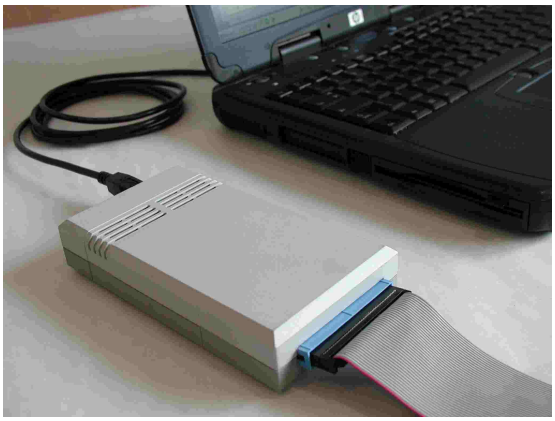
INTECO
Krakow, POLAND, inteco@kki.krakow.pl
www.inteco.com.pl

RT-DAC/USB2

I/O Board

Board version 1.03



User's Manual

Kraków 2010

Revision History

Version	Date	Resp.	Description
1.0	2010-09-30	KK	First release
1.1	2010-10-25	KK	Text improvements

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NOTES

1. GENERAL INFORMATION

The RT-DAC/USB2 is a multifunction analog and digital I/O board dedicated to real-time data acquisition and control in the Windows 95/98/NT/2000/XP environments. The board contains a Xilinx® FPGA chip. All boards are built as the OMNI version. It means the boards can be reconfigured to introduce a new functionality of all inputs and outputs without any hardware modification.
The default configuration of the FPGA chip accepts signals from incremental encoders and generates PWM outputs, typical for mechatronic control applications and is equipped with the general purpose digital input/outputs (GPIO), A/D and D/A converters, timers, counters, frequency meters and chronometers.
The RT-DAC/USB2 board is distributed in two versions:

- analog and digital (RT-DAC/USB2) and
- digital only (RT-DAC/USB2-D).

This manual contains description for the both versions. In the case, if any facility of the board relates to one version only, this fact is clearly marked.

1.1 Specification

Analog section (not available in the RT-DAC/USB2-D version)

Analog Inputs

Channels:	16 single-ended, multiplexed
Resolution:	12 bit
Input ranges:	±10V, programmable gain (x1, x2, x4, x8, x16)
Conversion time:	5.4 μs
Trigger:	all the A/D channels are scanned automatically when USB host requires data
Reference voltage:	on-board

Analog Outputs

Channels:	4
Resolution:	12 bit / 14 bit
Output range:	± 10V, ± 5V
Settling time:	10 μs (to 0.01%)
Reference voltage:	on-board

Digital section (version 1.03)

Digital Input/ Output

Channels:	26 bi-directional, direction setting; 8 channels shared with PWM outputs; some inputs shared with counter, timer, chronometer and frequency meter inputs
Direction:	bi-directional, individually software programmable
Input voltage:	V_{IH} = 2.0V÷3.6V, V_{IL} = - 0.5V÷0.8V
Output voltage:	V_{OH} = 2.4V (min), V_{OL} = 0.4V (max)
Output current:	2mA per channel
Standard:	LVTTL

Digital Timer/Counter

32 bit timer / counter :	2 channels, counts internal clock signal or external impulses . External pulse duration: min 50ns

PWM Outputs

Channels:	4
Resolution:	8/12 bits (software selected)
Base frequency:	programmable, initial 16-bits divider

Incremental encoders

Channels:	4
Output:	32 bit counter
Index	Software configured. 2 modes: with and without index, selectable active level of the index signal

USB features

USB 2.0 hi-speed specification compliant.

1.2 Board architecture

The block diagram of the RT-DAC/USB2 board is shown in Fig. 1.1. The block diagram of the digital version is presented in Fig. 1.2.

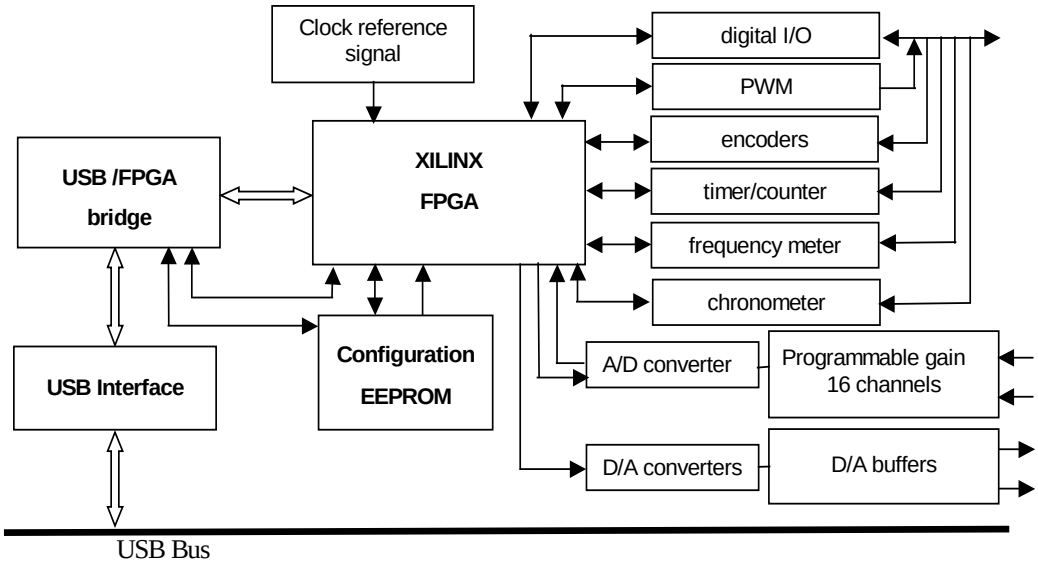

Fig. 1.1. General block diagram of the RT-DAC/USB2 board

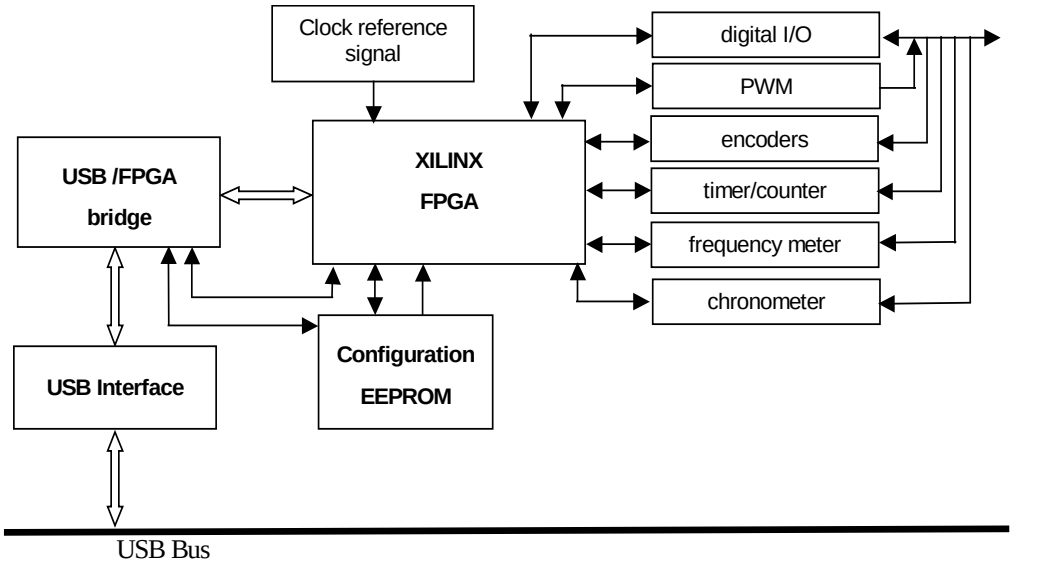

Fig. 1.2. General block diagram of the RT-DAC/USB2-D board

The board is equipped with the 12-bit successive approximation A/D converters that give the 5 mV resolution within the input range ±10V. A finer resolution can be achieved by the gain definition using digitally programmable analog amplifier. The A/D conversion time of the RT-DAC/USB2 board is equal to 5.4 µs.
The board contains four 12-bits D/A converters connected to four analog output channels (optionally 14-bit D/A converters are available). The output voltage of the channels is ± 10V. Each analog output channel can sink up to 10 mA.

Reprogramming the XILINX FPGA chip at the boards can change functions of the board. The information and specification how to reprogram XILINX FPGA is not included in this guide. Please, relate to *RTDAC/USB2 FPGA Programming Guide* distributed by INTECO separately.

2. BOARD INSTALLATION

The RT-DAC/USB2 setup contains:

- RT-DAC/USB2 board,
- Two 40-pin ribbon cables (only one cable when the digital version is distributed),
- USB cable,
- CD containing a software and e-manuals,
- terminal wiring board (optional),
- 9V-12V DC / 4W stabilised power supply (optional). The plug dimensions are given in Fig. 2.2.

The layout of the RT-DAC/USB2 board is presented in Fig. 2.1

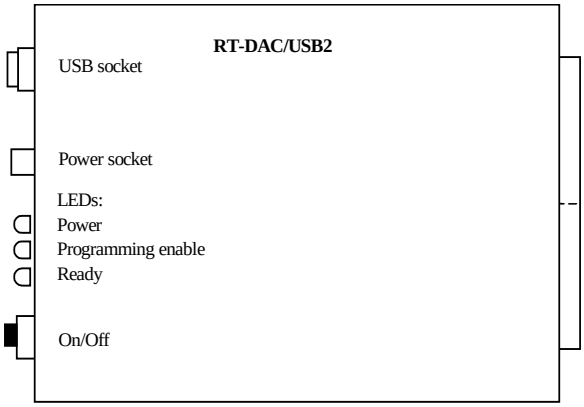

Fig. 2.1. The layout of the RT-DAC/USB2 board

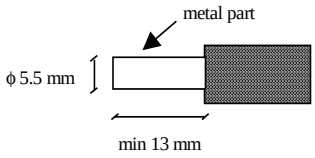

Fig. 2.2. The plug of the DC power supply

The CN1 connector is not visible at the Fig. 2.1 because it is placed below the CN2 connector. The digital version of the board is equipped with the CN1 connector only. The CN2 connector contains pins connected to A/D inputs and D/A outputs only.
The *Power* signalling LED is emitting light when the *On/Off* switch is on, *Ready* LED indicates that the communication between the RT-DAC/USB2 board and computer is running and *Programming Enable* LED is emitting light when the board is ready to be programmed.

