Micromega Corporation

Using uM-FPU V3.1 with the OOPic® Microcontrollers

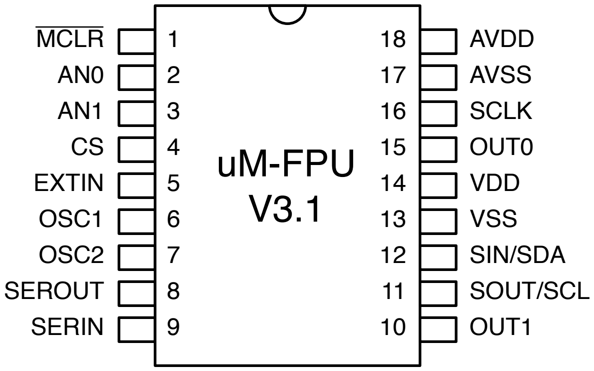
Introduction

The uM-FPU V3.1 chip is a 32-bit floating point coprocessor that can be easily interfaced with the OOPic® microcontroller to provide support for 32-bit IEEE 754 floating point operations and 32-bit long integer operations.

This document describes how to use the uM-FPU V3.1 chip with the OOPic. For a full description of the uM-FPU V3.1 chip, please refer to the *uM-FPU V3.1 Datasheet* and *uM-FPU V3.1 Instruction Reference*. Application notes and sample code are also available on the Micromega website.

uM-FPU V3.1 Pin Diagram and Pin Description

DIP-18, SOIC-18

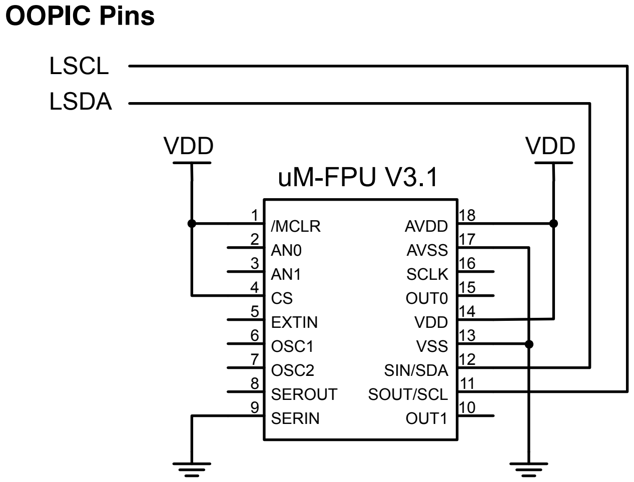


Pin	Name	Type	Description
1	/MCLR	Input	Master Clear (Reset)
2	AN0	Input	Analog Input 0
3	AN1	Input	Analog Input 1
4	CS	Input	Chip Select, Interface Select
5	EXTIN	Input	External Input
6	OSC1	Input	Oscillator Crystal (optional)
7	OSC2	Output	Oscillator Crystal (optional)
8	SEROUT	Output	Serial Output, Debug Monitor - Tx
9	SERIN	Input	Serial Input, Debug Monitor - Rx
10	OUT1	Output	Digital Output 1
11	SOUT SCL	Output Input	SPI Output, Busy/Ready Status I^{2}C Clock
12	SIN SDA	Input In/Out	SPI Input I^{2}C Data

13	VSS	Power	Digital Ground
14	VDD	Power	Digital Supply Voltage
15	OUT0	Output	Digital Output 0
16	SCLK	Input	SPI Clock
17	AVSS	Power	Analog Ground
18	AVDD	Power	Analog Supply Voltage

Connecting the OOPIC using I^{2}C

The uM-FPU is interfaced to the OOPic using the local I2C bus with a default node address of 100. The connection is as follows:



Brief Overview of the uM-FPU V3.1 Floating Point Coprocessor

For a full description of the uM-FPU V3.1 chip, please refer to the *uM-FPU V3.1 Datasheet*, *uM-FPU V3.1 Instruction Reference*. Application notes are also available on the Micromega website.

The uM-FPU V3.1 chip is a separate coprocessor with its own set of registers and instructions designed to provide microcontrollers with 32-bit floating point and long integer capabilities. The OOPic communicates with the FPU using an I^2C interface. Instructions and data are sent to the FPU, and the FPU performs the calculations. The OOPic is free to do other tasks while the FPU performs calculations. Results can be read back to the OOPic or stored on the FPU for later use. The uM-FPU V3.1 chip has 128 registers, numbered 0 through 127, that can hold 32-bit floating point or 32-bit long integer values. Register 0 is often used as a temporary register and is modified by some of the uM-FPU V3.1 instructions. Registers 1 through 127 are available for general use.

The `SELECTA` instruction is used to select any one of the 128 registers as register A. Register A can be regarded as an accumulator or working register. Arithmetic instructions use the value in register A as an operand and store the result of the operation in register A. If an instruction requires more than one operand, the additional operands are specified by the instruction. The following example selects register 2 as register A and adds register 5 to it:

`SELECTA, 2`	select register 2 as register A
`FSET, 5`	register[A] = register[A] + register[5]

Sending Instructions to the FPU

Appendix A contains a table that gives a summary of the uM-FPU V3.1 instructions, with enough information to follow the examples in this document. For a detailed description of each instruction, refer to the *uM-FPU V3.1 Instruction Reference*.

The OOPic communicates with the FPU using the local I^2C bus. The `Fpu` object (an instance of the `oI2C` object) is used to communicate with the FPU. Several procedures and functions are defined by the support software for interacting with the FPU. The `fpuReset` function must be called at the start of each program. It initializes the properties of the `Fpu` object with the required I^2C parameters and resets the uM-FPU V3.1 chip.

