1. Introduction.

The goal of the project is to manage a MCU AVR "AT tiny 85/84" using C/C++ code without using external libraries and avoiding the use of assembler coding (i.e.: very minimal use of assembler code). The full development should cover all aspects of the features these MCUs cover.

The source clock used to clock the MCU will be internal clock. This allows to use all the I/O pins the MCU has. I.E.: AT tiny 84 will use 8Mhz internal clock, AT tiny 85 will use 16 Mhz internal clock.

Although, at now, the code seems able to fit inside smaller tiny MCUs, the development will target "tiny 84/85" MCUs.

The actual state of art is very minimal; it try to cover timing, SPI communication (TWI should be better) and ADC conversions (not differential, only single channel are used).

This document is an overview of the developed software and it tries to discuss about the development approach. It contains general indications. All the developed modules have methods commented in the relevant include files and their use is/will be demonstrated with code examples.

1.1. Pre-requirements.

All the software have been and will be developed under Linux, but (I think) is possible to use all the software relevant to the MCUs also under other operating systems such as MS Windows or Mac platforms. This will not be always true for any software tools which have been developed specifically for PC, to get them run under other operating systems than Linux they will have to be modified.

The minimal requirements to use this software are the following items:

- A PC or something similar :)
- The avr-gcc compiler and tools (this software may be found in the Arduino suite).
- Something to program the MCU flash. You may use Atmel specific products. I use the SW ArduinoISP running on an Arduino Atmega 2560 board. The makefiles in this project has a rule (rom) to program MCU flash using avr-dude with the setting needing to use ArduinoISP.

2. SW Modules.

The SW is managed in a project directory that contains all the files needed to compile some small applications. For now, applications, C/C++ libraries and their include-files are together in the ./ path.

The include-files which describe the hardware, the data-types and some bit operations are in the ./include subdirectory; in the ./include/reg subdirectory are all the include-files describing the hardware registers and relevant settings.

Most of the macros which describe registers and settings have names fitting those in the Atmel MCU documentation.

The makefile to make the applications are in subdirectories, located under the ./ path, named as the application which will be compiled using the make program inside them.

2.1. HW initialization.

The only function used to pre-initialize the whole MCU is **inithw**(). This function is developed as in-line code, it's in the include-file inithw.h.

2.2. Timer module (attimer.cpp)

This module implements the class ATTimer which manages time. It manages a timer-counter to generate a 64 bits time expressed in microseconds with the resolution specified by the TTICK_us macro (attimerdefs.h). The only way to change the resolution is to modify the timer-counter clock-divisor (TCLK_DIV macro in the file attimerdefs.h) taking in account that the maximum tick the TTICK_us macro may represent is 1 microsecond.

2.2.1. Main methods.

The main methods this module exposes are:

begin	This method initializes the timer. The begin method of the first instance of the ATTimer class activates the HW.
reset	This method restarts the timer. The time count restarts from 0. The reset method of the first instance of the ATTimer class resets the HW.
baseTime	This method returns the time elapsed since the begin (or reset) method initialized the HW. This time is expressed in microseconds (a word 64 bits long).
udelay	This method waits a number of microseconds. The wait-time shall be rounded taking in account the value of the TTICK_us macro
time	This method returns the time elapsed since the begin (or reset) method was called. This time is expressed in microseconds (a word 64 bits long). Calling this method for the first instance of the ATTimer class has the same result of the method baseTime().