To install the board:

- install driver for the board (see below or CD:\DRIVER\readme*.txt),
- install RT-DAC/USB2 testing applications
- optionally install the RT-CON package,
- connect the board to the computer using the included USB cable,
- connect the national version of the DC 9V-12V stabilised power supply (not included). 9V DC voltage is recommended.
- test the board (see section 6).

3. DRIVER INSTALLATION

The driver for RT-DAC/USB2 board has to be installed. The user with administrator privileges must install the drivers for Windows 2000 and Windows XP.

Windows 2000/XP installation

1. Start Microsoft Windows 2000/XP
2. Connect the RT-DAC/USB2 device and turn power ON
3. System detects a new USB device
4. Select the file CD:\driver\w2k_xp\cyusb.inf and then press OK

If the driver is not installed and the RT-DAC/USB2 device is connected to the PC it appears as unknown device at the list of the devices in the Device Manager (see Fig. 3.1).

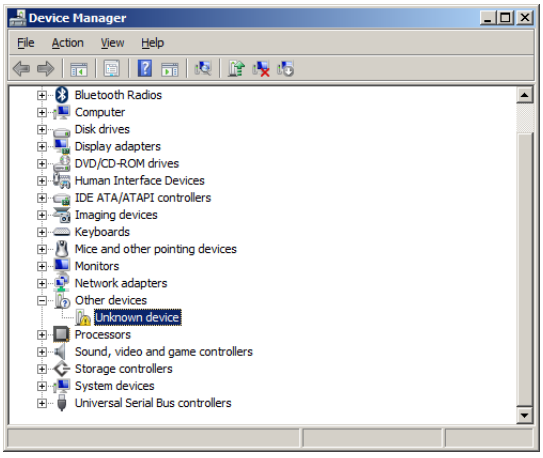

Fig. 3.1. Device list with an unknown device

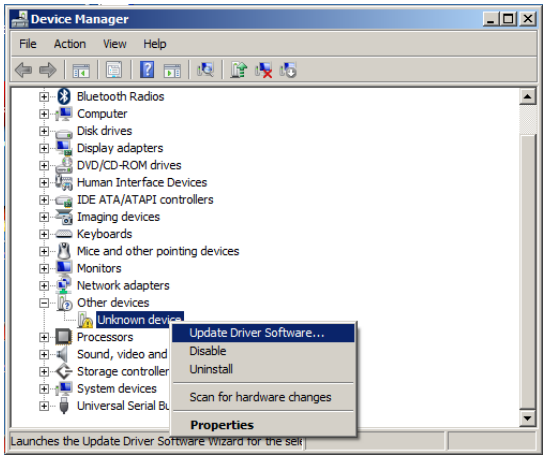

Fig. 3.2. Update driver option

Press the right mouse button at the *Unknown device* item and select the *Update Driver Software* item (see Fig. 3.2). Select the *Browse my computer for driver software* option (DO NOT select the *Search automatically for updated driver software*) and select the driver location as given in Fig. 3.3and Fig. 3.4.

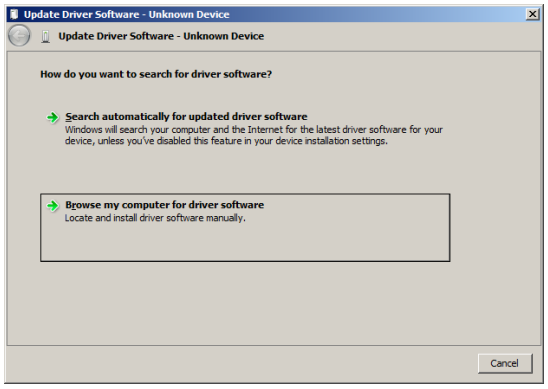

Fig. 3.3. Browse the computer option

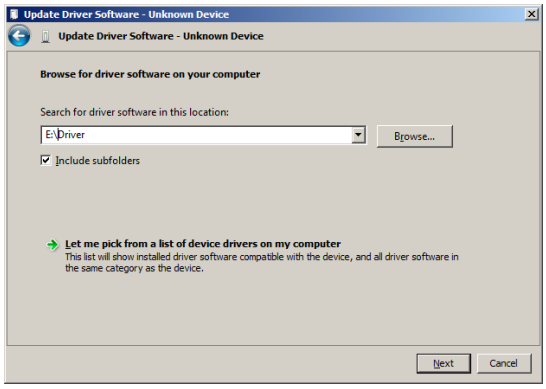

Fig. 3.4. Select the driver

Windows displays the security warning caused by the uncertified driver. Please force the driver to be installed (see Fig. 3.5). Finally the confirmation of the successful driver installation is given as presented in Fig. 3.6.

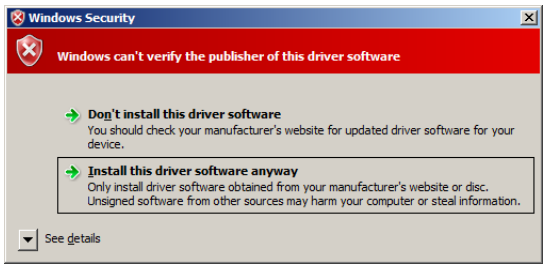

Fig. 3.5. Windows security warning

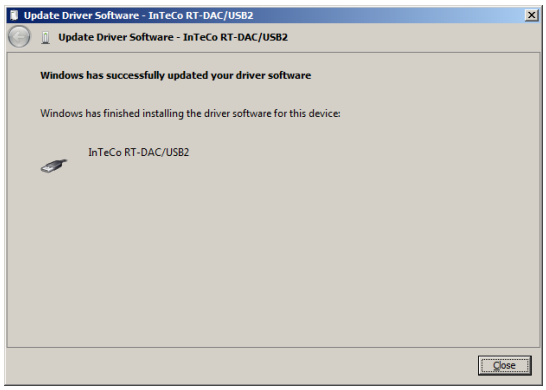

Fig. 3.6. Confirmation of the successful installation

The 64-bit versions of Windows require that all drivers are digitally certified, which the driver for the RT_DAC/USB2 is not. A user needs to reboot the Windows PC and press F8 to show the boot option list. The loading/installing unsigned drivers option has to be selected to allow installation of the driver.

When the RT-DAC/USB2 is properly installed it is visible in the *Device Manager* at the list of devices in the *Universal Serial Bus controllers* category as the *InTeCo RT-DAC/USB2* entry (see Fig. 3.7).

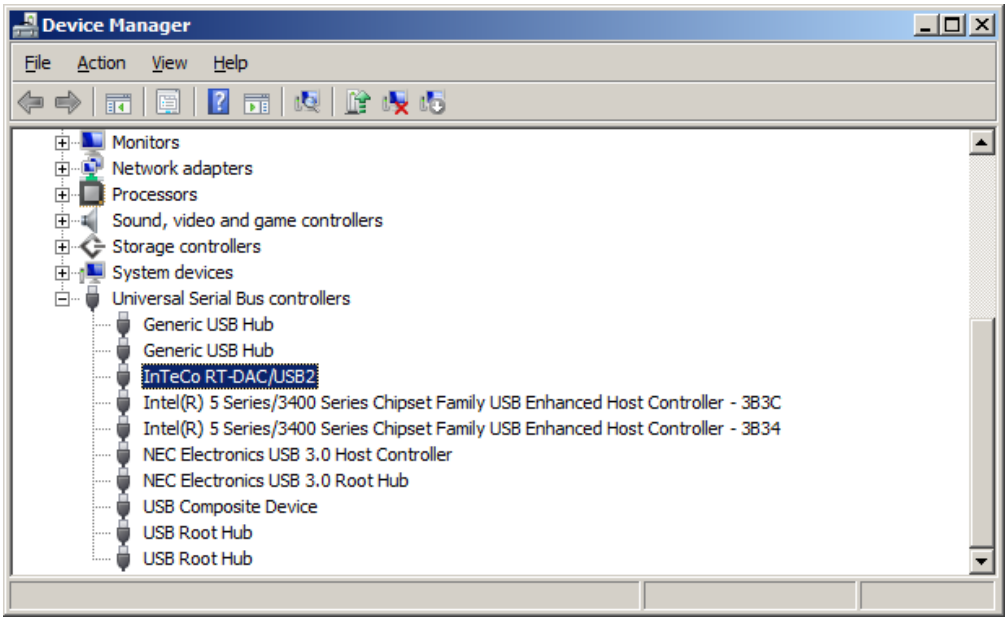

Fig. 3.7. RT-DAC/USB2 device at the list of installed devices

4. CONNECTOR PIN ASSIGNMENT

The digital version the RT-DAC/USB2D board is equipped with one 40-pin I/O connector CN1. The pin assignment of the connector is shown in Table 1 and Fig. 4.1.

Table 1. RT-DAC/USB2 I/O CN1 pin assignment

CN1 Pin No	Power supply	Digital I/O	Counter	PWM	Encoder	Frequency meter	Chronometer
1		DIO0			ENC0A	Fr0G	Ch0G
2	GND						
3		DIO1			ENC0B	Fr0St	Ch0St
4	GND						
5		DIO2		PWM0	ENC0I	Fr0I	Ch0StSt
6	GND						
7		DIO3			ENC1A	Fr1G	Ch1G
8	GND						
9		DIO4			ENC1B	Fr1St	Ch1St
10	GND						
11		DIO5		PWM1	ENC1I	Fr1I	Ch1StSt
12	GND						
13		DIO6			ENC2A	Fr2G	Ch2G
14	GND						
15		DIO7			ENC2B	Fr2St	Ch2St
16	GND						
17		DIO8		PWM2	ENC2I	Fr2I	Ch2StSt
18	GND						
19		DIO9			ENC3A	Fr3G	Ch3G
20	GND						
21		DIO10			ENC3B	Fr3St	Ch3St
22		DIO11		PWM3	ENC3I	Fr3I	Ch3StSt
23		DIO12			ENC4A	Fr4G	Ch4G
24		DIO13			ENC4B	Fr4St	Ch4St
25		DIO14		PWM4	ENC4I	Fr4I	Ch4StSt
26		DIO15			ENC5A	Fr5G	Ch5G
27		DIO16			ENC5B	Fr5St	Ch5St
28		DIO17		PWM5	ENC5I	Fr5I	Ch5StSt
29		DIO18			ENC6A	Fr6G	Ch6G
30		DIO19			ENC6B	Fr6St	Ch6St
31		DIO20		PWM6	ENC6I	Fr6I	Ch6StSt
32		DIO21			ENC7A	Fr7G	Ch7G
33		DIO22			ENC7B	Fr7St	Ch7St
34		DIO23		PWM7	ENC7I	Fr7I	Ch7StSt
35		DIO24	CNT 0				
36		DIO25	CNT 1				
37	GND						
38	GND						
39	+5.0 V						
40	+3.3 V						