To send instructions to the uM-FPU, the `Fpu` object is used as follows:

```
Fpu = FADD
Fpu = 5
```

The `Fpu` object is configured to accept byte value. To send a word value, the high byte is sent first, followed by the low byte.

```
Fpu = LOADWORD
Fpu = dataWord/256
Fpu = dataWord
```

All instructions have an opcode that tells the FPU which operation to perform. The following example calculates the square root of register A:

```
Fpu = SQRT
```

Some instructions require additional operands or data. These are specified by the bytes following the opcode. The following example adds register 5 to register A.

```
Fpu = FADD
Fpu = 5
```

Some instructions return data. This example reads the lower 8 bits of register A:

```
Fpu = LREADBYTE
Call fpuWait
dataByte = Fpu
```

The following example adds the value in register 5 to the value in register 2.

```
Fpu = SELECTA
Fpu = 2
Fpu = FADD
Fpu = 5
```

It's a good idea to use constant definitions to provide meaningful names for the registers. This makes your program code easier to read and understand. The same example using constant definitions would be:

```
Const Total = 2              ' total amount  (uM-FPU register)
Const Count = 5              ' current count (uM-FPU register)

Fpu = SELECTA                ' select Total as register A
Fpu = Total
Fpu = FADD                   ' add value of Count register to Total
Fpu = Count
```

Tutorial Examples

Now that we've introduced some of the basic concepts of sending instructions to the uM-FPU, let's go through a tutorial example to get a better understanding of how it all ties together. This example takes a temperature reading from a DS1620 digital thermometer and converts it to Celsius and Fahrenheit.

Most of the data read from devices connected to the OOPic will return some type of integer value. In this example, the interface routine for the DS1620 reads a 9-bit value and stores it in an OOPic variable called `rawTemp`. The value returned by the DS1620 is the temperature in units of 1/2 degrees Celsius. The following instructions load the `rawTemp` value to the uM-FPU, convert the value to floating point, then divides the value by 2 to get degrees in Celsius.

```
Fpu = SELECTA                 ' select DegC as register A
Fpu = DegC
Fpu = LOADWORD                ' load 16-bit value in rawTemp to register 0
Fpu = rawTemp/256             ‘ and convert to floating point
Fpu = rawTemp
Fpu = FSET0                   ' set DegC to value in register 0
Fpu = FDIVI                   ' divide by 2
Fpu = 2
```

To get degrees in Fahrenheit we use the formula F = C * 1.8 + 32. Since 1.8 is a floating point constant, it would often be loaded once in the initialization section of the program and used later in the program. The value 1.8 can be loaded using the ATOF instruction as follows:

```
Fpu = SELECTA                 ' select F1_8 as register A
Fpu = F1_8
Fpu = ATOF
FpuBuffer.String = "1.8"      ' load string to uM-FPU, convert to floating point
Call fpuWriteString           ' and store in register 0
Fpu = FSET0                   ' set F1_8 to value in register 0
```

Degrees in Fahrenheit (F = C * 1.8 + 32) is calculated as follows:

```
Fpu = SELECTA                 ' select degF as register A
Fpu = DegF
Fpu = FSET                    ' degF = degC
Fpu = DegC
Fpu = FMUL                    ' DegF = DegF * F1_8
Fpu = F1_8
Fpu = FADDI                   ' DegF = DegF + 32
Fpu = 32
```

Note: this tutorial example is intended to show how to perform a familiar calculation, but the `FCNV` instruction can be used to perform unit conversions in one step. See the *uM-FPU V3.1 Instruction Reference* for a full list of conversions.

Procedures are provided for printing floating point and long integer numbers. `printFloat` prints an unformatted floating point value with up to eight digits of precision, or a formatted floating point number. The desired format is specified by an argument passed to the procedure. The tens digit specifying the total number of characters to display, and the ones digit specifying the number of digits after the decimal point. The DS1620 has a maximum temperature of 125° Celsius and one decimal point of precision, so we'll use a format of 51. The following example prints the temperature in degrees Celsius and Fahrenheit.

```
Fpu = SELECTA
Fpu = DegC
Call printFloat(51)

Fpu = SELECTA
Fpu = DegF
Call printFloat(51)
```

Sample code for this tutorial and a wiring diagram for the DS1620 are shown at the end of this document. The files *demo1-LCD.osc* and *demo1_LCDSE.osc* are also included with the support software. A second set of files, *demo2-LCD.osc and demo2-LCDSE.osc,* extend the demo to include minimum and maximum temperature calculations. If you have a DS1620 you can wire up the circuit and try out the demos.

uM-FPU V3.1 Support Software

Template files containing uM-FPU V3.1 opcode definitions and support code are provided as follows:

umfpu-LCD.osc	provides template for using uM-FPU V3.1 with an LCD output
umfpu-LCDSE.osc	provides template for using uM-FPU V3.1 with a Scott Edwards LCD output
umfpu-serial.osc	provides template for using uM-FPU V3.1 with a serial output

These files can be used as the starting point for a new program, or the definitions and support code can be copied to an existing program. The FPU procedures and functions are the same in all files, only the output routines are different. A program can easily be changed from one output device to another (e.g. from LCD to serial output) by simply replacing the print object and print initialization procedure and handling any differences in the positioning of the output.