E.G.: This code is roughly “real-time” if the “Do something” actions have a duration of maximum 200 microseconds.

```
#include "include/inithw.h"
#include "attimer.h"
#include "include/h_types.h"

ATTimer timer();
void main(void) {
      uint64_t t0,t1,t2,t3;

      inithw();
      timer.begin();
```

```
        t3=t2=t1=baseTime();
        for(;;) {
              t0=timer.baseTime();

              if (t0-t1>=_Sec(1)) {
                    //Do something every second!
                    t1=timer.baseTime();
              }

              if (t0-t2>=_mSec(100)) {
                    //Do something every 100 msec!
                    t2=timer.baseTime();
              }

              if (t0-t3>=_uSec(300)) {
                    //Do something every 300 usec!
                    t3=timer.baseTime();
              }

              udelay(_uSec(100));
        }
  }
```

2.2.2. Remarks.

For now this module uses the counter timer 1 as default. This behavior should be modified because tiny 84 uses timer counter 1 for the PWM functionalities unlike tiny 85 which uses the timer counter 0. It's possible to make the module uses the counter timer 0 specifying -DWATCH_IS_TIMER0 when compiling the module attimer.

It's possible to have more instances of the ATTimer class, but only the first manages the HW behavior.

The reset method of the first instance doesn't reset all the ATTimer instances, then, when the method reset of the first instance is called, it need to call the method reset for all the other instances.

2.3. SPI Module (spi.cpp)

This module implements the class SPI which allows SPI master and slave communications. For now only mode 0 is implemented (I.E.: Data are sampled on the clock signal (SCK) rising edge and the clock signal is active-high).

This module has the following characteristics:

- The use of two circular buffers: one to receive data and one to keep the data to transmit.
- The use of SPI counter overflow interrupt to receive data when slave mode is selected.
- The use of polling to manage master communications.
- The capability to disconnect the SO (slave output) pin by means of a specific method when in slave mode.

- The capability to manage a protocol which allows to recognize the data validity (IE: The protocol is able to understand if 0xFF or 0x00 are data or not) and which slave is required to reply the master answers.

2.3.1. Mains methods.

The base mains methods the SPI module exposes are:

begin	This method initializes the module and specifies the communication mode and the communication buffers.
enabled	This method sets the direction of the pins needed for the required SPI communication mode and activates the interrupt for the slave receiver if “not master” has been specified by the begin method (default).
outputEnable	This method disables/enables the output pin.
getRcvdData	This method takes bytes (and types) from the receiver buffer.
getRcvdByte	This method takes a single byte from the receiver buffer.
getRcvdDataSize	This method returns the number of byte in the receiver buffer.
setData2Xmit	This method puts bytes (and types) in the transmission buffer.
setByte2Xmit	This method puts a single byte in the transmission buffer.
get2XmitDataSize	This method returns the number of byte in the transmission buffer.
sendMaster	This method is used from the master to send data that are kept into the transmission buffer. When the method is called it may or may not receive data from the slave ("don't receive data" means don't keep incoming data into the receive buffer), this is the default. To receive data you may call the method sendMaster with or without data in the transmission buffer and specifying the length of the data you want receive.

2.3.2. An idea of protocol.

The software in this project tries to implement a communication protocol based on the idea to use the character 0x1B as prefix. This allows the programs to avoid to read data due to link absence (I.E. 0xFF or 0x00) and allows a master to communicate via software a code act to enable the correct slave that recognize such a code.

This protocol uses the byte 0x1B as prefix for the bytes 0xFF, 0x00 and 0x1B. All other chars prefixed by the 0x1B will be kept as they are (without the 0x1B code), but their code will be stored as a slave-code.

For now also the code 0xAA shall be prefixed by the 0x1B code because it's intended as slave presence, but I think I will remove this feature.

2.3.3. Method for the protocol.

The method (in addition to what above specified) implemented to use the protocol are the following:

enhancedSetData2Xmit	This method puts bytes (and types) in the transmission buffer.
enhancedGetRcvdData	This method takes bytes (and types) from the receiver buffer.
masterSetActiveSlave2Xmit	This method sets the activation code that a master will be sent to activate a slave.
activeSlave	This method reads the eventual slave activation code the master has sent.
setOutput	This method allows the slave to disconnect its output from the communication buffer.

2.3.4. Remarks.

I apologize, but this module is not capable of very high communication speed. In slave mode the limits is due to the ISR preamble load; in master mode the limits is due to the actual SCLK management (polling).