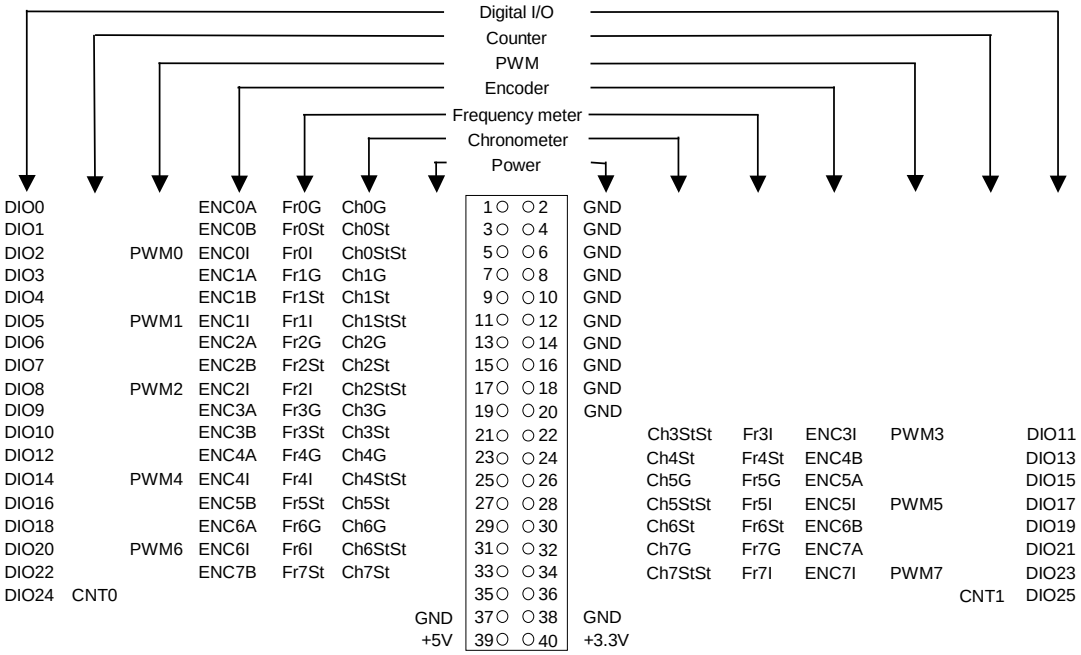

Fig. 4.1. RT-DAC/USB2 I/O CN1 connector

The analog and digital version of the RT-DAC/USB2 board is equipped additionally with the CN2 40-pin connector. The pin assignment of the connector is shown in Fig. 4.2.

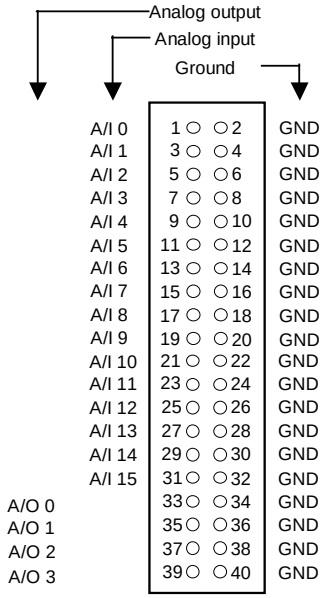

Fig. 4.2. RT-DAC/USB2 I/O CN2 connector

The RT-DAC/USB2 board is equipped with 16 multiplexed analog inputs located at the CN2 connector. They are named from A/I 0 down to A/I 15. The output of the analog multiplexer is connected to the input of the digital programmable analog amplifier. The board is also equipped with four 12-bit D/A converters. These outputs are named from A/O 0 down to A/O 3.

Only 26 pins at the CN1 connector are used as general-purpose digital I/O signals (DIO0 to DIO25). The remaining pins are the ground and power (GND, +5V, +3.3V). The general purpose digital I/O signals can be individually configured to be either the input or output.

As the number of general-purpose digital I/O signals is limited, all of them are shared with the signals of the specialized blocks. The specialized blocks are implemented as the modules in the on-board FPGA structure.

It means that **the functions of the specialized block are hardware-implemented**. The specialized blocks are:

- PWM generators – there are eight PWM blocks. The outputs are marked: *PWM0*, *PWM1*, *PWM2*, *PWM3*, *PWM4*, *PWM5*, *PWM6* and *PWM7*,
- incremental encoders – the device contains eight incremental encoder channels. Each channel requires three input signals – wave A (named from *ENC0_A* down to *ENC7_A*), wave B (from *ENC0_B* to *ENC7_B*) and index (from *ENC0_I* to *ENC7_I*),
- counters – there are two counters available. The input signals are marked *CNT0* and *CNT1* respectively,
- frequency meters – RT-DAC/USB2 contains eight such blocks. The signals are named from *Fr0_G*, *Fr0_St* and *Fr0_I* to *Fr7_G*, *Fr7_St* and *Fr7_I*,
- eight chronometer blocks – the signals are named from *Ch0_G*, *Ch0_St* and *Ch0_StSt* down to *Ch7_G*, *Ch7_St* and *Ch7_StSt*.

There are two kinds of specialized blocks:

- the first kind of the specialized blocks contains digital output signals (PWM blocks). In this case the appropriate pins of the CN1 connector can operate as the general purpose digital I/O signals or as the output of the specialized block. The operating mode is determined by a mode configuration register (CN1 Pin Mode Register). If they operate as general purpose digital I/Os their directions and states are determined by the software. If they operate as the outputs of the specialized blocks the state of the output is controlled by the PWM block. The states of the output signals can be read by the software (the software can check the PWM output),
- the second kind of the specialized blocks contains only the digital input signals (the incremental encoders, counters, frequency meters and chronometers). In this case it is not necessary to select the operating mode of the block signals. If the appropriate general purpose I/O signals are configured to be the inputs then their states can be read by the software and simultaneously the signals excite the specialized block (see Fig. 4.3). If the shared general purpose I/O signals are configured to be outputs their states can be set by the software and simultaneously the signals excite the specialized block (see Fig. 4.4). This operating mode can be applied for testing of the specialized blocks – for example the encoder can be excited and read in a software manner. This testing strategy is not significant during common device applications. It may be very useful when one wants to design and test his own FPGA blocks (see *"USB Device XILINX Programming Guide"*)

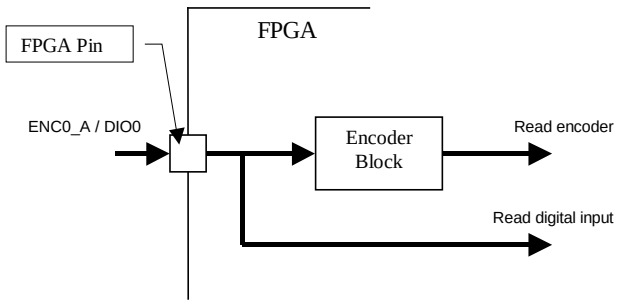

Fig. 4.3. The shared FPGA pin configured as the input

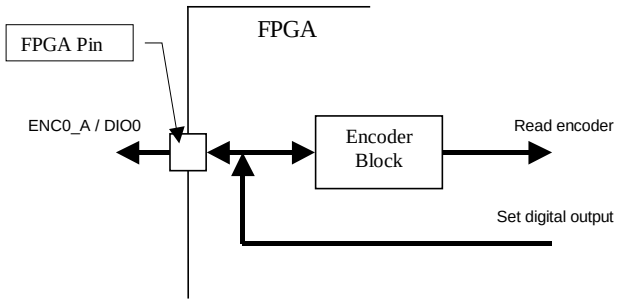

Fig. 4.4. The shared FPGA pin configured as the output

5. USB ACCESS FUNCTIONS

The software for the RT-DAC/USB2 device is developed as:

- C language procedures,
- .NET C# properties and methods,
- Simulink blocks and S-functions.

Test applications for the functions of the RT-DAC/USB2 device are available as well. The applications are described in section 6.

5.1 General description of software interfaces

The software platforms applied to access the RT-DAC/USB2 I/Os apply some basic items used by the interface functions. This section contains the general description of the common items. The detailed description is presented in the following subsections related to the different types of I/O channels.

Communication with the board is performed by transferring a data frame. A dedicated binary buffer placed at the board, in the FPGA chip, contains all information of the board. In this buffer are kept measurements and all settings of the board. The FPGA logic manages the binary buffer. The data stored in the buffer can be read from the buffer as well as data can be written to the buffer by transferring data frames over USB link. The API functions hide the details of the structure of the binary buffer and allow easy access to the features of the RT-DAC/USB2 device

The communication with the board is realized by two main functions:

- the first reads binary buffer from USB board
- the second writes data to the binary buffer at USB board.

Using these two functions one can maintain all features of the USB board.

5.1.1 C interface

The RT-DAC/USB2 access functions are defined in the *rtdacusb2.c* and the *rtdacusb2.h* files. These files contain the API macro definitions and C API functions referred to the description of the board functions.
In programs, which use API functions, the *cyapi.h* file is applied. To build an executable the *cyapi.lib* library has to be linked. Both the *cyapi.h* and *cyapi.lib* files come from the Cypress Semiconductor company.

From the computer side the communication buffer is visible as a sequence of the words however the communication functions access the buffer as a nested structure of C language. The data type definition applied to communicate with the device has the following form:

```
typedef struct {
  unsigned int  LogicVersion;
  char          ApplicationName[7];
  unsigned long LogicDate;
  unsigned int  NoOfChannels[12];
  unsigned int  CN1PinMode;
  unsigned int  CN1Direction;
  unsigned int  CN1Output;
  unsigned int  CN1Input;
  PWMType       PWM[ NO_OF_PWM ];
  EncoderType   Encoder[ NO_OF_ENCODER ];
  TmrCntType    TmrCnt[ NO_OF_TMRCNT ];
  GeneratorType Generator[ NO_OF_GENERATOR ];
  ChronoType    Chrono[ NO_OF_CHRONO ];
  FreqMType     FreqM[ NO_OF_FREQM ];
  ADType        AD[ NO_OF_AD ];
  unsigned int  DA[ NO_OF_DA ];
} RTDACUSB2BufferType;
```

The name of the data type is *RTDACUSB2BufferType*. The type contains some fields. The detailed description of the fields is given in the following sections.