The template files contain the following:

- opcode definitions for all uM-FPU V3.1 instructions
- definitions for the data objects used by the FPU support routines
- sample program template
- FPU support routines and print routines as described below

fpuReset

This procedure must be called at the start of every program. It initializes the properties of the `Fpu` object with the required I^2C parameters, and resets the uM-FPU V3.1 chip. A sample reset call is included in the template files.

fpuSync

This function confirms communications with the FPU and is usually sent after the `fpuReset` procedure. It sends a `SYNC` instruction, then reading a byte to see if the synchronization code (&h5C) is returned. The function returns `cvTrue` if successful, or `cvFalse` if the synchronization failed. A sample synchronization call is included in the template files.

fpuWait

Before sending an instruction that reads data from the FPU, all previous instructions must be completed, and the FPU must be ready to return data. The `fpuWait` procedure checks the status of the uM-FPU and waits until it is ready. The print routines call `fpuWait`, so it isn't necessary to call `fpuWait` before calling a print routine, but if your program reads directly from the uM-FPU, a call to `fpuWait` must be made prior to reading data. An example of reading a byte value is as follows:

```
call fpuWait                ' wait for the uM-FPU to be ready
Fpu = LREADBYTE             ' send the READBYTE instruction
dataByte = Fpu              ' read the  byte value
```

The uM-FPU V3.1 chip has a 256 byte instruction buffer. In most cases, data will be read back before 256 bytes have been sent to the FPU. If a long calculation is done which requires more than 256 bytes to be sent to the FPU, an `fpuWait` call must be done at least every 256 bytes, to ensure that the instruction buffer doesn't overflow.

fpuWriteString

This procedure sends the string contained in the `FpuBuffer` object to the FPU, followed by a zero terminator.

fpuReadString

This procedure reads a zero-terminated string from the FPU and stores it in the `FpuBuffer` object. The user should ensure that the length of the `FpuBuffer` object is sufficient for the string being read.

printVersion

Prints the FPU version string to the LCD or serial output.

printFloat

The value in register A is displayed on the LCD or serial output as a floating point value. The format is specified by the argument passed to the `printFloat` procedure. If the format byte is zero, up to eight significant digits will be displayed if required. Very large or very small numbers are displayed in exponential notation. The displayed value can be 3 to 12 characters in length. The special cases of NaN (Not a Number), +Infinity, -Infinity, and -0.0 are handled. Examples of the display format are as follows:

```
1.0           NaN           0.0
1.5e20        Infinity      -0.0
3.1415927     -Infinity     1.0
-52.333334    -3.5e-5       0.01
```

If the format parameter is non-zero, the tens digit specifies the total number of characters to display and the ones digit specifies the number of digits after the decimal point. If the value is too large for the format specified, then asterisks will be displayed. If the number of digits after the decimal points is zero, no decimal point will be displayed. Examples of the display format are as follows:

Value in A register	format	Display format
`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`

printLong

The value in register A is displayed on the LCD or serial output as a long integer value. The format is specified by the argument passed to the `printLong` procedure. If the format byte is zero, a signed long integer is displayed. The displayed value can range from 1 to 11 characters in length. Examples of the display format are as follows:

```
1
500000
-3598390
```

If the format parameter is non-zero, and between 1 and 15, it specifies the width of the display field for a signed long integer. The number is displayed right justified. If the format value has 100 added to it, the value is displayed as an unsigned long integer. If the value is larger than the specified width, asterisks will be displayed. If the width is specified as zero, as many digits as necessary will be displayed. Examples of the display format are as follows:

Value in register A	format	Display format
`-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

6               (signed 6)              1000
```

printFpuString

The contents of the FPU string buffer are displayed on the LCD or serial output.

Loading Data Values to the FPU

Most of the data read from devices connected to the OOPic will return some type of integer value. There are several ways to load integer values to the FPU and convert them to 32-bit floating point or long integer values.

8-bit Integer to Floating Point

The `FSETI`, `FADDI`, `FSUBI`, `FSUBRI`, `FMULI`, `FDIVI`, `FDIVRI`, `FPOWI`, and `FCMPI` instructions read the byte following the opcode as an 8-bit signed integer, convert the value to floating point, and then perform the operation. It's a convenient way to work with constants or data values that are signed 8-bit values. The following example stores the lower 8 bits of variable `dataByte` to the `Result` register on the FPU.

```
Fpu = SELECTA
Fpu = Result
Fpu = FSETI
Fpu = dataByte
```

The `LOADBYTE` instruction reads the byte following the opcode as an 8-bit signed integer, converts the value to floating point, and stores the result in register 0.

The `LOADUBYTE` instruction reads the byte following the opcode as an 8-bit unsigned integer, converts the value to floating point, and stores the result in register 0.

16-bit Integer to Floating Point

The `LOADWORD` instruction reads the two bytes following the opcode as a 16-bit signed integer (MSB first), converts the value to floating point, and stores the result in register 0. The following example adds the lower 16 bits of variable `dataWord` to the `Result` register on the FPU.

```
Fpu = SELECTA
Fpu = Result
Fpu = LOADWORD
Fpu = dataWord/256
Fpu = dataWord
Fpu = FADD0
```

The `LOADUWORD` instruction reads the two bytes following the opcode as a 16-bit unsigned integer (MSB first), converts the value to floating point, and stores the result in register 0.

32-bit Integer to Floating Point

A 32-bit integer constant can be written to the FPU, then converted to floating point using the `FLOAT` instruction. The following example sets register 10 to 500000.0.

```
Fpu = SELECTA                   ' select register 10 as register A
Fpu = 10
Fpu = LWRITEA                   ' load 500000 (0007A120 hexadecimal)
Fpu = &h00
Fpu = &h07
Fpu = &hA1
Fpu = &h20
Fpu = FLOAT                     ' convert to floating point
```

The OOPic doesn't have support 32-bit variables, so 32-bit long integer values are stored in 4-byte array objects. The following example writes the 32-bit integer value stored in the `lval` object to register A.