In slave mode the SW may receive data sent by the master at speed till 1 Mbit/sec (and over I think), but it need a delay of at least 10 microseconds after each received byte. This means the master may transmit at a speed of 1 Mbit/sec, but it has to insert a delay of at least 10 microseconds before sending another character.

2.4. ADC Module (atadc.cpp)

This module implements the class ATADC which manages ADC conversions. For now, it manages only conversions from each single ADC converter, but not differential conversions. It uses a single ADC channel at time and can set reference voltage, single acquisition and continuous acquisition.

This class doesn't have methods to accomplish the ADC channels calibration.

2.4.1. Main methods.

begin	sets the general parameters for the acquisitions that the acquire() method will make. This method may be used to change the acquisition parameters and mux channel when the acquisition is not enabled (disable() method allows to disable the acquisition). This method doesn't enable the acquisition.
beginTemperature	overloads the method begin(). It allows to set the mux channel needed to acquire temperature measurements using the AT tiny internal thermal sensor.
enable	enables the selected channel (the method begin() selected it) to acquire. This method shall be called before to make the first acquisition.
disable	disables the selected channel. This method stops the acquisitions. It shall be used before to change the used channel. (begin() may be used to change the acquisition parameters)
acquire	allows to acquire the conversions that the selected channel sampled. This method may be used continuously. It returns the 10 bits read from the channel

or -1 if errors occur.

2.4.2. Remarks.

The simplest way to use objects of the ATADC class is to use the begin() method declaring the channel to use and leaving the other parameters as specified by default. After you have called one time only the enable() method you have to use the acquire() method each time you need.

You may change the channel to manage. To do that you have to use the disable() method before to set the new channel using the begin() method. Then, after you have called one time only the enable() method you have to use the acquire() method each time you need.

Changing parameters or channel mux when the enable () method had been already called and before to call the disable () method produces incorrect behaviors.

For now the object of this class cannot manages differential channel and other ADC stuff. Only single channel acquisition are managed.

This class doesn't have methods to accomplish ADC channel calibration.

2.5. Circular buffer module (circbuff.cpp)

This module implements a circular buffer class.

2.6. Some standard C functions and not. (fnclib.c)

The file fnclib.c implements some standard C functions prefixed by the underscore character “_”: _strcpy, _strlen, _strcat, _memcpy, _memset.

For now is possible to declare inline _memcpy and _memset using the declarations #define __FNC_INLINE_MEMCPY and #define __FNC_INLINE_MEMSET before the declaration #include “fnclib.h”.

An other function implemented in this module is strntoll. This function converts a string in its corresponding 64 bits integer value. It also understands standard C basis specifications IE: 0xnnnn (for hexadecimal) and 0nnnn (for octals), moreover this function understands the format “*Bnnnnnn” where B indicates a numerical basis IE: "*21011" will be converted in the decimal value 11; the value of the B field may be also a letter where "A" is interpreted as 10 basis and so on till "Z" that is interpreted as 36 basis. (see the include file fnclib.h)

2.7. Include files.

2.7.1. MCU Clock settings.

The include-file timing.h describes the MCU-clock settings. It's in the subdirectory ./include/reg. The only way to specify different clock is to modify its contents.

Pay attention: the modifications of the timing in the file timing.h are not directly reflected on the MCU clock that shall be configured in the fuse-memory (see: AVR manuals).

The actual software configuration assumes the following fuse-memory configurations.