5.1.2 .NET interface

The class diagram of the .NET interface is given in Fig. 5.1. The main class is *RTDACUSB2_0103*. It creates interface to version 1.03 of the RT-DAC/USB2 device. The class contains one constructor and two methods – one for reading and one for sending data over the USB link. The names of the methods are *ReadUSBFrame* and *SendUSBFrame* respectively.

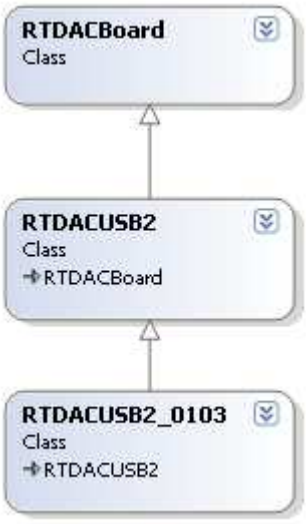

Fig. 5.1. .NET class diagram

The *RTDACUSB2_0103* class derives from *RTDACUSB2*. The *RTDACUSB2* class is responsible for transferring data over the USB link.
The *RTDACUSB2* class derives from the *RTDACBoard* class. This class manages the features of the I/O channels of the board. Each I/O channel type contains his own class definition (see Fig. 5.2). The properties of the classes from Fig. 5.2 are described in the following sections.

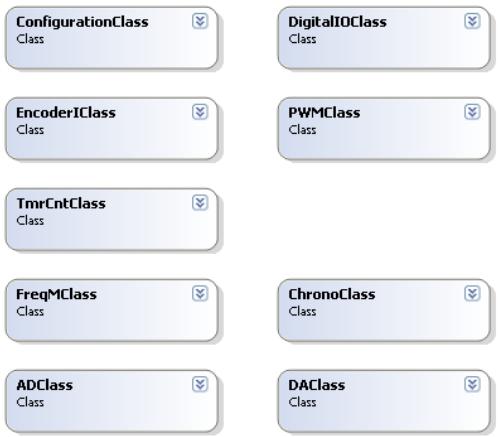

Fig. 5.2. Class types encapsulated in the *RTDACBoard* class

5.1.3 MATLAB/Simulink interface

A data frame is send to or read from the RT-DAC/USB2 board by the Simulink interface C-source code S-functions (and respective mex-files).
The S-function block that read data from the board is shown in Fig. 5.3. It contains 46 outputs – most of them are vector lines. The first output contains the status code of the read data frame operation. The remaining outputs contain all configuration data, setups and measurements from all I/O channels read from the board. The details of the output ports are described in the following sections.

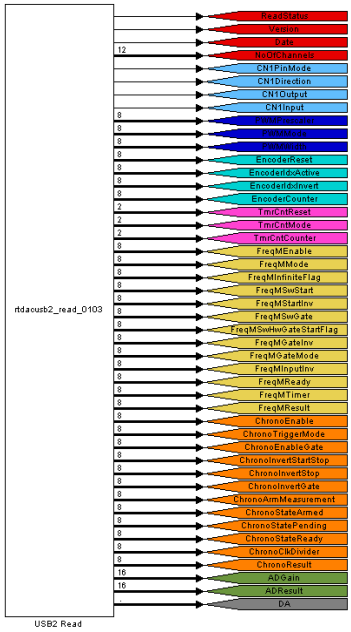

Fig. 5.3. Read S-function block

The S-function block that sends data to the board is shown in Fig. 5.4. It contains single output and 35 inputs. Most of the inputs are vector lines. The output contains the status code of the send operation. The remaining inputs contain all setups send to the board. The details of the input ports are described in the following sections.

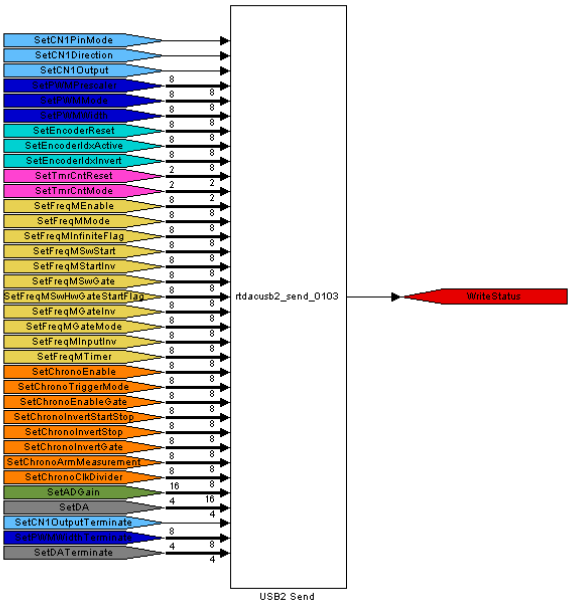

Fig. 5.4. Send S-function block

The parameters of the S-function *USB Read* and *USB Send* blocks are shown in Fig. 5.5. The windows contain the names of the S-functions and two parameters.
The first parameter is a serial number of the RT-DAC/USB2 board the block communicates with. The serial number is assigned to each RT-DAC/USB2 device during the assembling process and is unique for each RT-DAC/USB device. The serial numbers are applied to select a board in the case when more than one RT-DAC/USB2 is connected to the computer. The serial numbers are positive integer values. If the first parameter is negative (-1 value in Fig. 5.5) it means that only a single RT-DAC/USB2 board is connected to the computer and the serial numbers are not applied to distinguish the boards.
The second parameter is the sampling period of the block.

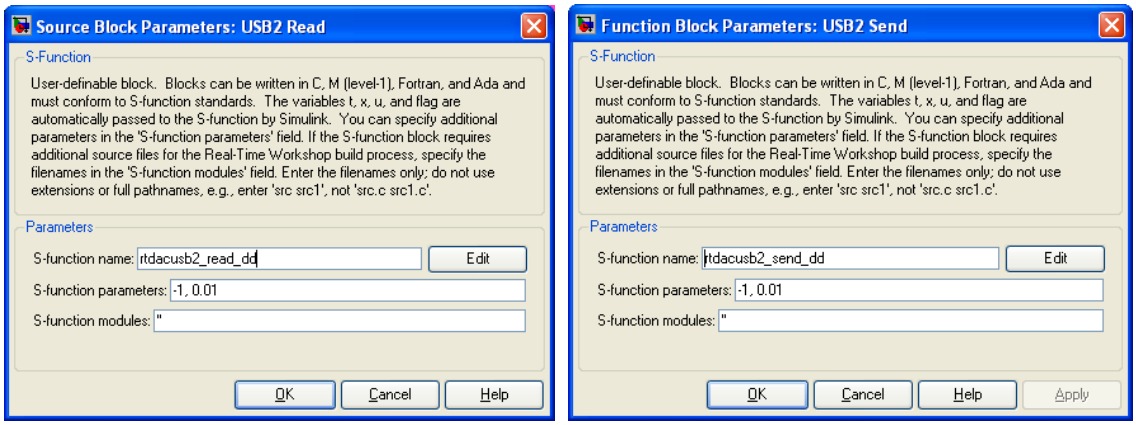

Fig. 5.5. Interfaces to the read and send S-function blocks

The S-function blocks shown in Fig. 5.3 and Fig. 5.4 contain a lot of inputs and outputs. The most frequently used features of the board are as follows: general-purpose digital I/Os, encoders, PWM outputs, D/A and A/D converters. A simplified version of the read and send S-functions can be also applied (see Fig. 5.6).

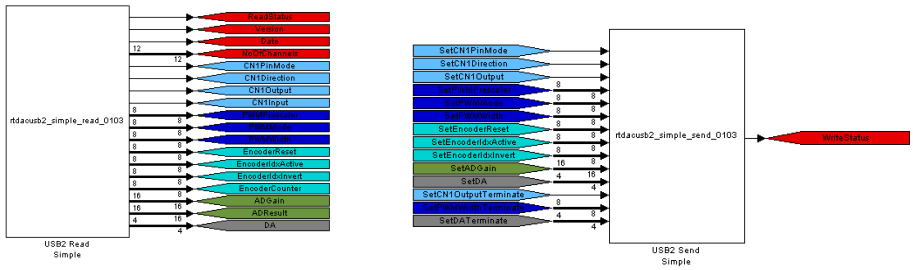

Fig. 5.6. Simplified read and send S-function blocks

5.2 USB functions

There is a common sequence of operations required to communicate with the RT-DAC/USB2 board:

- the first one has to open the communication channel. The RT-DAC/USB2 devices are distinguished by its serial number. Usually the device serial number is the argument of the open functions. The device serial number is not necessary only when a single RT-DAC/USB2 device is connected to the computer,
- a contents of the data buffer is read. It gives access to the current context of the device. Reading of the buffer allows to get measurements and set-ups,
- if ones requires to change the state of the RT-DAC/USB2 then the appropriate elements of the buffer are set. Each element of the buffer corresponds to a certain function of the board – usually only a few of them are changed. Writing to the buffer sets a new state of the device,
- closing the USB communication finishes the current session.

Each function returns an integer value. If the value is negative it means that the function failed. Zero or positive returned value indicates a successful function execution.

5.2.1 C interface

The C interface contains the following functions.

int USB2NumOfDevices(void);

DESCRIPTION
The function returns the number of the RT-DAC/USB2 devices connected to the computer..

ARGUMENTS
None

RETURNED VALUE
If successful the function returns the number of the RT-DAC/USB2 device connected to the computer. It returns zero if none RT-DAC/USB2 can be found. In the case of an error it returns a negative error code.

int USB2Open(void);

DESCRIPTION
The function opens the RT-DAC/USB2 device connected to the computer. The function opens the first device from the list of devices connected to the computer. As it can not distinguish RT-DAC/USB2 devices it should be called if only a single RT-DAC/USB2 is applied.

ARGUMENTS
None

RETURNED VALUE
If successful the function returns the handler to the opened RT-DAC/USB2 device. The handler is a non-negative integer value. The handler is the first argument of the RT-DAC/USB2 communication functions.
In the case of an error it returns a negative error code.

int USB2OpenBySerialNo(int SerialNo);

DESCRIPTION
The function opens the RT-DAC/USB2 device connected to the computer identified by the serial number. The serial number is a positive integer value assigned to each RT-DAC/USB2 device.

ARGUMENTS
SerialNo – serial number of the RT-DAC/USB2 device.

RETURNED VALUE
IF successful the function returns the handler to the opened RT-DAC/USB2 device. The handler is a non-negative integer value.
In the case of an error it returns a negative error code.

int USB2Close(int Idx);

DESCRIPTION
The function closes the connected RT-DAC/USB2 device. It is called when all operations with the device are finished.

ARGUMENTS
Idx – the handler to the RT-DAC/USB2 unit. The handler is returned by the *USB2Open* or *USB2OpenBySerialNo* functions.