```
Fpu = LWRITEA
```

```
lval.Location = 0
Fpu = lval
lval.Location = 1
Fpu = lval
lval.Location = 2
Fpu = lval
lval.Location = 3
Fpu = lval
```

32-bit Floating Point to Floating point

A 32-bit floating point constant can be written directly to the FPU. This is one of the more efficient ways to load floating point constants, but requires knowledge of the internal representation for floating point numbers (see Appendix B). The *uM-FPU V3 IDE* can be used to easily generate the 32-bit values. This example sets Angle = 20.0 (the floating point representation for 20.0 is $41A00000).

```
Fpu = SELECTA                  ' select Angle as register A
Fpu = Angle
Fpu = LWRITEA                  ' load 500000 (0007A120 hexadecimal)
Fpu = &h41
Fpu = &hA0
Fpu = &h00
Fpu = &h00
```

The OOPic doesn't have support 32-bit variables, so 32-bit floating point values are stored in 4-byte array objects. The following example writes the 32-bit floating point value stored in the `fval` object to register A.

```
Fpu = FWRITEA
fval.Location = 0
Fpu = fval
fval.Location = 1
Fpu = fval
fval.Location = 2
Fpu = fval
fval.Location = 3
Fpu = fval
```

ASCII string to Floating Point

The `ATOF` instruction is used to convert zero-terminated strings to floating point values. The instruction reads the bytes following the opcode (until a zero terminator is read), converts the string to floating point, and stores the result in register 0. The following example sets the register `Angle` to 1.5885.

```
Fpu = SELECTA
Fpu = Angle
Fpu = ATOF
FpuBuffer.String = "1.5885"
Call FpuWriteString
Fpu = FSET0
```

8-bit Integer to Long Integer

The `LSETI`, `LADDI`, `LSUBI`, `LMULI`, `LDIVI`, `LCMPI`, `LUDIVI`, `LUCMPI`, and `LTSTI` instructions read the byte following the opcode as an 8-bit signed integer, convert the value to long integer, and then perform the operation. It's a convenient way to work with constants or data values that are signed 8-bit values. The following example adds the lower 8 bits of variable `dataByte` to the `Total` register on the FPU.

```
Fpu = SELECTA
```

```
Fpu = Total
Fpu = LADDI
Fpu = dataByte
```

The `LONGBYTE` instruction reads the byte following the opcode as an 8-bit signed integer, converts the value to long integer, and stores the result in register 0.

The `LONGUBYTE` instruction reads the byte following the opcode as an 8-bit unsigned integer, converts the value to long integer, and stores the result in register 0.

16-bit Integer to Long Integer

The `LONGWORD` instruction reads the two bytes following the opcode as a 16-bit signed integer (MSB first), converts the value to long integer, and stores the result in register 0. The following example adds the lower 16 bits of variable `dataWord` to the `Total` register on the FPU.

```
Fpu = SELECTA
Fpu = Total
Fpu = LOADWORD
Fpu = dataWord/256
Fpu = dataWord
Fpu = LADD0
```

The `LONGUWORD` instruction reads the two bytes following the opcode as a 16-bit unsigned integer (MSB first), converts the value to long integer, and stores the result in register 0.

32-bit integer to Long Integer

A 32-bit integer constant can be written directly to the FPU. The following example sets register 10 to 500000.

```
Fpu = SELECTA                ' select register 10 as register A
Fpu = 10
Fpu = LWRITEA                ' load 500000 (0007A120 hexadecimal)
Fpu = &h00
Fpu = &h07
Fpu = &hA1
Fpu = &h20
```

ASCII string to Long Integer

The `ATOL` instruction is used to convert strings to long integer values. The instruction reads the bytes following the opcode (until a zero terminator is read), converts the string to long integer, and stores the result in register 0. The following example sets the register `Total` to 500000.

```
Fpu = SELECTA
Fpu = Total
Fpu = LTOA
FpuBuffer.String = "500000"
Call fpuWriteString
Fpu = FSET0
```

The fastest operations occur when the FPU registers are already loaded with values. In time critical portions of code floating point constants should be loaded beforehand to maximize the processing speed in the critical section. With 128 registers available on the FPU, it's often possible to pre-load all of the required constants. In non-critical sections of code, data and constants can be loaded as required.

Reading Data Values from the FPU

The uM-FPU V3.1 chip has a 256 byte instruction buffer which allows data transmission to continue while previous instructions are being executed. Before reading data, you must check to ensure that the previous instructions have completed, and the FPU is ready to send data. The fpuWait procedure is used to wait until the FPU is ready, then a read instruction is sent, and the data can be read.

8-bit Integer

The `LREADBYTE` instruction reads the lower 8 bits from register A. The following example stores the lower 8 bits of register A in variable `dataByte`.

```
Call fpuWait
Fpu = LREADBYTE
dataByte = Fpu
```

16-bit Integer

The `LREADWORD` instruction reads the lower 16 bits from register A. The following example stores the lower 16 bits of register A in variable `dataWord.`

```
Call fpuWait
Fpu = LREADWORD
dataWord = Fpu * 256
dataWord = dataWord + Fpu
```

32-bit Integer

The OOPic doesn't have support 32-bit variables, so 32-bit long integer values are stored in 4-byte array objects. The following example reads the 32-bit integer value from register A, and stores the value in the `lval` object.