AT Tiny 85	16 MHz	lfuse:0xE1 hfuse:0xdf efuse:0xff
AT Tiny 84	8 MHz	lfuse:0xE2 hfuse:0xdf efuse:0xff

2.7.2. HW registers.

The HW registers and relevant settings are described in the include files contained in the directory ./include/reg.

regdport.h	digital I/O ports.
regtiming.h	timer counters.
regusi.h	USI (Universal Serial Interface)
regadc.h	ADC (Analog to Digital converters)

2.7.3. Other include files.

Some include files are in the directory ./include.

bits.h

h_types.h

inithw.h

3. Examples.

3.1. sblk85.cpp

The program sblk85.cpp starts with an output signal that blinks fast then blinks with a period of 2 seconds high and 2 seconds low. On the AT Tiny 85 is used the pin B4, on the AT Tiny 84 is used the pin B2. The software is configured as SPI slave and is able to receive simple commands that are the following:

t#	This command returns information about the MCU timing.
	
	t xx yy zzzz OK (each char is a byte)
	
	Where: xx is the MCU tick in tenth of nanosecond, yy is the timer resolution in microseconds, zzzz is the time, in microseconds, elapsed from the timer activation (the low 4 bytes – the time is 8 byte long).
	
	The MCU generates the output data using this code:
	spi.setData2Xmit((uint16_t)TICK_ns_10th);
	spi.setData2Xmit((uint16_t)timer.uTick());
	spi.setData2Xmit((uint32_t)timer.baseTime());

bltttnnnnn#	This command obtains the signal specified by l blinks tt times with a period of nnnnn milliseconds. l may be 1 or 0 for the AT Tiny 84 (for the AT Tiny 85 is indifferent). On the tiny 84 1 means to send the signal on the pin B0, 0 means to send the signal on the pin B2. On the Tiny 85 is used only the pin B4.
lnnnnnnnn#	This command changes the time for which the signal B2 (AT Tiny 84) - or B4 (AT Tiny 85) - is alternatively high or low.

If the received data are correct the program replies with a number of bytes depending of the command. IE: "x[n bytes]OK" (n may be 0) where x is the first byte received as command and OK Is OK :)

If the received data are not correct the program replies with 3 bytes “x?y” where x is the first byte received as command and y is an error code, ? Is ? :)

This program has been written to use the configuration 1 which is specified in the chapter “Hardware”.

3.1.1. How to make the example.

To compile the example go in the directory project/sblk85 and type:

#make all <enter>

To upload the MCU you may use:

#make rom <enter>

(see the paragraph Pre-requirements)

To compile for the AT Tiny 84 you have to set the CPU before to execute make:

#export CPU=tiny84

then:

#make clean

#make all

If you want the MCU uses the timer-counter 0 (that is correct when you use the AT Tiny 84) instead the timer counter 1 you have to specify this:

#export DEFS=-DWATCH_IS_TIMER0

then:

#make clean

#make all

When you change configurations you have to remember to execute:

#make clean

before recompile the software.

3.1.2. Remarks.

This program has been written to use the configuration 1 which is specified in the chapter “Hardware”.

3.2. adc84.cpp.

The program adc84.cpp acts in similar fashion to the program sblk85, but add the capability to read the ADCs. At start time the program is configured to read the ADC connected to the internal thermal sensor; it communicates in SPI slave and is able to receive simple commands that are the following:

t#	This command returns information about the MCU timing and the ADC conversions. t xx yy zzzz OK (each char is a byte) Where: xx is the MCU tick in tenth of nanosecond, yy (16 bits) is the ADC acquired value (10 bits), zzzz is the time, in microseconds, elapsed from the timer activation (the low 4 byte – the time is 8 byte long). The yy 16 bits word results as 0xAAAA when ADC sampling is disabled. It results as 0xFFFF when an error occurs during sampling time. A normal value read from a channel is numerically correct if between 0x0000 and 0x03FF.
av#	This command indicates which ADC channel the MCU will have to use to acquire data. “v” may be t (temperature), d (disable all ADC sampling) or a number from 0 to the max number of ADC channels the MCU has.
blttnnnnn#	This command obtains the signal specified by l blinks tt times with a period of nnnnn milliseconds. l may be 1 or 0 for the AT Tiny 84 (for the AT Tiny 85 is indifferent). On the tiny 84 1 means to send the signal on the pin B0, 0 means to send the signal on the pin B2. On the Tiny 85 is used only the pin B4.
lnnnnnnnn#	This command changes the time for which the signal B2 (AT Tiny 84) - or B4 (AT Tiny 85) - is alternatively high or low.

