



Micromega Corporation

Using uM-FPU V3.1 with Arduino

Introduction

This document describes how to use the uM-FPU V3.1 floating point coprocessor (FPU) with the Arduino open-source physical computing platform. 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 are also available on the Micromega website.

Installing uM-FPU V3.1 Support Software for Arduino

The support software for using the uM-FPU V3.1 chip with Arduino is contained in a file called *UMFPU-V3-Arduino.zip*. Download and unzip the file. It contains three folders, *Fpu*, *FpuSerial* and *Spi*, which are Arduino libraries for using the uM-FPU V3.1 chip. Move these folders to the *hardware/libraries* subdirectory of the *Arduino application directory*.

The *Fpu* library provides support functions for using the uM-FPU V3.1 chip with Arduino. The *FpuSerial* library provides functions for sending FPU strings to the serial monitor. The *Spi* library contains support functions for using the Arduino Serial Peripheral Interface (SPI). A descriptions of each library functions is provided later in this document.

Various examples are also provided with the *Fpu* library. The examples can be opened from the Arduino software using the *File>Sketchbook>Examples>Library-Fpu* command.

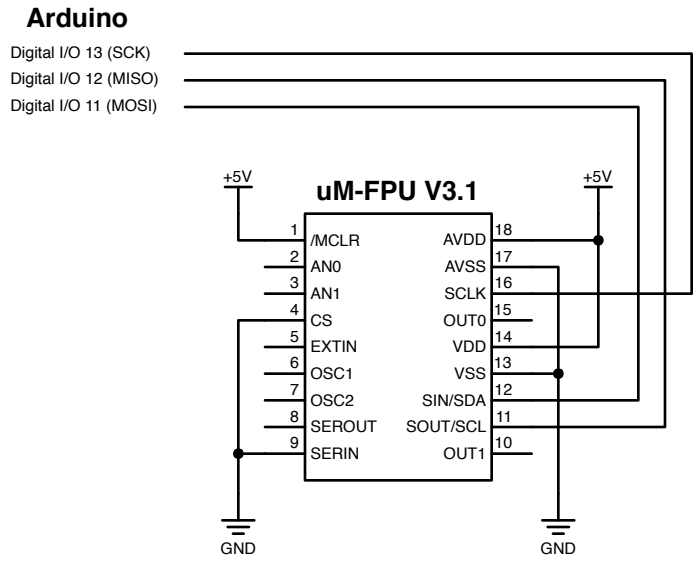
Connecting the uM-FPU V3.1 chip to Arduino

The FPU is connected to Arduino using the hardware SPI interface. The pins used on Arduino to interface with the FPU are as follows:

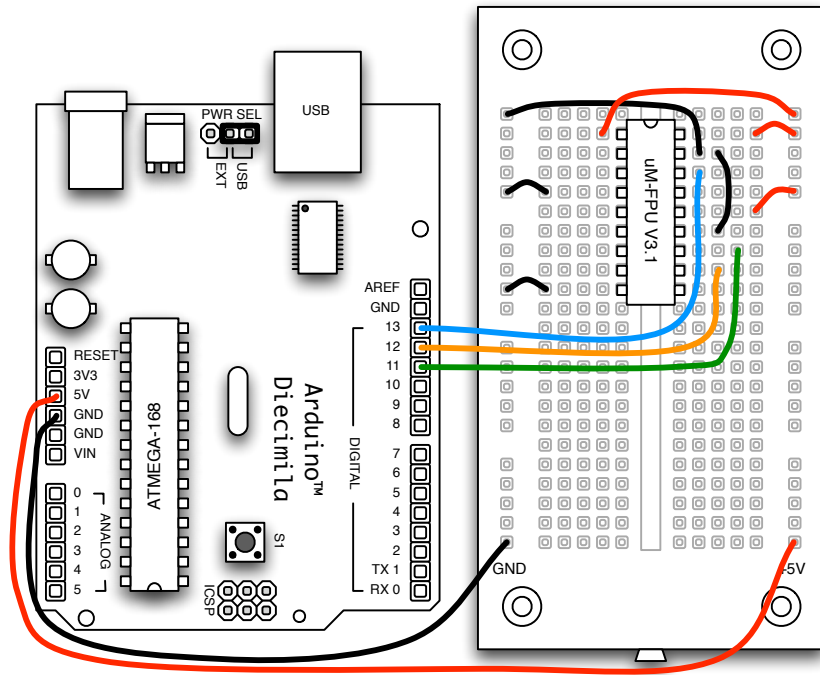
pin 13	SCK	SPI clock (connects to FPU SCLK pin)
pin 12	MISO	SPI master in, slave out (connects to FPU SOUT pin)
pin 11	MOSI	SPI master out, slave in (connects to FPU SIN pin)
pin 10	SS	SPI slave select

Initially, the FPU will be connected to Arduino as the only SPI device. The FPU CS pin will be tied to ground, and the SPI slave select pin will not be connected. If multiple devices are connected to the SPI interface, the FPU needs to be configured for chip select. This is discussed later in the document. For now, only the FPU will be connected to the SPI interface. The following diagram shows the connections.