```
Call fpuWait
Fpu = LREADA
lval.Location = 0
lval = Fpu
lval.Location = 1
lval = Fpu
lval.Location = 2
lval = Fpu
lval.Location = 3
lval = Fpu
```

Long Integer to ASCII string

The `LTOA` instruction can be used to convert long integer values to an ASCII string. The `printLong` procedure uses this instruction to read the long integer value from register A and display it on the LCD or serial output.

Floating Point

The OOPic doesn’t have support 32-bit variables, so 32-bit floating point values are stored in 4-byte array objects. The following example reads the 32-bit floating point value from register A, and stores the value in the `fval` object.

```
Call fpuWait
Fpu = FREADA
fval.Location = 0
fval = Fpu
fval.Location = 1
fval = Fpu
fval.Location = 2
fval = Fpu
fval.Location = 3
fval = Fpu
```

Floating Point to ASCII string

The `FTOA` instruction can be used to convert floating point values to an ASCII string. The `printFloat` routine uses this instruction to read the floating point value from register A and display it on the LCD or serial output.

Comparing and Testing Floating Point Values

Floating point values can be zero, positive, negative, infinite, or Not a Number (which occurs if an invalid operation is performed on a floating point value). The status byte is read using the `fpuReadStatus` function. It waits for the FPU to be ready before sending the `READSTATUS` instruction and reading the current status from the FPU. Definitions for the status bits are provided as follows:

```
const status_Zero = &h01      ' Zero status bit (0-not zero, 1-zero)
const status_Sign = &h02      ' Sign status bit (0-positive, 1-negative)
const status_NaN  = &h04      ' Not a Number status bit (0-valid number, 1-NaN)
const status_Inf  = &h08      ' Infinity status bit (0-not infinite, 1-infinite)
```

The `FSTATUS` and `FSTATUSA` instructions are used to set the status byte to the floating point status of the selected register. The following example checks the floating point status of register A:

```
Fpu = FSTATUSA
tmp = fpuReadStatus
If ((tmp And status_Sign) <> 0) Then
  print.String = "Result is negative"
End If
If ((tmp And status_Zero) <> 0) Then
  print.String = "Result is zero"
End If
```

The `FCMP`, `FCMP0`, and `FCMPI` instructions are used to compare two floating point values. The status bits are set for the result of register A minus the operand (the selected registers are not modified). For example, to compare register A to the value 10.0:

```
Fpu = FCMPI
Fpu = 10
tmp = fpuReadStatus
If ((tmp And status_Zero) <> 0) Then
   print.String = "Value1 = Value2"
Elseif ((tmp And status_Sign) <> 0) Then
   print.String = "Value1 < Value2"
Else
   print.String = "Value1 > Value2"
End If
```

The `FCMP2` instruction compares two floating point registers. The status bits are set for the result of the first register minus the second register (the selected registers are not modified). For example, to compare registers `Value1` and `Value2`:

```
Fpu = FCMP2
Fpu = Value1
Fpu = Value2
tmp = fpuReadStatus
```

Comparing and Testing Long Integer Values

A long integer value can be zero, positive, or negative. The status byte is read using the `fpuReadStatus` function. It waits for the FPU to be ready before sending the `READSTATUS` instruction and reading the status. Definitions for the status bits are provided as follows:

```
const status_Zero = &h01      ' Zero status bit (0-not zero, 1-zero)
const status_Sign = &h02      ' Sign status bit (0-positive, 1-negative)
```

The `LSTATUS` and `LSTATUSA` instructions are used to set the status byte to the long integer status of the selected register. The following example checks the long integer status of register A:

```
Fpu = LSTATUSA
tmp = fpuReadStatus
If ((tmp And status_Sign) <> 0) Then
  print.String = "Result is negative"
End If
If ((tmp And status_Zero) <> 0) Then
  print.String = "Result is zero"
End If
```

The `LCMP`, `LCMP0`, and `LCMPI` instructions are used to do a signed comparison of two long integer values. The status bits are set for the result of register A minus the operand (the selected registers are not modified). For example, to compare register A to the value 10:

```
Fpu = LCMPI
Fpu = 10
tmp = fpuReadStatus
If ((tmp And status_Zero) <> 0) Then
   print.String = "Value1 = Value2"
Elseif ((tmp And status_Sign) <> 0) Then
   print.String = "Value1 < Value2"
Else
   print.String = "Value1 > Value2"
End If
```

The `LCMP2` instruction does a signed compare of two long integer registers. The status bits are set for the result of the first register minus the second register (the selected registers are not modified). For example, to compare registers `Value1` and `Value2`:

```
Fpu = LCMP2
Fpu = Value1
Fpu = Value2
tmp = fpuReadStatus
```

The `LUCMP`, `LUCMP0`, and `LUCMPI` instructions are used to do an unsigned comparison of two long integer values. The status bits are set for the result of register A minus the operand (the selected registers are not modified).

The `LUCMP2` instruction does an unsigned compare of two long integer registers. The status bits are set for the result of the first register minus the second register (the selected registers are not modified).

The `LTST`, `LTST0` and `LTSTI` instructions are used to do a bit-wise compare of two long integer values. The status bits are set for the logical `AND` of register A and the operand (the selected registers are not modified).

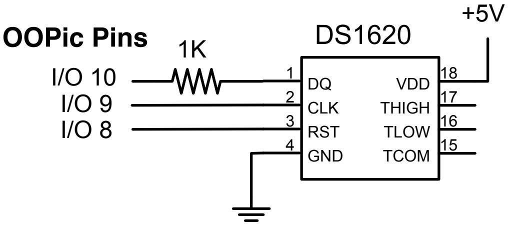
Further Information

The following documents are also available:

uM-FPU V3.1 Datasheet	provides hardware details and specifications
uM-FPU V3.1 Instruction Reference	provides detailed descriptions of each instruction
uM-FPU Application Notes	various application notes and examples

Check the Micromega website at www.micromegacorp.com for up-to-date information.

DS1620 Connections for Demo 1



Sample Code for Tutorial (demo1-LCD.osc)

```
' This program demonstrates the use of the uM-FPU V2 floating point coprocessor
' with the OOPic. It takes temperature readings from a DS1620 digital
' thermometer, converts them to floating point and displays them in degrees
' Celsius and degrees Fahrenheit on an LCD.
'
' Note: uM-FPu V3.1 defintiions and support routines are not shown,
' see demo1-LCD.osc file for full listing.