If the received data are correct the program replies with a number of bytes depending of the command. IE: "x[n bytes]OK" (n may be 0) where x is the first byte received as command and OK Is

OK :)

If the received data are not correct the program replies with 3 bytes “x?y” where x is the first byte received as command and y is an error code, ? Is ? :)

This program has been written to use the configuration 1 which is specified in the chapter “Hardware”.

3.2.1. How to make the example.

To compile the example go in the directory project/adc84 and type:

#make all <enter>

To upload the MCU you may use:

#make rom <enter>

(see the paragraph Pre-requirements)

To compile for the AT Tiny 85 you have to set the CPU before to execute make:

#export CPU=tiny85

then:

#make clean

#make all

3.2.2. Remarks.

This program has been written to use the configuration 1 which is specified in the chapter “Hardware”.

The default CPU the makefile selects at compile time is AT Tiny 84 instead of AT Tiny 85 because the different number of pins. If you want to use ADC channels on the Tiny 85, other than internal temperature channel, you have to remove the led indicated in the hardware configuration (chapter Hardware). Using the Tiny 84 you may easily use the channels connected to pins PA0, PA1, PA2 and PA3.

The program is able to be compiled for Tiny 85; When you choose to use the ADC channel connected to the pin B4 all digital signals directed to such a pin will not be executed[1].

The use of the ADC channels connected to the SPI dedicated pins harms the communications.

1 The program verifies the use of the pin as ADC and doesn't execute the commands relevant to digital signals moreover the method which enables the ADC acquisition inhibits the digital buffer of the pin used as ADC channel.

3.3. Make specifications.

3.3.1. Settings.

The makefile contains/uses some defined variables which specify tools and some other stuff.

CPU	specifies the CPU where the program will run. CPU may be set by the operating system using the command export. E.G. export CPU=tiny84[or tiny85]
ARDUINODIR	specifies the directory where are the tool to compile and flash the program. The default is ARDUINODIR=/opt/arduino-1.6.0 . If you need to modify this you have to modify the makefile.
DEFS	specifies the definition (-D or -U gcc options) that will be used to compile the program. DEFS may be set by the operating system using the command export. E.G. export DEFS=-DWATCH_IS_TIMER0.

3.3.2. Make rules.

#make all

This compiles the code.

#make rom

This sends the code in the flash memory of the MCU (using as programmer an “Arduino as ISP”).

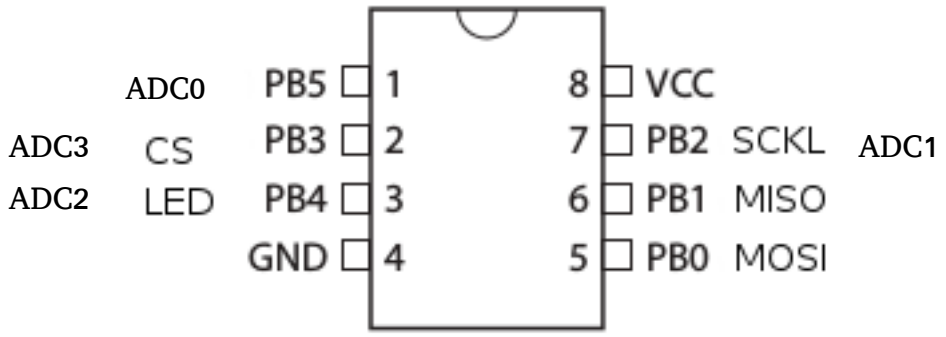
#make clock

This sets the MCU fuses to have the required timing (using as programmer an “Arduino as ISP”).

4. Hardware.

4.1. Configuration 1.

AT Tiny 85



AT Tiny 84