Connecting the FPU as a single device on the SPI bus Schematic Diagram



Breadboard Example using Arduino Diecimila



Example Programs

Several example programs are provided with the FPU library. After connecting the FPU as shown above, run the Arduino software and load the *sample* program with the following menu command:

```
File>Sketchbook>Examples>Library-Fpu>sample
```

The *sample* program takes the diameter of a circle in centimeters, converts it to inches, and calculates the circumference and area. Compile and upload the program to the Arduino. Open the Serial Monitor and set the baud rate to 9600 baud. The following output should be displayed on the Serial Monitor:

```
Sample
uM-FPU V3.1.2

Diameter (cm):      25
Diameter (in.):     9.8425197
Circumference (in.): 30.921188
Area (sq.in.):      76.085601

Done.
```

If you would like to try another example, load the graph program with the following menu command:

```
File>Sketchbook>Examples>Library-Fpu>graph
```

The *graph* program displays a simple graph of the sine and cosine function on the Serial Monitor. An example of the sine graph is shown below:

```
Graph
uM-FPU V3.1.2

Graph of sine
-1      0      1
-----
          *      0.00000
          |      *      0.30902
          |      *      0.58779
          |      *      0.80902
          |      *      0.95106
          |      *      1.00000
          |      *      0.95106
          |      *      0.80902
          |      *      0.58779
          |      *      0.30902
          |      *      -0.00000
          |      *      -0.30902
          *      |      -0.58779
          *      |      -0.80902
          *      |      -0.95106
          *      |      -1.00000
          *      |      -0.95106
          *      |      -0.80902
          *      |      -0.58779
          *      |      -0.30902
          *      |      0.00000
```

Let's look at the code for the *sample* program, section by section, to understand how it works.

After the initial comments the *Spi*, *Fpu* and *FpuSerial* libraries are included as follows:

```

#include <Spi.h>
#include <Fpu.h>
#include <FpuSerial.h>

```

The FPU has 128 32-bit registers that can be used for calculations. Meaningful symbol names are defined for the FPU registers used by the program.

```

//----- uM-FPU register definitions -----

#define DiameterIn      10           // diameter in inches
#define Circumference   11           // circumference
#define Area            12           // area
#define Pi              13           // constant pi

```

The setup() function initializes the devices. The serial port is initialized to 9600 baud, and the name of the program is displayed.

```

//----- setup -----

void setup()
{
  Serial.begin(9600);
  Serial.println("Sample");
}

```

The *Fpu* library is initialized using the default pin assignment.

```
Fpu.begin();
```

The FPU is reset. If successful, a sync character is returned, and the FPU version string is displayed on the Serial Monitor.

```

if (Fpu.reset() == SYNC_CHAR)
{
  FpuSerial.printVersion();
  Serial.println();
}

```

If the reset fails, an error message is displayed and further execution is stopped.

```

else
{
  Serial.print("uM-FPU not detected");
  while(1) ;
}
}

```

The sample calculations are performed in the loop() function. Instructions are data are sent to the FPU using the write function. Definitions for all FPU opcodes are included in the *fpu.h* header file. Comments in the program explain each part of the calculations. The results are displayed on the Serial Monitor.

```

//----- loop -----

void loop()
{
  byte diameterCm;

  // Load constant for later use.
  Fpu.write(SELECTA, Pi, LOADPI, FSET0);

  // Get diameter in centimeters. The value would typically come from a