'-------------------- LCD objects ---------------------------------------------

Dim print As New oLCD                ' use LCD for print output

'-------------------- DS1620 objects ------------------------------------------

Dim DS_RST As New oDIO1              ' DS1620 reset pin
Dim DS_CLK As New oDIO1              ' DS1620 clock pin
Dim DS_DATA As New oDIO1             ' DS1620 data pin

'-------------------- uM-FPU register definitions -----------------------------

Const  DegC      = 1                 ' degrees Celsius
Const  DegF      = 2                 ' degrees Fahrenheit

'-------------------- variables -----------------------------------------------

Dim rawTemp As New oWord             ' raw temperature reading
Dim bitcnt As New oByte              ' bit count

'==============================================================================
'-------------------- main routine --------------------------------------------
'==============================================================================

Sub main()

    ' initialize devices
    ' ------------------
    ooPIC.Snode = 1                  ' assign node value for debugging
    Call printSetup                  ' initialize the print object

    print.String = "Demo1"
```

```
print.Locate(1,0)

' reset the uM-FPU and check for synchronization
' ----------------------------------------------
Call fpuReset                       ' reset the uM-FPU
If fpuSync Then                     ' check for synchronization
   Call printVersion
Else
   print.String = "uM-FPU not detected"
End If

Call init_DS1620                    ' initialize the DS1620
print.Clear                         ' clear the LCD

Do
   ' get temperature reading from DS1620
   ' -----------------------------------
   Call read_temperature            ' get temperature reading from DS1620

   ' load rawTemp to uM-FPU, convert to float, and store in register
   ' ---------------------------------------------------------------
   Fpu = SELECTA                    ' select DegC as register A
   Fpu = DegC
   Fpu = LOADWORD                   ' load rawTemp to register 0 and
   Fpu = rawTemp / 256              ' convert to floating point
   Fpu = rawTemp
   Fpu = FSET0                      ' set DegC to value in register 0

   ' divide rawTemp by 2 to get degrees Celsius
   ' ------------------------------------------
   Fpu = FDIVI                      ' divide by 2
   Fpu = 2

   ' DegF = FCNV(DegC, 1)
   ' --------------------
   Fpu = SELECTA                    ' select DegF as register A
   Fpu = DegF
   Fpu = FSET                       ' set DegF to value in DegC register
   Fpu = DegC
   Fpu = FCNV                       ' convert to Celsius
   Fpu = 1

   ' display degrees Celsius
   ' -----------------------
   print.Locate(0,0)                ' move to line 1
   print.String = "Deg C:"
   Fpu = SELECTA                    ' select DegC as A register
   Fpu = DegC
   Call printFloat(51)              ' display floating point value in 5.1 format

   ' display degrees Fahrenheit
   ' --------------------------
   print.Locate(1,0)                ' move to line 2
   print.String = "Deg F:"
   Fpu = SELECTA                    ' select DegF as A register
   Fpu = DegF
   Call printFloat(51)              ' display floating point value in 5.1 format
```

```
        ' delay for 2 seconds and repeat main loop
        ' ----------------------------------------
        ooPIC.Delay = 200
    Loop

End Sub

'-------------------- print routines -----------------------------------------

Sub printSetup()
    print.IOLineRS = 14             ' RS on I/O line 14
    print.IOLineE = 15              ' E on I/O line 15
    print.IOGroup = 3               ' data lines on I/O group 3
    print.Nibble = 1
    print.Operate = 1
    print.Init                      ' initialize the LCD
    print.Clear                     ' clear the LCD
End Sub

'-------------------- DS1620 support routines ---------------------------------

Sub init_DS1620()
    DS_RST.IOLine = 8               ' define DS1620 interface pins
    DS_RST.Direction = cvOutput
    DS_CLK.IOLine = 9
    DS_CLK.Direction = cvOutput
    DS_DATA.IOLine = 10

    DS_RST = 0                      ' set initial state of pins
    DS_CLK = 1
    ooPIC.Delay = 10

    DS_RST = 1
    Call write_DS1620(&h0C)         ' configure for CPU control
    Call write_DS1620(&h02)
    DS_RST = 0
    ooPIC.Delay = 10

    DS_RST = 1
    Call write_DS1620(&h0EE)        ' start temperature conversion
    DS_RST = 0

    ooPIC.Delay = 100               ' delay for first conversion
End Sub

Sub write_DS1620(val As Byte)
    DS_DATA.Direction = cvOutput    ' set data pin for output

    For bitcnt = 1 To 8             ' send 8 bit value to DS1620 (LSB first)
        DS_DATA = val
        DS_CLK = 0
        DS_CLK = 1
        val = val / 2
    Next bitcnt
End Sub
```

```
Sub read_temperature()
   DS_RST = 1                       ' enable the DS1620
   write_DS1620(&hAA)               ' send read temperature command
   DS_DATA.Direction = cvInput      ' set data pin for input
   rawTemp = 0                      ' clear the temperature value