RETURNED VALUE
If successful then the zero value is returned. Otherwise it returns a negative error code.

int CommandSend_0103(int Idx, RTDACUSB2BufferType *pBufferToSend);

DESCRIPTION
The function sends the data buffer to the RT-DAC/USB2 device. When the buffer is sent the new values of the board outputs and set-ups are immediately applied.

ARGUMENTS
Idx – the handler to the RT-DAC/USB2 unit to which new data are sent. The handler is returned by the *USB2Open* or *USB2OpenBySerialNo* functions.
pBufferToSend – pointer to the structure that contains the new data sent to the RT-DAC/USB2 board. The pointer points to the structure of the *RTDACUSB2BufferType* type.

RETURNED VALUE
If successful then the zero value is returned. Otherwise it returns a negative error code.

int CommandRead_0103(int Idx, RTDACUSB2BufferType *pBufferToRead);

DESCRIPTION
The function reads a data buffer from the RT-DAC/USB2 device. After the read operation the buffer contains the current state of the board.

ARGUMENTS
Idx – the handler to the RT-DAC/USB2 unit applied to read the data buffer. The handler is returned by the *USB2Open* or *USB2OpenBySerialNo* functions.
pBufferToSend – pointer to the structure that contains the data read from the RT-DAC/USB2 board. The pointer points to the structure of the *RTDACUSB2BufferType* type.

RETURNED VALUE
If successful then the zero value is returned. Otherwise it returns a negative error code.

int USB2LastError(void);

DESCRIPTION
The function returns an error code of the last operation.

ARGUMENTS
None.

RETURNED VALUE
Returns an error code. The codes are given in the following table.

Table 2. Error codes.

Error code value	Description
0	Successful operation
-1	Too many opened RT-DAC/USB2 devices
-2	Can not find any RT-DAC/USB2 device
-3	Invalid board index
-4	Can not access USB transfer endpoint
-5	Can not access USB NULL endpoint
-6	Endpoint are not closed
-7	Invalid device pointer
-8	Invalid synchronous OUT transfer
-9	Invalid synchronous IN transfer
-10	Invalid synchronous JTAG OUT transfer
-11	Invalid synchronous JTAG IN transfer
-12	Can not find device serial number

*char *USB2LastErrorMsg(void);*

DESCRIPTION
The function returns the pointer to a string that describes the status of the last operation

ARGUMENTS
None.

RETURNED VALUE
Returns the pointer to a string. The error codes and the strings pointed by the pointer and returned by the function are given in the following table.

Table 3. Error codes and respective strings.

Error code value	Description
0	RTDAC_OK
-1	RTDAC_TOO_MANY_USB_DEVICES
-2	RTDAC_CAN_NOT_FIND_USB_DEVICE
-3	RTDAC_TOO_HIGH_BOARD_INDEX
-4	RTDAC_CAN_NOT_ACCESS_ENDPOINTS
-5	RTDAC_CAN_NOT_ACCESS_NULL_ENDPOINT
-6	RTDAC_ENDPOINTS_NOT_CLOSED
-7	RTDAC_INVALIED_DEVICE_POINTER
-8	RTDAC_INVALIED_SYNCHRONOUS_OUT_TRANSFER
-9	RTDAC_INVALIED_SYNCHRONOUS_IN_TRANSFER
-10	RTDAC_INVALIED_SYNCHR_JTAG_OUT_TRANSFER
-11	RTDAC_INVALIED_SYNCHR_JTAG_IN_TRANSFER
-12	RTDAC_CAN_NOT_FIND_SERIAL_NUMBER

5.2.2 .NET interface

The .NET interface consists of the definition of the *RTDACUSB2_0103* class. The class contains a simple constructor and a few methods.

RTDACUSB2_0103 class

DESCRIPTION
The class RTDACUSB2_0103 creates the main interface to the RT-DAC/USB2 board equipped with FPGA configuration number 103. It contains a simple constructor and a few methods.

CONSTRUCTOR
The constructior does not require any input arguments and is activated by the command:

```
RTDACUSB2_0103 brd = new RTDACUSB2_0103();
```

The command creates the *brd* object of the *RTDACUSB2_0103* type.

int NumOfDevices( )

DESCRIPTION
The method of the *RTDACUSB2_0103* class. Returns the number of RT-DAC/USB2 devices connected to the computer.
The method can be called before opening a communication channel with any RT-DAC/USB2 unit.

ARGUMENTS
None.

RETURNED VALUE
A number of the RT-DAC/USB2 devices connected to the computer is returned.

int OpenBySerialNumber(int SerialNumber)

DESCRIPTION
The method of the *RTDACUSB2_0103* class. Opens the communication with the RT-DAC/USB2 with the serial number given by the input argument.

ARGUMENTS
Serial number of the RT-DAC/USB2 device given as the integer number. Each RT-DAC/USB2 board contains his own unique positive integer serial number. The serial number are applied to distinguish the boards if multiple boards are used simultaneously.
The *SerialNumber* argument can be negative in the case when only a single board is connected to the computer. In such a case the methods opens the communication regardless the real serial number of the connected RT-DAC/USB2 unit.

RETURNED VALUE
If successful the method returns zero. A negative value indicates an error. The following error codes are available:

-2 - can not find any RT-DAC/USB2 unit connected to the computer,
-12 - can not find an RT-DAC/USB2 with the given serial number.

int Open( )

DESCRIPTION
The method of the *RTDACUSB2_0103* class. Opens the communication with the RT-DAC/USB2 board. Can be called when only a single board is connected to the computer.

ARGUMENTS
None.

RETURNED VALUE
If successful the method returns zero. The (–2) value indicates that any RT-DAC/USB2 unit connected to the computer can not be found.

int ReadUSBFrame( )

DESCRIPTION
The method of the *RTDACUSB2_0103* class. Reads a single frame from the RT-DAC/USB2 board. Data from the frame are applied to update the values of the properties of the *RTDACUSB2_0103* class. After this method is called the properties contain up-to-date values of setups and measurements.

ARGUMENTS
None.

RETURNED VALUE
If successful the method returns zero. A negative value indicates an error.

int SendUSBFrame( )

DESCRIPTION
The method of the *RTDACUSB2_0103* class. The properties of the *RTDACUSB2_0103* class are packed into a data frame sent to the RT-DAC/USB2 board.

ARGUMENTS
None.

RETURNED VALUE
If successful the method returns zero. A negative value indicates an error.

5.3 Version management

The RT-DAC/USB2 devices contain some data applied to distinguish the configurations of the on-board FPGA chips. The data are: version of the FPGA configuration, name of the FPGA configuration, synthesis date of the FPGA configuration and the numbers of I/O channels implemented in FPGA.
The data are accessible after a successful read operation. In C language the `CommandRead_0103` function has to be called. Data are included in a variable of `RTDACUSB2BufferType` type. In .NET environment the `ReadUSBFrame` method has to be activated. Data are visible as properties of an object of `RTDACUSB2_0103` type. In Simulink a block that contains the read S-function block has to be run. Data are accessible at the outputs of the Simulink read S-function block.
All the version management fields are read-only.

5.3.1 Logic version

C interface	**`unsigned int LogicVersion`**
.NET interface	**`uint LogicVersion`**
Simulink interface	**`Version`**

DESCRIPTION
The field contains a number of the logic version applied in the FPGA chip. The version is coded as hexadecimal 16-bit number.

5.3.2 Application name

C interface	**`char ApplicationName[7]`**
.NET interface	**`string ApplicationName`**
Simulink interface	Not available

DESCRIPTION
The field contains a string that describes the application type of the RT-DAC/USB2 board. The string contains 6 characters.

5.3.3 Synthesis date

C interface	**`unsigned int LogicDate`**
.NET interface	**`string SynthesisDate`**
Simulink interface	**`Date`**

DESCRIPTION
The field contains the synthesis date of the FPGA configuration. The date is coded as hexadecimal 32-bit number in the form YYYYMMDD.

5.3.4 Number of channels

C interface	***unsigned int NoOfChannels[12]***
.NET interface	***uint Configuration.NoOfPWM***
	uint Configuration.NoOfTmrCnt
	uint Configuration.NoOfEncoderI
	uint Configuration.NoOfChrono
	uint Configuration.NoOfFreqM
Simulink interface	Not available

DESCRIPTION

The field contains the number of available I/O channels.

In C interface the elements of the *NoOfChannels* array contain the following data:

NoOfChannels[0] – number of PWM blocks,

NoOfChannels[2] – number of encoder blocks,

NoOfChannels[5] – number of timer/counter blocks,

NoOfChannels[7] – number of frequency meter blocks,

NoOfChannels[8] – number of chronometer blocks,

The remaining elements of the *NoOfChannels* array are reserved for future use.

In the .NET interface the number of channels are stored as respected properties.

5.3.5 Example

Check if an RT-DAC/USB2 board is connected. Open the board and read some configuration data. It is assumed that only a single RT-DAC/USB2 is connected, so the open operation does not require as the argument the serial number of the board.

C language

```
RTDACUSB2BufferType RTDACUSBBuffer;
int NoOfDetectedUSBDevices;
int BoardIdx;

// Detect the number of connected RT-DAC/USB2 devices
NoOfDetectedUSBDevices = USB2NumOfDevices( );
if( NoOfDetectedUSBDevices < 1 ) {
  printf ( "Can not detect any RT-DAC/USB2 device\n");
  return;
}
// Open the RT-DAC/USB2 device
BoardIdx = USB2Open( );
if( BoardIdx < 0 ) {
  printf( "Can not open an RT-DAC/USB2 device\n" );
  return;
}
// Read the data buffer
if( CommandRead_0103( BoardIdx, &RTDACUSBBuffer ) < 0 ) {
  printf( "Can not read the RT-DAC/USB2 device\n" );
  return;
}
printf("Number of detected RT-DAC/USB2 devices: %d          "
       "Logic version: %04X / %s",
       NoOfDetectedUSBDevices, RTDACUSBBuffer.LogicVersion,
       RTDACUSBBuffer.ApplicationName );

// Close the device
```

```
USB2Close( BoardIdx );
```

C# language

```
RTDACUSB2_0103 brd = new RTDACUSB2_0103();

// Detect the number of connected RT-DAC/USB2 devices
if (brd.NumOfDevices() < 1)
{
    MessageBox.Show("Can not find any RT-DAC/USB2 device.",
                    "DI/O example",
                     MessageBoxButtons.OK,
                     MessageBoxIcon.Exclamation);
    return;
}

// Open the RT-DAC/USB2 device
if (brd.Open() < 0)
{
    MessageBox.Show("Can not open the device.",
                    "DI/O example",
                    MessageBoxButtons.OK,
                    MessageBoxIcon.Exclamation);
    return;
}
// Read the data buffer
if (brd.ReadUSBFrame() < 0)
{
    MessageBox.Show("Can not read data frame.",
                    "DI/O example",
                     MessageBoxButtons.OK,
                     MessageBoxIcon.Exclamation);
    return;
}
String sAux;
sAux = "Number of detected RT-DAC/USB2 devices: " +
       String.Format("{0:D}", brd.NumOfDevices() ) + "\n" +
       "Logic version: " +
       String.Format("{0:X}", brd.LogicVersion ) + @" / " +
       brd.ApplicationName;
MessageBox.Show(sAux, "DI/O example",
                MessageBoxButtons.OK. );
// Closing not necessary !!!
// Done automatically when the object destroyed
```

5.4 Operating mode of the shared output signals

Some pins are shared between the digital I/O lines and outputs of the PWM blocks. When a shared pin works as an output it must exist a method to determine whether the pin is controlled by a general purpose digital I/O or by a PWM block. For this reason the *CN1PinMode* field is applied. The field sets the operation mode of the shared pins.
In the .NET interface the pin mode data are stored in the dedicated `DigitalIOClass` class.

