = reg[A] shift reg[nn]
LMIN	C4	nn		reg[A] = min(reg[A], reg[nn])
LMAX	C5	nn		reg[A] = max(reg[A], reg[nn])
LONGBYTE	C6	bb		reg[0] = long(signed byte bb)
LONGUBYTE	C7	bb		reg[0] = long(unsigned byte bb)
LONGWORD	C8	b1, b2		reg[0] = long(signed b1*256 + b2)
LONGUWORD	C9	b1, b2		reg[0] = long(unsigned b1*256 + b2)
SETSTATUS	CD	ss		Set status byte
SEROUT	CE	bb bb, bd bb, aa...00		Serial output
SERIN	CF	bb		Serial input
SETOUT	D0	bb		Set OUT1 and OUT2 output pins
ADCMODE	D1	bb		Set A/D trigger mode
ADCTRIG	D2			A/D manual trigger
ADCSCALE	D3	ch		ADCscale[ch] = reg[0]
ADCLONG	D4	ch		reg[0] = ADCvalue[ch]
ADCLOAD	D5	ch		reg[0] = float(ADCvalue[ch]) * ADCscale[ch]
ADCWAIT	D6			wait for next A/D sample
TIMESET	D7			time = reg[0]
TIMELONG	D8			reg[0] = time (long integer)
TICKLONG	D9			reg[0] = ticks (long integer)
EESAVE	DA	nn, ee		EEPROM[ee] = reg[nn]
EESAVEA	DB	ee		EEPROM[ee] = reg[A]
EELOAD	DC	nn, ee		reg[nn] = EEPROM[ee]
EELOADA	DD	ee		reg[A] = EEPROM[ee]
EEWRITE	DE	ee, bc, b1...bn		Store bytes starting at EEPROM[ee]
EXTSET	E0			external input count = reg[0]
EXTLONG	E1			reg[0] = external input counter
EXTWAIT	E2			wait for next external input
STRSET	E3	aa...00		Copy string to string buffer
STRSEL	E4	bb, bb		Set selection point
STRINS	E5	aa...00		Insert string at selection point
STRCMP	E6	aa...00		Compare string with string selection
STRFIND	E7	aa...00		Find string
STRFCHR	E8	aa...00		Set field separators
STRFIELD	E9	bb		Find field

STRTOF	EA			Convert string selection to floating point
STRTOL	EB			Convert string selection to long integer
READSEL	EC		aa...00	Read string selection
STRBYTE	ED			Insert byte at selection point
STRINC	EE			Increment string selection point
STRDEC	EF			Decrement string selection point
SYNC	F0		5C	Get synchronization byte
READSTATUS	F1		ss	Read status byte
READSTR	F2		aa...00	Read string from string buffer
VERSION	F3			Copy version string to string buffer
IEEEMODE	F4			Set IEEE mode (default)
PICMODE	F5			Set PIC mode
CHECKSUM	F6			Calculate checksum for uM-FPU code
BREAK	F7			Debug breakpoint
TRACEOFF	F8			Turn debug trace off
TRACEON	F9			Turn debug trace on
TRACESTR	FA	aa...00		Send string to debug trace buffer
TRACEREG	FB	nn		Send register value to trace buffer
READVAR	FC	bb		Read internal register value
RESET	FF			Reset (9 consecutive FF bytes cause a reset, otherwise it is a NOP)

Notes:

Opcode	Opcode value in hexadecimal
Arguments	Additional data required by instruction
Returns	Data returned by instruction
nn	register number (0-127)
mm	register number (0-127)
fn	function number (0-63)
bb	8-bit value
b1,b2	16-bit value (b1 is MSB)
b1,b2,b3,b4	32-bit value (b1 is MSB)
b1...bn	string of 8-bit bytes
ss	Status byte
bd	baud rate and debug mode
cc	Condition code
ee	EEPROM address slot (0-255)
ch	A/D channel number
bc	Byte count
tc	32-bit value count
t1...tn	String of 32-bit values
aa...00	Zero terminated ASCII string