   For bitcnt = 1 To 8              ' read low 8 bits from DS1620 (LSB first)
      DS_CLK = 0
      If DS_DATA = 1 Then rawTemp = rawTemp + 256
      rawTemp = rawTemp / 2
      DS_CLK = 1
   Next bitcnt

   DS_CLK = 0                       ' read 9th bit and extend the sign
   If DS_DATA = 1 Then rawTemp = rawTemp + &hFF00
   DS_CLK = 1
   DS_RST = 0                       ' disable the DS1620
End Sub
```

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
CLRX	05			reg[X] = 0, X = X + 1
CLR0	06			reg[nn] = 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
COPY0	10	nn		reg[nn] = reg[0]
COPYI	11	bb,nn		reg[nn] = long(unsigned byte bb)
SWAP	12	nn,mm		Swap reg[nn] and reg[mm]
SWAPA	13	nn		Swap reg[A] and reg[nn]
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]
FWRITEX	18	b1,b2,b3,b4		Write 32-bit floating point to reg[X]
FWRITE0	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]
FREAD0	1C		b1,b2,b3,b4	Read 32-bit floating point from reg[0]
ATOF	1E	aa…00		Convert ASCII to floating point
FTOA	1F	bb		Convert floating point to ASCII
FSET	20	nn		reg[A] = reg[nn]
FADD	21	nn		reg[A] = reg[A] + reg[nn]
FSUB	22	nn		reg[A] = reg[A] - reg[nn]
FSUBR	23	nn		reg[A] = reg[nn] - reg[A]
FMUL	24	nn		reg[A] = reg[A] * reg[nn]
FDIV	25	nn		reg[A] = reg[A] / reg[nn]
FDIVR	26	nn		reg[A] = reg[nn] / reg[A]
FPOW	27	nn		reg[A] = reg[A] ** reg[nn]
FCMP	28	nn		Compare reg[A], reg[nn], Set floating point status
FSET0	29			reg[A] = reg[0]
FADD0	2A			reg[A] = reg[A] + reg[0]

FSUB0	2B			reg[A] = reg[A] - reg[0]
FSUBR0	2C			reg[A] = reg[0] - reg[A]
FMUL0	2D			reg[A] = reg[A] * reg[0]
FDIV0	2E			reg[A] = reg[A] / reg[0]
FDIVR0	2F			reg[A] = reg[0] / reg[A]
FPOW0	30			reg[A] = reg[A] ** reg[0]
FCMP0	31			Compare reg[A], reg[0], Set floating point status
FSETI	32	bb		reg[A] = float(bb)
FADDI	33	bb		reg[A] = reg[A] - float(bb)
FSUBI	34	bb		reg[A] = reg[A] - float(bb)
FSUBRI	35	bb		reg[A] = float(bb) - reg[A]
FMULI	36	bb		reg[A] = reg[A] * float(bb)
FDIVI	37	bb		reg[A] = reg[A] / float(bb)
FDIVRI	38	bb		reg[A] = float(bb) / reg[A]
FPOWI	39	bb		reg[A] = reg[A] ** bb
FCMPI	3A	bb		Compare reg[A], float(bb), Set floating point status
FSTATUS	3B	nn		Set floating point status for reg[nn]
FSTATUSA	3C			Set floating point status for reg[A]
FCMP2	3D	nn,mm		Compare reg[nn], reg[mm] Set floating point status
FNEG	3E			reg[A] = -reg[A]
FABS	3F			reg[A] = | reg[A] |
FINV	40			reg[A] = 1 / reg[A]
SQRT	41			reg[A] = sqrt(reg[A])
ROOT	42	nn		reg[A] = root(reg[A], reg[nn])
LOG	43			reg[A] = log(reg[A])
LOG10	44			reg[A] = log10(reg[A])
EXP	45			reg[A] = exp(reg[A])
EXP10	46			reg[A] = exp10(reg[A])
SIN	47			reg[A] = sin(reg[A])
COS	48			reg[A] = cos(reg[A])
TAN	49			reg[A] = tan(reg[A])
ASIN	4A			reg[A] = asin(reg[A])
ACOS	4B			reg[A] = acos(reg[A])
ATAN	4C			reg[A] = atan(reg[A])
ATAN2	4D	nn		reg[A] = atan2(reg[A], reg[nn])
DEGREES	4E			reg[A] = degrees(reg[A])
RADIANS	4F			reg[A] = radians(reg[A])
FMOD	50	nn		reg[A] = reg[A] MOD reg[nn]
FLOOR	51			reg[A] = floor(reg[A])
CEIL	52			reg[A] = ceil(reg[A])
ROUND	53			reg[A] = round(reg[A])
FMIN	54	nn		reg[A] = min(reg[A], reg[nn])
FMAX	55	nn		reg[A] = max(reg[A], reg[nn])
FCNV	56	bb		reg[A] = conversion(bb, reg[A])
FMAC	57	nn,mm		reg[A] = reg[A] + (reg[nn] * reg[mm])
FMSC	58	nn,mm		reg[A] = reg[A] - (reg[nn] * reg[mm])

LOADBYTE	59	bb		reg[0] = float(signed bb)
LOADUBYTE	5A	bb		reg[0] = float(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,b1,b2		Select matrix A
SELECTMB	66	nn,b1,b2		Select matrix B
SELECTMC	67	nn,b1,b2		Select matrix C
LOADMA	68	b1,b2		reg[0] = Matrix A[bb, bb]
LOADMB	69	b1,b2		reg[0] = Matrix B[bb, bb]
LOADMC	6A	b1,b2		reg[0] = Matrix C[bb, bb]
SAVEMA	6B	b1,b2		Matrix A[bb, bb] = reg[A]
SAVEMB	6C	b1,b2		Matrix B[bb, bb] = reg[A]
SAVEMC	6D	b1,b2		Matrix C[bb, bb] = reg[A]
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	bb		Call user-defined function in Flash
EECALL	7F	bb		Call user-defined function in EEPROM
RET	80			Return from user-defined function
BRA	81	bb		Unconditional branch
BRA	82	cc, bb		Conditional branch
JMP	83	b1, b2		Unconditional jump
JMP	84	cc, b1, b2		Conditional jump
TABLE	85	tc,t0…tn		Table lookup
FTABLE	86	cc,tc,t0…tn		Floating point reverse table lookup
LTABLE	87	cc,tc,t0…tn		Long integer reverse table lookup
POLY	88	tc,t0…tn		reg[A] = nth order polynomial
GOTO	89	nn		Computed GOTO
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] = I reg[A] I
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] = B
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	mm,nn		EEPROM[nn] = reg[mm]