C interface	***unsigned int CN1PinMode***	
.NET interface	***UInt32 DigitalIO.CN1PinMode***	
Simulink interface	***CN1PinMode***	output of the read S-function
	SetCN1PinMode	input of the send S-function

DESCRIPTION
The field sets/means a mode of the shared pins. Data determine the source of the output signals: DIO2/PWM0, DIO5/PWM1, DIO8/PWM2, DIO11/PWM3, DIO14/PWM4, DIO17/PWM5, DIO20/PWM6 and DIO23/PWM7. If a bit is set to zero it means the pin is defined as the output of the general purpose digital I/O. If a bit is equal to "1" the corresponding pin is defined as the output of a PWM block.
This feature of the board is coded as 32-bit double word but only eight bits are used as it is shown in the following tables.

Bit No	7	6	5	4	3	2	1	0
	-	-	DIO5 PWM1	-	-	DIO2 PWM0	-	-

Bit No	15	14	13	12	11	10	9	8
	-	DIO14 PWM4	-	-	DIO11 PWM3	-	-	DIO8 PWM2

Bit No	23	22	21	20	19	18	17	16
	DIO23 PWM7	-	-	DIO20 PWM6	-	-	DIO17 PWM5	-

Bit No	31	30	29	28	27	26	25	24
	-	-	-	-	-	-	-	-

5.5 Digital I/O

The RT-DAC/USB2 board contains 26 general-purpose digital input/output lines named as DIO0, DIO2,…,DIO25. The digital I/O lines are connected to pins of the CN1 connector. All digital I/O signals are shared with inputs or outputs of PWM, encoder, counter, frequency meter and chronometer blocks. To use digital signals as general-purpose I/Os the respective pin mode bit (see section 5.4) has to be set to '0'.
The general purpose digital I/O signals can be individually configured to become either inputs or outputs. The direction of each line can be set independently using the field *CN1Direction*.

The configuration of the general-purpose digital I/Os is shown in the following figure. Each signal is associated with the dedicated tri-state buffer. If a pin at the CN1 connector is configured to be input its state can be read by a program. If a pin is an output its state can be set. As well a program can read the state of the output signals. Such a read operations allow to verify if the states assigned to the output I/Os are really present as the board outputs.

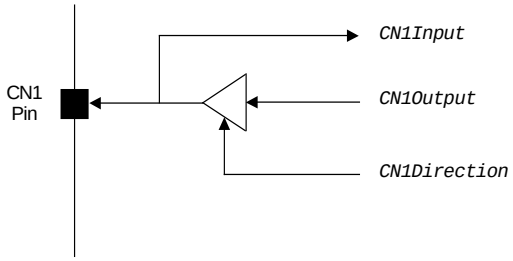

Fig. 5.7. Interfaces to a general-purpose digital I/O signal

In the .NET interface the direction and state of the I/Os are stored in dedicated `DigitalIOClass` class.

5.5.1 Direction

C interface	***unsigned int CN1Direction***	
.NET interface	***UInt32 DigitalIO.CN1Direction***	
Simulink interface	***CN1Direction***	output of the read S-function
	SetCN1Direction	input of the send S-function

DESCRIPTION
The field sets/means a direction of the digital I/O signals. If a bit is set to zero it means the pin is defined as the output. If a bit is equal to "1" the corresponding pin is defined as the input line.
This feature of the board is coded as 32-bit double word but only 26 bits are used as it is shown in the following tables.

Bit No	7	6	5	4	3	2	1	0
	DIO7	DIO6	DIO5	DIO4	DIO3	DIO2	DIO1	DIO0

Bit No	15	14	13	12	11	10	9	8
	DIO15	DIO14	DIO13	DIO12	DIO11	DIO10	DIO9	DIO8

Bit No	23	22	21	20	19	18	17	16
	DIO23	DIO22	DIO21	DIO20	DIO19	DIO18	DIO17	DIO16

Bit No	31	30	29	28	27	26	25	24
	-	-	-	-	-	-	DIO25	DIO24

5.5.2 Input

C interface	***unsigned int CN1Input***	
.NET interface	***UInt32 DigitalIO.CN1Input***	
Simulink interface	***CN1Input***	output of the read S-function

DESCRIPTION
The field contains values of signals at the CN1 connector. It is a read-only value.
For input signals it reads the digital inputs. For output signals it reads the real signal values present at the CN1 connector. If a pin is configured as a PWM output the respective bit relates to the output state of the PWM block.
This feature of the board is coded as 32-bit double word but only 26 bits are used in the same order as in the case of direction bits (see section 5.5.1).

5.5.3 Output

C interface	***unsigned int CN1Output***	
.NET interface	***UInt32 DigitalIO.CN1Output***	
Simulink interface	***CN1Output***	output of the read S-function
	SetCN1Output	input of the send S-function
	SetCN1OutputTerminate	input of the send S-function

DESCRIPTION
The field contains values applied to excite output buffers. If a pin is defined to be an output the respective bit from the *CN1Output* register appears at the CN1 connector.
This feature of the board is coded as 32-bit double word but only 26 bits are used in the same order as in the case of direction bits (see section 5.5.1).
In Simulink interface in the send S-function there are two inputs related with the digital outputs: *SetCN1Output* and *SetCN1OutputTerminate*. The first one is applied during each sampling period to update the state of the digital outputs. The second input is used only once – when the simulation terminates. The value at the *SetCN1OutputTerminate* are send to the digital outputs when the execution of the Simulink model terminates.

5.5.4 Example

Open the RT-DAC/USB2 device which serial number is 14. Set the DIO0-DIO15 lines as outputs. Set DIO16, DIO17,…,DIO25 as the inputs. Set all output lines to logic state ‘1’ and read all 10 inputs.

C language

```
RTDACUSB2BufferType RTDACUSBBuffer;
int NoOfDetectedUSBDevices;
int BoardIdx;

RTDACUSB2BufferType RTDACUSBBuffer;
int BoardIdx;
unsigned int Input;

BoardIdx = USB2OpenBySerialNo( 14 );
if( BoardIdx < 0 ) {
  printf(  "Can not open the given RT-DAC/USB2 device\n" );
  return;
}
if( CommandRead_0103( BoardIdx, &RTDACUSBBuffer ) < 0 ) {
  printf( "Can not read the RT-DAC/USB2 device\n" );
  return;
}
// Set all lines as general purpose inputs/outputs
RTDACUSBBuffer.CN1PinMode = 0;
// Set directions
RTDACUSBBuffer.CN1Direction =  0x3FF0000;
// Set outputs
RTDACUSBBuffer.CN1Output =  0xFFFF ;

if( CommandSend_0103( BoardIdx, &RTDACUSBBuffer ) < 0 ) {
  printf( "Can not send data to the RT-DAC/USB2 device\n" );
  return;
}

// wait ….

if( CommandRead_0103( BoardIdx, &RTDACUSBBuffer ) < 0 ) {
  printf( "Can not read the RT-DAC/USB2 device\n" );
  return;
}
Input = RTDACUSBBuffer.CN1Input;
Input = (Input >> 16) & 0x3FF;

USB2Close( BoardIdx );
```

C# language

```
RTDACUSB2_0103 brd = new RTDACUSB2_0103();
if (brd.OpenBySerialNumber(14) < 0)
{
    MessageBox.Show("Can not open the device.",
                    "DI/O example",
                    MessageBoxButtons.OK,
                    MessageBoxIcon.Exclamation);
    return;
}
if (brd.ReadUSBFrame() < 0)
{
    MessageBox.Show("Can not read data frame.",
                    "DI/O example",
                    MessageBoxButtons.OK,
                    MessageBoxIcon.Exclamation);
    return;
}
// Set all lines as general purpose inputs/outputs
brd.DigitalIO.CN1PinMode = 0;
// Set directions
brd.DigitalIO.CN1Direction = 0x3FF0000;
// Set outputs
brd.DigitalIO.CN1Output = 0xFFFF;
if (brd.SendUSBFrame() < 0)
{
    MessageBox.Show("Can not send data frame.", "DI/O example",
                    MessageBoxButtons.OK,
                    MessageBoxIcon.Exclamation);
    return;
}

// Wait

if (brd.ReadUSBFrame() < 0)
{
    MessageBox.Show("Can not read data frame.",
                    "DI/O example",
                    MessageBoxButtons.OK,
                    MessageBoxIcon.Exclamation);
    return;
}
UInt32 Input = brd.DigitalIO.CN1Input;
Input = (Input >> 16) & 0x3FF;
```

5.6 Counter/timer

RT-DAC/USB2 contains two 32-bit timer/counter channels. Both counter/timer channels can operate either in the counter or timer modes. In the timer mode the timer/counter channels count pulses of the internal board clock. The frequency of the clock corresponds to the board version (20 MHz is the default frequency value). In the counter mode the timer/counter channels count external pulses respectively from the CNT0 and CNT1 inputs. In the timer mode the blocks does not use any external signals.
In the counter mode the counter inputs are named: DIO24/CNT0 and DIO25/CNT1 and are located at the CN1 connector at pins 35 and 36. The inputs of the counters CTN0 and CNT1 are shared with the general purpose digital I/Os DIO24 and DIO25. If the DIO24/CNT0 or DIO25/CNT1 signals are defined to be the inputs, their states can be read (typically as the digital inputs) and simultaneously they excite the respective counter block. If the signals are set to be outputs, their states are determined by software (typically as the digital outputs) and simultaneously they excite the respective counter block (this operating mode can be applied to test the blocks in a programming manner).
The configuration of the timer/counter block is shown below. The *Mode* flag selects between counter and time modes. The *Reset* flag is applied to reset the counter. 32-bit counter stores a number of the internal clock periods or a number of the external pulses (the rising edges of the pulses are counted).