```

```

// sensor reading, but in this example an assumed value of 25 is used.
diameterCm = 25;
Serial.print("\r\nDiameter (cm):      ");
Serial.println(diameterCm, DEC);

// Convert inches to centimeters
Fpu.write(SELECTA, DiameterIn, FSETI, diameterCm);
Fpu.write(FCNV, 5);
Serial.print("Diameter (in.):      ");
FpuSerial.printFloat(0);
Serial.println();

// circumference = diameter * pi
Fpu.write(SELECTA, Circumference, FSET, DiameterIn);
Fpu.write(FMUL, Pi);
Serial.print("Circumference (in.): ");
FpuSerial.printFloat(0);
Serial.println();

// area = (diameter / 2)^2 * pi
Fpu.write(SELECTA, Area, FSET, DiameterIn);
Fpu.write(FDIVI, 2);
Fpu.write(FMUL, Area, FMUL, Pi);
Serial.print("Area (sq.in.):      ");
FpuSerial.printFloat(0);
Serial.println();

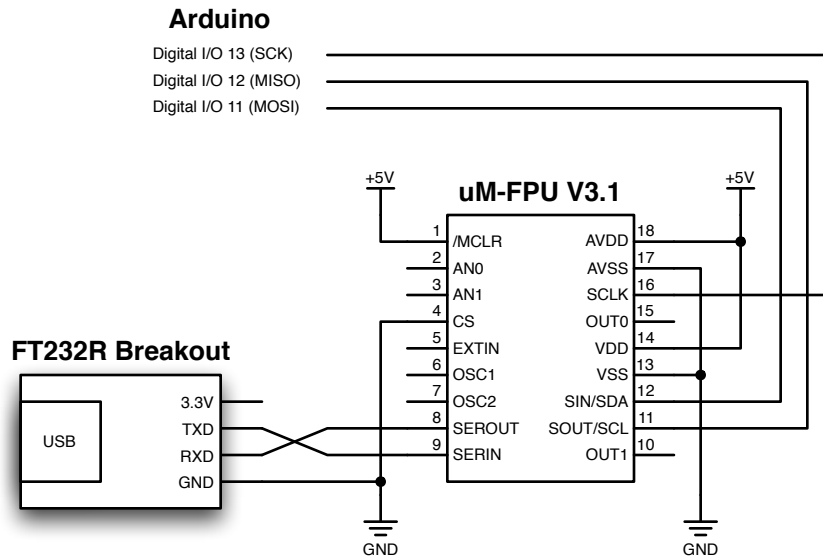
Serial.println("\r\nDone.");
while(1) ;
}

```

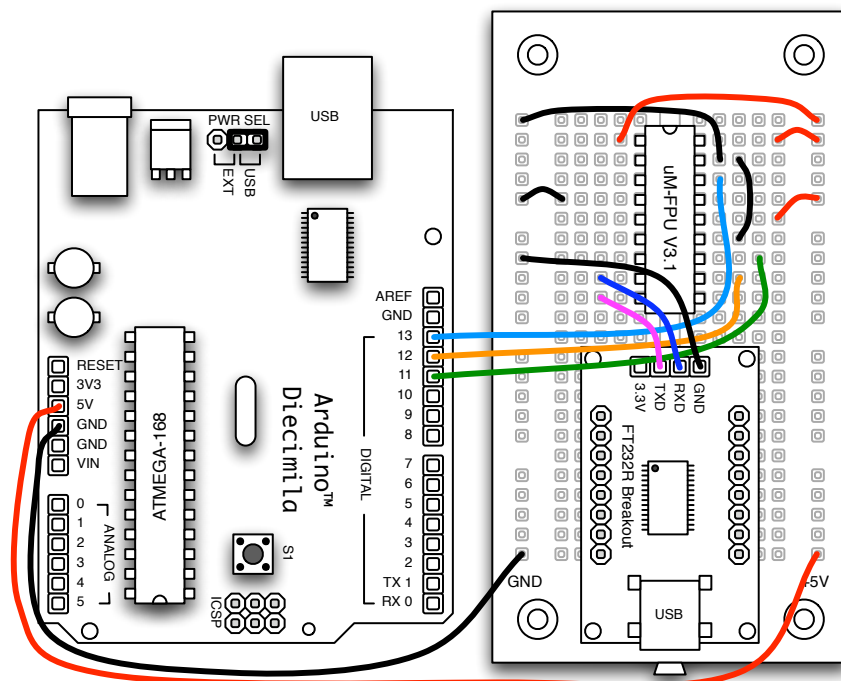
Enabling the uM-FPU V3.1 Debug Monitor

The uM-FPU V3.1 chip has a built-in debug monitor that can be used to display the contents of uM-FPU registers, trace the execution of uM-FPU instructions, set breakpoints for debugging, and program user functions in Flash memory on the FPU. To enable the debug monitor, the SERIN and SEROUT pins on the FPU must be connected through a serial interface to a PC. The *uM-FPU V3 IDE* software running on a PC communicates with the debug monitor and provides a graphical user interface for debugging and programming the FPU. The following example shows the connection using an FT232R breakout board from SparkFun Electronics.