EESAVEA	DB	nn		EEPROM[nn] = reg[A]
EELOAD	DC	mm,nn		reg[mm] = EEPROM[nn]
EELOADA	DD	nn		reg[A] = EEPROM[nn]
EEWRITE	DE	nn,bc,b1…bn		Store bytes in EEPROM
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 buffer
STRFIND	E7	aa…00		Find string and set selection point

STRFCHR	E8	aa…00		Set field separators
STRFIELD	E9	bb		Find field and set selection point
STRTOF	EA			Convert selected string to floating point
STRTOL	EB			Convert selected string to long integer
READSEL	EC		aa…00	Read selected string
STRBYTE	ED	bb		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	nn		Read internal register value
RESET	FF			Reset (9 consecutive FF bytes cause a reset, otherwise it is a NOP)

Notes:

Opcode	Instruction opcode 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

In the FPUdefs.bas file, LEFT, RIGHT, READ, SIN, COS, GOTO, SEROUT, SERIN have been renamed to include an F_ prefix (e.g. F_SIN, F_COS, etc.) to avoid conflicts with reserved symbol names.

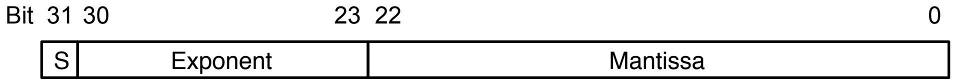
Appendix B
Floating Point Numbers

Floating point numbers can store both very large and very small values by “floating” the window of precision to fit the scale of the number. Fixed point numbers can’t handle very large or very small numbers and are prone to loss of precision when numbers are divided. The representation of floating point numbers used by the uM-FPU V3.1 is defined by the 32-bit IEEE 754 standard. The number of significant digits for a 32-bit floating point number is slightly more than 7 digits, and the range of values that can be handled is approximately ± $10^{38.53}$.

32-bit IEEE 754 Floating Point Representation

IEEE 754 floating point numbers have three components: a sign, exponent, the mantissa. The sign indicates whether the number is positive or negative. The exponent has an implied base of two and a bias value. The mantissa represents the fractional part of the number.

The 32-bit IEEE 754 representation is as follows:



Sign Bit (bit 31)

The sign bit is 0 for a positive number and 1 for a negative number.

Exponent (bits 30-23)

The exponent field is an 8-bit field that stores the value of the exponent with a bias of 127 that allows it to represent both positive and negative exponents. For example, if the exponent field is 128, it represents an exponent of one (128 – 127 = 1). An exponent field of all zeroes is used for denormalized numbers and an exponent field of all ones is used for the special numbers +infinity, -infinity and Not-a-Number (described below).

Mantissa (bits 30-23)

The mantissa is a 23-bit field that stores the precision bits of the number. For normalized numbers there is an implied leading bit equal to one.

Special Values

Zero

A zero value is represented by an exponent of zero and a mantissa of zero. Note that +0 and –0 are distinct values although they compare as equal.

Denormalized

If an exponent is all zeros, but the mantissa is non-zero the value is a denormalized number. Denormalized numbers are used to represent very small numbers and provide for an extended range and a graceful transition towards zero on underflows. Note: The uM-FPU does not support operations using denormalized numbers.

Infinity

The values +infinity and –infinity are denoted with an exponent of all ones and a fraction of all zeroes. The sign bit distinguishes between +infinity and –infinity. This allows operations to continue past an overflow. A nonzero number divided by zero will result in an infinity value.

Not A Number (NaN)

The value NaN is used to represent a value that does not represent a real number. An operation such as zero divided by zero will result in a value of NaN. The NaN value will flow through any mathematical operation. Note: The uM-FPU initializes all of its registers to NaN at reset, therefore any operation that uses a register that has not been previously set with a value will produce a result of NaN.

Some examples of 32-bit IEEE 754 floating point values displayed as 32-bit hexadecimal constants are as follows:

```
00000000     ' 0.0
3DCCCCCD     ' 0.1
3F000000     ' 0.5
3F400000     ' 0.75
3F7FF972     ' 0.9999
3F800000     ' 1.0
40000000     ' 2.0
402DF854     ' 2.7182818 (e)
40490FDB     ' 3.1415927 (pi)
41200000     ' 10.0
42C80000     ' 100.0
447A0000     ' 1000.0
449A522B     ' 1234.5678
49742400     ' 1000000.0
80000000     ' -0.0
BF800000     ' -1.0
C1200000     ' -10.0
C2C80000     ' -100.0
7FC00000     ' NaN (Not-a-Number)
7F800000     ' +inf
FF800000     ' -inf
```