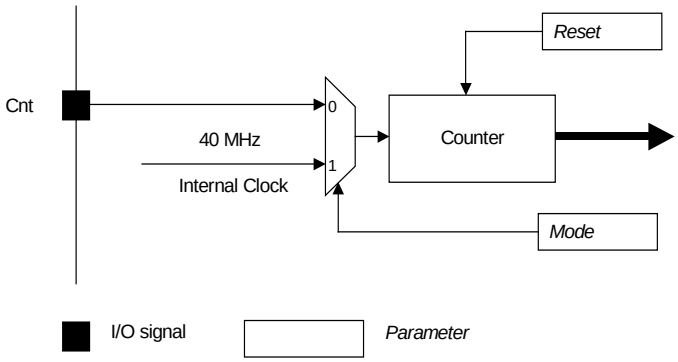

Fig. 5.8. Configuration of the timer/counter block

In the C language interface the features of the channels are controlled by the *TmrCntType* structure. The main structure contains the array:

```
TmrCntType    TmrCnt[ 2 ];
```

that is applied to communicate with the timer/counter blocks
In the .NET interface the state of the timer/counter blocks are described in the dedicated *TmrCntClass* class.

5.6.1 Mode

C interface	***unsigned int Mode***	
.NET interface	***TmrCntClass.ModeState Mode***	
Simulink interface	***TmrCntMode***	output of the read S-function
	SetTmrCntMode	input of the send S-function

DESCRIPTION
The field sets/means the operating mode of the timer/counter.
In the C and Simulink interfaces the value equal to 0 sets/means the counter mode; the value equal to 1 means the timer mode.
In the .NET interface the value equal to *CounterMode* sets/means the counter mode; *TimerMode* means that the block operates as a timer.

5.6.2 Reset

C interface	***unsigned int Reset***	
.NET interface	***TmrCntClass.ResetState Reset***	
Simulink interface	***TmrCntReset***	output of the read S-function
	SetTmrCntReset	input of the send S-function

DESCRIPTION
In the C and Simulink interfaces the value equal to 1 sets/means that the counter remains in reset state; 0 means the working mode.
In the .NET interface the value ***On*** sets/means that the counter is reset; ***Off*** means the working mode.
The *Counter* field remains equal to 0 until the R*eset* field is equal to 1.

5.6.3 Counter

C interface	***unsigned int Counter***	
.NET interface	***uint Counter***	
Simulink interface	***TmrCntCounter***	output of the read S-function

DESCRIPTION
32-bit unsigned integer value of the counter. The field is read-only.

5.6.4 Example

Set the first channel as the timer and the second channel as the counter. Reset both channels, start counting and read the values of both channels.

C language

```
RTDACUSB2BufferType   RTDACUSBBuffer;
int NoOfDetectedUSBDevices;
int BoardIdx;

NoOfDetectedUSBDevices = USB2NumOfDevices( );
if( NoOfDetectedUSBDevices < 1 ) {
  printf ( "Can not detect any RT-DAC/USB2 device\n");
  return;
}
BoardIdx = USB2Open( );
if( BoardIdx < 0 ) {
  printf(  "Can not open the RT-DAC/USB2 device\n" );
  return;
}
if( CommandRead_0103( BoardIdx, &RTDACUSBBuffer ) < 0 ) {
  printf(  "Can not read the RT-DAC/USB2 device\n" );
  return;
}

RTDACUSBBuffer.TmrCnt[0].Mode = 1; // First channel as timer
RTDACUSBBuffer.TmrCnt[1].Mode = 0; // Second channel as counter

// Reset both channels
RTDACUSBBuffer.TmrCnt[0].Reset = RTDACUSBBuffer.TmrCnt[1].Reset = 1;
CommandSend_0103( BoardIdx, &RTDACUSBBuffer );

// Start counting
RTDACUSBBuffer.TmrCnt[0].Reset = RTDACUSBBuffer.TmrCnt[1].Reset = 0;
CommandSend_0103( BoardIdx, &RTDACUSBBuffer );

// wait ….

CommandRead_0103( BoardIdx, &RTDACUSBBuffer );
printf( " Timer: %d,  Counter: %d\n",
         RTDACUSBBuffer.TmrCnt[0].Counter,
         RTDACUSBBuffer.TmrCnt[1].Counter );

USB2Close( BoardIdx );
```

C# language

```
RTDACUSB2_0103 brd = new RTDACUSB2_0103();
if (brd.Open() < 0)
{
  MessageBox.Show("Can not open the device.", "Tmr/Cnt example",
                  MessageBoxButtons.OK, MessageBoxIcon.Exclamation);
  return;
}
if (brd.ReadUSBFrame() < 0)
{
  MessageBox.Show("Can not read data frame.", "Tmr/Cnt example",
                   MessageBoxButtons.OK, MessageBoxIcon.Exclamation);
  return;
}
// Set modes
brd.TmrCnt(0).Mode = TmrCntClass.ModeState.TimerMode;
brd.TmrCnt(1).Mode = TmrCntClass.ModeState.CounterMode;

// Reset both channels
brd.TmrCnt(0).Reset = TmrCntClass.ResetState.On;
brd.TmrCnt(1).Reset = TmrCntClass.ResetState.On;
if (brd.SendUSBFrame() < 0)
{
  MessageBox.Show("Can not send data frame.", "Tmr/Cnt example",
                   MessageBoxButtons.OK, MessageBoxIcon.Exclamation);
  return;
}

// Start counting
brd.TmrCnt(0).Reset = TmrCntClass.ResetState.Off;
brd.TmrCnt(1).Reset = TmrCntClass.ResetState.Off;
if (brd.SendUSBFrame() < 0)
{
  MessageBox.Show("Can not send data frame.", "Tmr/Cnt example",
                  MessageBoxButtons.OK, MessageBoxIcon.Exclamation);
  return;
}

// wait ….

if (brd.ReadUSBFrame() < 0)
{
  MessageBox.Show("Can not read data frame.", "Tmr/Cnt example",
                  MessageBoxButtons.OK, MessageBoxIcon.Exclamation);
  return;
}
String sAux;
sAux = "Timer: " +
       String.Format("{0:D}", brd.TmrCnt(0).Counter) + "\n" +
       "Counter: " +
       String.Format("{0:X}", brd.TmrCnt(1).Counter);
MessageBox.Show(sAux, "Tmr/Cnt example", MessageBoxButtons.OK);
```

5.7 PWM

The RT-DAC/USB2 board includes eight output PWM channels named: PWM0, PWM1, PWM2, PWM3, PWM4, PWM5, PWM6 and PWM7, located at the CN1 connector at pins: 5, 11, 17, 22, 25, 28, 31 and 34. These pins are shared between PWM outputs and eight general purpose digital I/Os. The PWM operating mode is determined by the contents of the direction register and the mode configuration register. The direction register must set the PWM signals to become the outputs. The pin mode configuration register determines whether the signals are associated with the specialized PWM blocks or operate as the general purpose digital IOs. In the first case the states of the outputs are constructed by the PWM block. In the second case the state of the outputs are defined by the software.
The basic PWM period and the period of the "H" state (width) of each channel are selected independently. The operating principle of the PWM channels is illustrated in Fig. 5.9. The input basic frequency of the PWM channels is set to the default 20MHz value. This frequency is divided by the counter (called the prescaler), which creates the PWM basic period. The basic period wave excites the 8 or 12-bit counter. The output of the counter is compared to the 8 or 12-bit width of the "H" state. The valid prescaler value is a number taken from the range [0 - 65535]. The PWM counters and the "H" state duration registers can operate in either 8 or 12-bit modes. The 8-bit mode allows PWM to operate in a high speed and the 12-bit mode allows to achieve higher accuracy of the output.

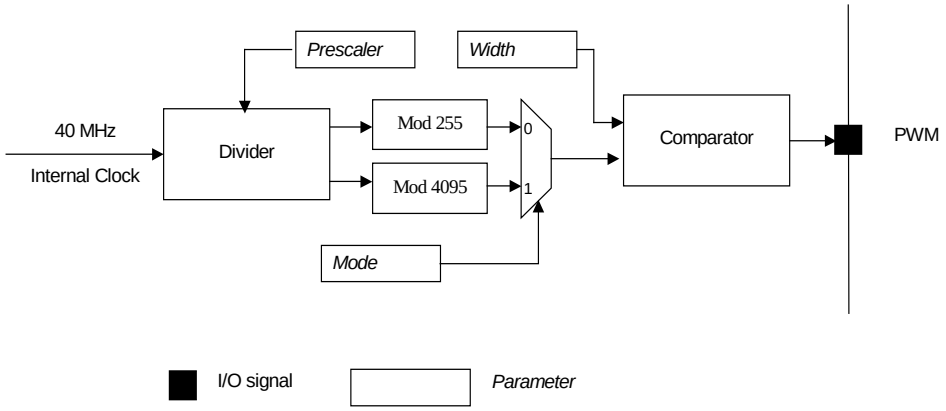

Fig. 5.9. Block diagram of the PWM generator

In the 12-bit mode a single PWM period contains 4095 impulses of the output prescaler counter. The duration of the 'H' state is set by a number from 0 to 4095. In the 8-bit mode a PWM period contains 255 impulses of the output prescaler. The duration of the 'H' state is set by a number from 0 to 255.
The frequency of the PWM wave is given by the formulas:

$$f_{PWM} = \frac{f_{basic}}{(prescaler+1)*255} \quad \text{for 8-bit mode}$$

$$f_{PWM} = \frac{f_{basic}}{(prescaler+1)*4095} \quad \text{for 12-bit mode}$$

where f_{basic} equals to 20MHz.

In the C language interface the features of the PWM channels are controlled by the `PWMType` structure. The main structure of the `RTDACUSB2BufferType` type contains the array:

```
PWMType        PWM[ 8 ];
```

that is applied to communicate with the PWM blocks.
In the .NET interface the state of the PWM blocks are described in the dedicated `PWMClass` class.