Connecting the Debug Monitor - Schematic Diagram



Breadboard Example using Arduino Diecimila

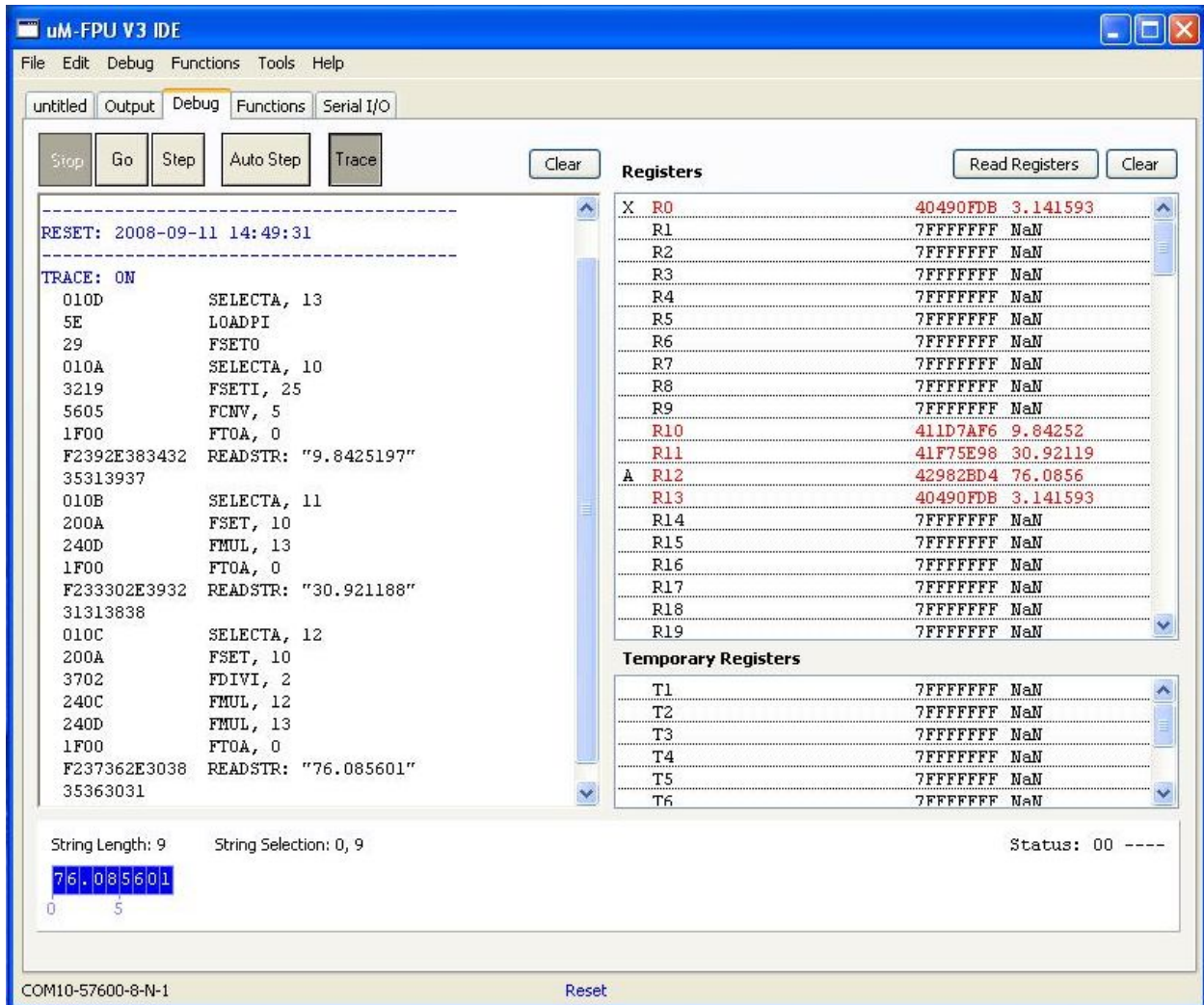


The debug trace can be turned on and off with the TRACEON and TRACEOFF instructions. To turn on the debug trace, the following instruction should be added to the end of the setup() function:

```
Fpu.write(TRACEON);
```

Alternatively, the *Trace on Reset* setting can be enabled with the *uM-FPU V3 IDE* using the *Functions>Set Parameters...* menu command. A debug trace and the contents of the FPU registers are shown below for the *sample* program discussed above.

uM-FPU V3 IDE - Debug Window



SPI bus with Multiple Devices

To use the FPU on an SPI bus with multiple devices, the CS pin on the FPU must be enabled to act as a chip select. The function of the CS pin is determined by bits 1:0 of the mode parameter byte. The factory setting for these bits is *CS pin selects interface (default)*, which uses the CS pin to select either the SPI or I²C interface at reset.

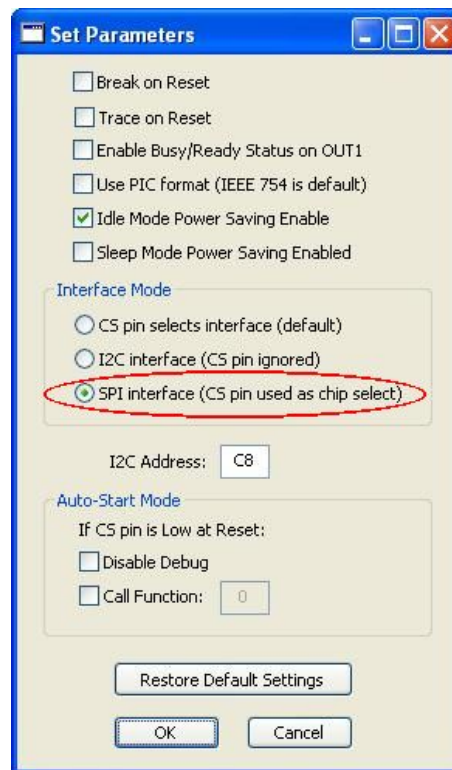
You can use the uM-FPU V3 IDE software to change the setting to *SPI interface (CS pin used as chip select)*.

Enabling the CS pin as a chip select

The parameter bytes are stored in Flash memory on the uM-FPU V3.1 chip, and programmed using the built-in debug monitor (see *uM-FPU V3.1 Datasheet* for details). Since the parameter bytes are stored in Flash memory, these bits only need to be set once.

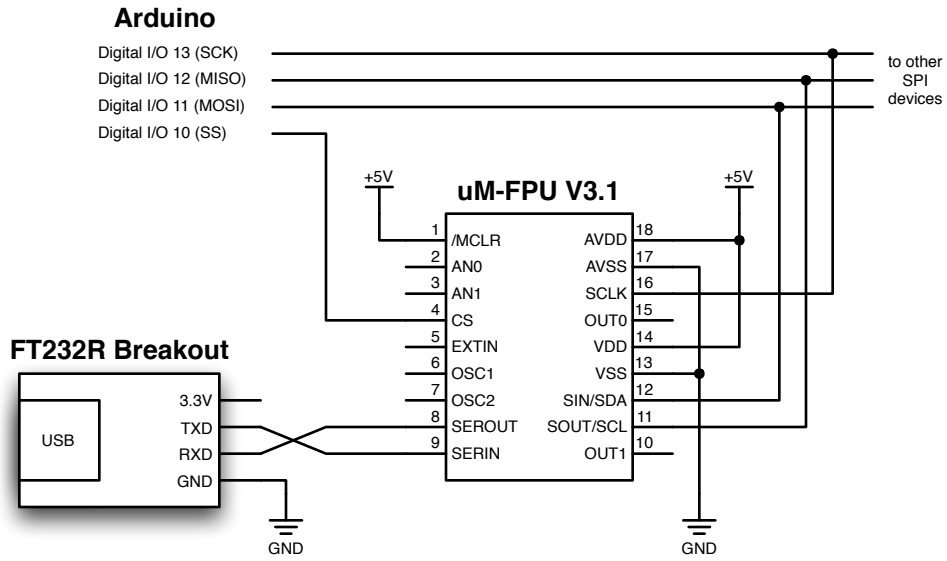
To set the interface mode, the uM-FPU V3 IDE (Integrated Development Environment) software can be used. The *Set Parameters...* command in the *Functions* menu displays the dialog shown below. Select the *SPI interface (CS pin used as chip select)* interface mode.

Selecting SPI interface with CS pin used as chip select

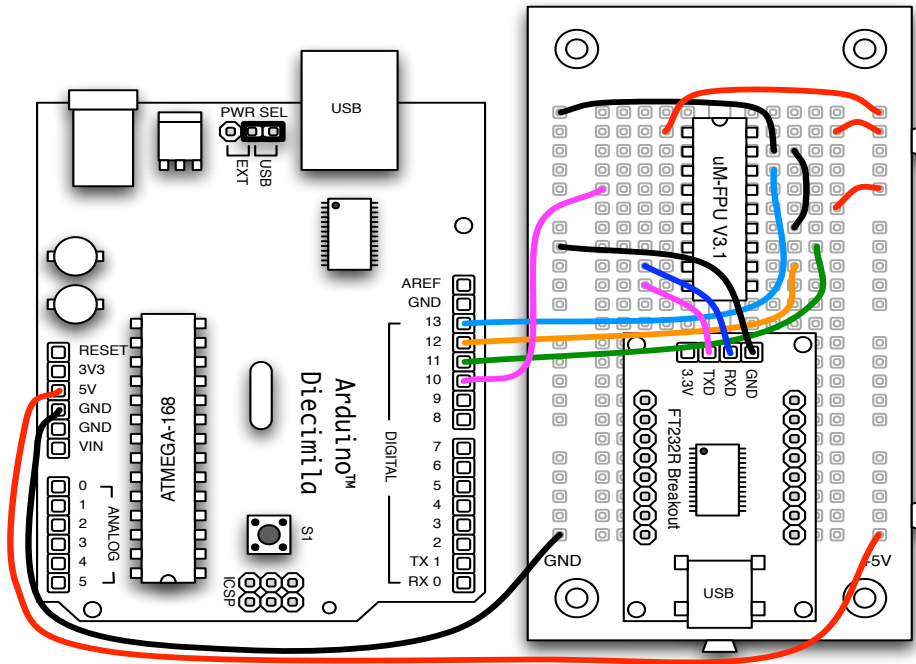


When this mode is selected, the SPI interface is automatically selected at Reset, and the CS pin is enabled as an active low chip select. The SOUT pin is high impedance when the uM-FPU V3.1 chip is not selected. By default, the *Fpu* library uses Arduino pin 10 for the FPU chip select. This can be changed to an alternate pin using the `Fpu.begin(pin)` function. A schematic for connecting the FPU to an SPU bus is shown below:

[Connecting the FPU on an SPI bus with Multiple Devices Schematic Diagram



Breadboard Example using Arduino Diecimila

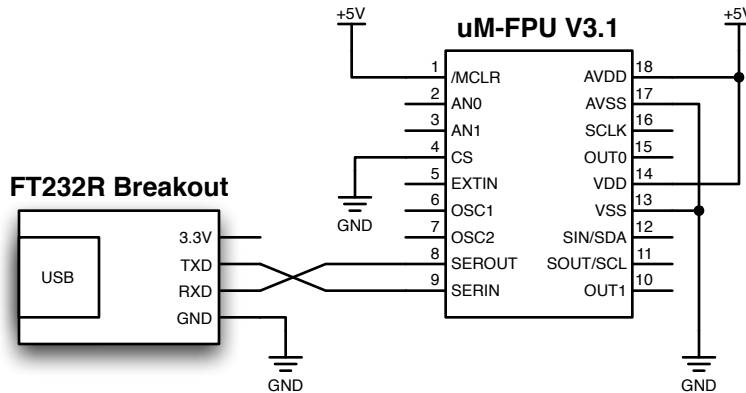


Using the uM-FPU V3.1 chip with 3.3V Arduino Boards

Some Arduino boards (e.g. Arduino Pro, Arduino Pro Mini) have an operating voltage of 3.3V. The uM-FPU V3.1 chip can run at 3.3V, but the internal oscillator must be reduced to 14.74 MHz (see the uM-FPU V3.1 Datasheet for details). The FPU must first be connected to 5V to change the clock source from the default setting of 29.48 MHz, the. The procedure is summarized below.

Step 1

On a breadboard, connect the FPU chip to a 5V supply, and connect the SERIN and SEROUT pins to a serial interface.



Step 2

Connect the serial interface to a PC, and use a terminal emulator program (e.g. HyperTerminal) to communicate with the FPU debug monitor. The communication settings should be 57,600 8-N-1 with no flow control.

Step 3

Turn on power to the FPU chip. Using the terminal emulator, press the Return key once or twice to get the debug monitor's command prompt.

e.g.

```
{RESET}  
>
```

Step 4

Type \$C and press the return key. (Note: the command is not echoed until the return key is pressed.)

The current setting will be displayed followed by a colon. Type EA. The clock will be changed and the FPU will reset.

e.g.

```
>$C  
E3  
:EA  
{RESET}
```

Step 5

Confirm the change by typing V and pressing the Return key. The FPU is now ready for 3.3V operation.

e.g.

```
>V  
uM-FPU V3.1.2, SPI 14.74 MHz
```

Fpu Library Functions

The *Fpu* library provides support functions for using the uM-FPU V3.1 chip with Arduino.

begin()

begin(byte pin)

This function must be called in `setup()` to initialize the pins used to interface with the uM-FPU V3.1 chip, configure the SPI, and reset the FPU chip. It must be called before any other *Fpu* library functions are called. The pins used on the Arduino to interface with the FPU chip are as follows:

pin 13	SCK	SPI clock (connects to FPU SCLK pin)
pin 12	MISO	SPI master in, slave out (connects to FPU SOUT pin)
pin 11	MOSI	SPI master out, slave in (connects to FPU SIN pin)
pin 10	SS	SPI slave select

The `pin` parameter specifies the pin to use as the FPU slave select (FPU CS). If the `pin` parameter is not specified, pin 10 is used by default. Even if a different pin is used, pin 10 is still set as a digital output, as required by the SPI hardware module.

e.g.

```
Fpu.begin();           // (default) use pin 10 for FPU chip select
Fpu.begin(8);         // (alternative example) use pin 8 for FPU chip select
```

reset()

Reset the FPU and configure the SPI hardware. This function is called by `begin()`, so a separate call is not required in `setup()`.

byte sync()

Confirms communication with the FPU. It returns `SYNC_CHAR` (0x5C) if successful.

e.g.

```
if (Fpu.sync() == SYNC_CHAR) Serial.println("FPU sync OK");
```

wait()

The uM-FPU V3.1 chip has a 256 byte instruction buffer which allows it to process in parallel with the Arduino. Before sending an instruction to read data from the FPU, the `wait()` function must be called to ensure that all instructions in the buffer have been completed, and the FPU is ready to send data.

e.g.

```
byte bval;
Fpu.wait();           // wait until FPU is ready, then read byte
Fpu.write(LREADBYTE); // read 8-bit integer from register A
dataByte = Fpu.readByte();
```

If a long series of calculations is done, `wait` must be called at least every 256 bytes to ensure that the instruction buffer doesn't overflow. A `wait` call is not required before using any of the *FpuPrint* functions, since they call the `wait` function themselves.

write(byte b1)

write(byte b1, byte b2)

write(byte b1, byte b2, byte b3)

write(byte b1, byte b2, byte b3, byte b4)

write(byte b1, byte b2, byte b3, byte b4, byte b5)

write(byte b1, byte b2, byte b3, byte b4, byte b5, byte b6)

These functions are used to send instructions and data to the FPU. Each parameter specifies an 8-bit integer value to

be sent to the FPU. Definitions for all of the FPU opcodes are included in the *Fpu.h* header file.

e.g.

```
Fpu.write(SELECTA, 1, LOADPI, FSET0);
```

writeWord(int wval)

Sends a 16-bit integer value to the FPU.

e.g.

```
Fpu.write(SELECTA, 1, LOADWORD);  
Fpu.writeWord(1000);  
Fpu.write(FSET0);
```

writeLong(long lval)

Sends a 32-bit integer value to the FPU.

e.g.

```
Fpu.write(LWRITE, 1);  
Fpu.writeLong(500000);
```

writeFloat(float fval)

Sends a 32-bit floating point value to the FPU.

e.g.

```
Fpu.write(FWRITEA);  
Fpu.writeFloat(350.75);
```

writeString(char *s)

Sends a zero-terminated string to the FPU.

e.g.

```
Fpu.write(SELECTA, 1, ATOF);  
Fpu.writeString("125.3335");  
Fpu.write(FSET0);
```

byte read()

Reads an 8-bit value from the FPU.

e.g.

```
byte bval;  
Fpu.wait(); // wait until FPU is ready  
Fpu.write(LREADBYTE); // read 8-bit integer from register A  
bval = Fpu.readByte();
```

int readWord()

Reads an 16-bit value from the FPU.

e.g.

```
int wval;  
Fpu.wait(); // wait until FPU is ready  
Fpu.write(LREADWORD); // read 16-bit integer from register A  
wval = Fpu.readWord();
```

long readLong()

Reads an 32-bit long integer value from the FPU.

e.g.

```
long lval;  
Fpu.wait(); // wait until FPU is ready  
Fpu.write(LREAD0); // read 32-bit integer from register 0  
lval = Fpu.readLong();
```

float readFloat()

Reads an 32-bit floating point value from the FPU.

e.g.

```
float fval;
Fpu.wait();           // wait until FPU is ready
Fpu.write(FREAD, 2); // read 32-bit float from register 2
fval = Fpu.readFloat();
```

char *readString(char *s)

char *readString(char *s, byte opcode)

Reads a zero-terminated string from the FPU and stores it at the location specified by the **s* parameter. A pointer to the string is returned. By default, the entire string buffer is read using the READSTR opcode. If the *opcode* parameter is READSEL, only the current string selection is read. Note: The following functions are called internally before the string is read:

```
Fpu.wait()
Fpu.write(READSTR) or Fpu.write(READSEL)
Fpu.readDelay()
```

Characters are read and stored in sequential bytes until a zero terminator is read. Care must be taken to ensure that the string buffer is large enough for the string being read.

e.g.

```
Fpu.wait();           // wait until FPU is ready
Fpu.write(FREAD, 2); // read 32-bit float from register 2
longData = Fpu.readLong();
```

byte Fpu.readStatus()

Reads the status byte from the FPU. Note: The following functions are called internally before the status byte is read:

```
Fpu.wait()
Fpu.write(READSTATUS)
Fpu.readDelay()
```

Definitions for the bits in the status byte are defined in the *Fpu.h* header file.

e.g.

```
Fpu.write(FSTATUSA); // get the status of register A
if ((Fpu.readStatus() && STATUS_SIGN) == 1) Serial.println("Negative value");
```

readDelay()

After a read instruction is sent, and before the first data byte is read, a read setup delay is required to ensure that the FPU is ready to send data. This function provides the required read setup delay. Note: All functions in the *Fpu* library that read data call `readDelay()`, so user programs do not normally call this function directly.

FpuSerial Library Functions

The *FpuSerial* library provides functions for sending FPU strings to the serial port.

printVersion()

Sends the VERSION opcode, then calls `printString` to send the version string on the serial port.

e.g.

```
FpuSerial.printVersion(VERSION); // display FPU version string
```

printFloat(char format)

Sends the FTOA, `format` opcode to convert the floating point value in register A to a formatted string. It then calls `printString` to send the string on the serial port. The `format` parameter is used to specify the desired format. If `format` is zero, the length of the displayed value is variable and can be from 3 to 12 characters in length. Up to eight significant digits will be displayed if required, and very large or very small numbers are displayed in exponential notation. 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 `format` 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 in register A 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]

e.g.

```
Fpu.write(SELECTA, 1); // select register 1
FpuSerial.printFloat(63); // display float in 6.3 format
```

printLong(char format)

Sends the LTOA, `format` opcode to convert the 32-bit integer value in register A to a formatted string. It then calls `printString` to send the string on the serial port. The `format` parameter is used to specify the desired format. If `format` is zero, the length of the displayed value is variable and the displayed value can range from 1 to 11 characters in length. Examples of the display format are as follows:

```
1
500000
-3598390
```

If `format` parameter is non-zero, it determines the display format. A value between 0 and 15 specifies the number of characters to display. The formatted string is right justified, with blank fill if `format` is positive, or zero fill if `format` is negative. If the value 100 is added to `format` the value is displayed as an unsigned long integer. If the value in register A is too large for the format specified, asterisks will be displayed. If the number of character to display is specified as zero, as many characters as required to display the number will be used. 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]
1000	-6 (signed 6)	[001000]

e.g.

```
Fpu.write(SELECTA, 1); // select register 1
FpuSerial.printLong(5); // display signed 32-bit integer(5 character field)
or
Fpu.write(SELECTA, 1); // select register 1
FpuSerial.printLong(100) // display as unsigned 32-bit integer
```

printString()

printString(byte opcode)

Reads a zero-terminated string from the FPU and sends the string to the serial port. By default, the entire string buffer is read using the READSTR opcode. If the opcode parameter is READSEL, only the current string selection is read. The following functions are called by printString before the string is read:

```
wait()
write(READSTR) or Fpu.write(READSEL)
readDelay()
```

e.g.

```
FpuSerial.printString(); // display string buffer
or
FpuSerial.printString(READSEL); // display current string selection
```

Spi Library Functions

The *Spi* library provides functions for transferring information using the Serial Peripheral Interface (SPI). The SPI interface is automatically initialized when the *Spi* library is included in a sketch. It sets the following digital I/O pins:

```
pin 13  SCK      SPI clock
pin 12  MISO     SPI master in, slave out
pin 11  MOSI     SPI master out, slave in
pin 10  SS       SPI slave select
```

The default SPI configuration is as follows:

```
SPI Master enabled
MSB of the data byte transmitted first
SPI mode 0 (CPOL = 0, CPHA = 0)
SPI clock frequency = system clock / 4
```

mode(byte config)

Sets the SPI configuration register. Only required if the default configuration described above must be modified. The **SPE** (SPI enabled) and **MSTR** (SPI master) bits are always set. If there are multiple SPI devices on the bus which require different SPI configurations, this function can be called before accessing each different device type to set the appropriate configuration.

e.g.

```
Spi.mode((1<<CPOL) | (1 << CPHA));    // set SPI mode 3
or
Spi.mode(<<SPR0);                    // set SPI clock to system clock / 16
```

byte transfer(byte b)

Sends and receives a byte from the SPI bus.

e.g.

```
n = Spi.transfer(0x2A);              // sends the byte 0x2A
                                     // and returns the byte received
```

byte transfer(byte b, byte delay)

Delays for a number of microseconds, then sends and receives a byte from the SPI bus. This function is used if there are timing considerations associated with the data transfer.

e.g.

```
n = Spi.transfer(0x2A, 2);          // waits 2 usec, then sends the byte 0x2A
                                     // and returns the byte received
```

Further Information

The following documents are also available:

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

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