5.7.1 Mode

C interface	***unsigned int Mode***	
.NET interface	***PWMClass.PWMMode Mode***	
Simulink interface	***PWMMode***	output of the read S-function
	SetPWMMode	input of the send S-function

DESCRIPTION
The field sets/means the operating mode of the timer/counter.
In the C and Simulink interfaces the value equals to "0" indicates the 8-bit PWM mode. If this integer value is equal to "1" then the 12-bit PWM mode is selected.
In the .NET interface the value equal to *PWM8BitMode* indicates 8-bit mode; *PWM12BitMode* indicates that the block operates in 12-bit mode.

5.7.2 Prescaler

C interface	***unsigned int Prescaler***	
.NET interface	***uint Prescaler***	
Simulink interface	***PWMPrescaler***	output of the read S-function
	SetPWMPrescaler	input of the send S-function

DESCRIPTION
16-bit value that defines the prescaler parameter. The internal clock reference is divided by (prescaler+1) to generate the basic PWM period.
The maximum frequency of the PWM output is approximately equal to 156kHz and is generated in the 8-bit mode when the prescaler is equal to 0. The minimum frequency of the PWM output is approximately equal to 0.15Hz and is generated in the 12-bit mode when the prescaler is equal to 65535.

5.7.3 Width

C interface	***unsigned int Width***	
.NET interface	***uint Width***	
Simulink interface	***PWMWidth***	output of the read S-function
	SetPWMWidth	input of the send S-function
	SetPWMWidthTerminate	input of the send S-function

DESCRIPTION
The 12-bit unsigned value sets the duration of the "H" state in each PWM period. When the PWM channel operates in the 8-bit mode only the least significant 8-bits are applied.
In the Simulink there are two inputs of the S-functions applied to set the duration of the "H" state in each PWM period. The first one, *SetPWMWidth*, is applied during each sampling period. The second input, *SetPWMWidthTerminate*, is used when the simulation terminates.

5.7.4 Example

For the first PWM channel select the 8-bit operating mode, set the frequency to 300 Hz and set the duty cycle to 25% (the “H” state lasts 25% of the PWM period). For the second PWM channel select the 12-bit operating mode, set the frequency to 10 Hz and set the duty cycle to 75%.

C language

```
RTDACUSB2BufferType   RTDACUSBBuffer;
int NoOfDetectedUSBDevices;
int BoardIdx;

NoOfDetectedUSBDevices = USB2NumOfDevices( );
if( NoOfDetectedUSBDevices < 1 ) {
  printf ( "Can not detect any RT-DAC/USB2 device\n");
  return;
}
BoardIdx = USB2Open( );
if( BoardIdx < 0 ) {
  printf(  "Can not open the RT-DAC/USB2 device\n" );
  return;
}
if( CommandRead_0103( BoardIdx, &RTDACUSBBuffer ) < 0 ) {
  printf(  "Can not read the RT-DAC/USB2 device\n" );
  return;
}

// Switch pin mode to allow PWM outputs for PWM0 and PWM1
RTDACUSBBuffer.CN1PinMode |= 0x0000024;

// Set respective pins to be outputs
RTDACUSBBuffer.CN1Direction &= 0x0FFFFFDB;

RTDACUSBBuffer.PWM[0].Mode = 0; // 8-bit PWM mode
RTDACUSBBuffer.PWM[1].Mode = 1; // 12-bit PWM mode

// The prescaler value of 522 defines the 300Hz frequency
// The width equal to 64 means 25% duty cycle (64 is 25% of 256)
RTDACUSBBuffer.PWM[0].Prescaler = 522;
RTDACUSBBuffer.PWM[0].Width = 64;

// The prescaler value of 60 defines the 10Hz frequency
// The width equal to 3072 means 75% duty cycle (3072 is 75% of 4096)
RTDACUSBBuffer.PWM [ 1 ].Prescaler = 60;
RTDACUSBBuffer.PWM [ 1 ].Width = 3072;

// Start PWM output generation
CommandSend_0103( BoardIdx, &RTDACUSBBuffer );

USB2Close( BoardIdx );
```

C# language

```
RTDACUSB2_0103 brd = new RTDACUSB2_0103();
if (brd.Open() < 0)
{
  MessageBox.Show("Can not open the device.", "PWM example",
                  MessageBoxButtons.OK, MessageBoxIcon.Exclamation);
  return;
}
if (brd.ReadUSBFrame() < 0)
{
  MessageBox.Show("Can not read data frame.", " PWM example",
                  MessageBoxButtons.OK, MessageBoxIcon.Exclamation);
  return;
}
// Switch pin mode to allow PWM outputs for PWM0 and PWM1
brd.DigitalIO.CN1PinMode |= 0x0000024;
// Set respective pins to be outputs
brd.DigitalIO.CN1Direction &= 0x0FFFFFDB;

brd.PWM(0).Mode = PWMClass.PWMMode.PWM8BitMode;
brd.PWM(1).Mode = PWMClass.PWMMode.PWM12BitMode;

// The prescaler value of 522 defines the 300Hz frequency
// The width equal to 64 means 25% duty cycle (64 is 25% of 256)
brd.PWM(0).Prescaler = 522;
brd.PWM(0).Width = 64;

// The prescaler value of 60 defines the 10Hz frequency
// The width equal to 3072 means 75% duty cycle (3072 is 75% of 4096)
brd.PWM(1).Prescaler = 60;
brd.PWM(1).Width = 3072;

// Start PWM output generation
if (brd.SendUSBFrame() < 0)
{
  MessageBox.Show("Can not send data frame.", " PWM example",
                  MessageBoxButtons.OK, MessageBoxIcon.Exclamation);
  return;
}
```

5.8 Encoder

RT-DAC/USB2 includes eight 32-bit incremental quadrature encoder channels. Each channel counts the changes of two input waves and optionally applies the input index signal to reset the encoder counter. The relation between the changes of the A and B waves and the changes of the counter value are illustrated in Fig. 5.10.

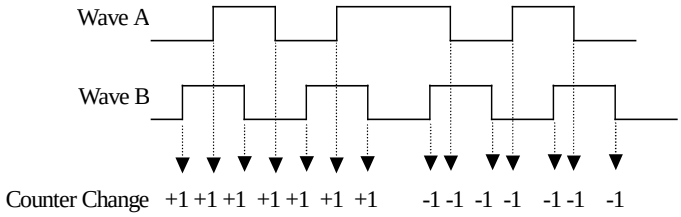

Fig. 5.10. Operation of the quadrature encoder counter

The initial value of each encoder counter can be set to zero in a programmable way or using the active index signal. Encoders can work in two modes: with or without index signal. The software activates and deactivates the index signals and sets the active levels of the index signals as well. The structure of the encoder blocks is given in Fig. 5.11.

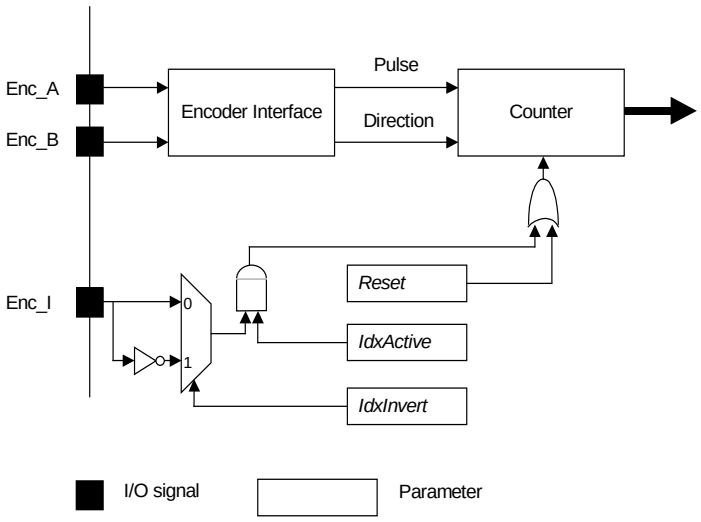

Fig. 5.11. Structure of the quadrature encoder blocks

Each encoder channel contains three inputs: wave A, wave B and index I. The respective signals are marked as:

- ENC0_A, ENC0_B and ENC0_I for the first encoder,
- ENC1_A, ENC1_B and ENC1_I for the second encoder,
- ENC2_A, ENC2_B and ENC2_I for the third encoder,
- ENC3_A, ENC3_B and ENC3_I for the fourth encoder,
- ENC4_A, ENC4_B and ENC4_I for the fifth encoder,
- ENC5_A, ENC5_B and ENC5_I for the sixth encoder,
- ENC6_A, ENC6_B and ENC6_I for the seventh encoder and
- ENC7_A, ENC7_B and ENC7_I for the eighth encoder.

All the pins used by the encoder signals are also used by the general purpose digital I/Os. If the encoder signals are defined to be inputs, their states can be read (typically as the digital inputs) and simultaneously they excite the respective encoder block. If the signals are set to be outputs, their states are determined by the software (typically as the digital outputs) and simultaneously they excite the respective encoder block (this operating mode can be applied to test the blocks in a programming manner).
All encoder channels are assigned to the pins at the CN1 connector and are shared with the general-purpose digital input/output signals (see Fig. 4.1). If the direction of DI/O's are set to be the output the appropriate

pins operate as the digital outputs. Usually the encoder works if the shared pins are set to be inputs. In such a case they excite the encoder inputs and can be read simultaneously as the digital inputs.

In the C language interface the features of the encoder channels are controlled by the *EncoderType* structure. The main structure of the *RTDACUSB2BufferType* type contains the array:

```
EncoderType   Encoder[ 8 ];
```

that is applied to communicate with the encoder blocks.
In the .NET interface the state of the encoder blocks are described in *EncoderIClass* class dedicated to be an interface to quadrature encoders equipped with the index signal.

5.8.1 Reset

C interface	***unsigned int Reset***	
.NET interface	***ResetState Reset***	
Simulink interface	***EncoderReset***	output of the read S-function
	SetEncoderReset	input of the send S-function

DESCRIPTION
The field sets/means the reset state of the block. If the block remains in the reset state the counter is equal to zero.
In the C and Simulink interfaces the value equal to “1” indicates reset of the block counter. If this integer value is equal to “0” the block traces the A and B inputs and changes the counter value.
In the .NET interface the value equal to *On* indicates reset state; *Off* indicates that the block counts impulses.

5.8.2 IdxActive

C interface	***unsigned int IdxAvtive***	
.NET interface	***IdxActiveState IdxActive***	
Simulink interface	***EncoderIdxActive***	output of the read S-function
	SetEncodeIdxActive	input of the send S-function

DESCRIPTION
This flag activates the encoder index signal. When the index signal is active the active level of the external *ENCx_I* signal resets the encoder counter.
In the C and Simulink interfaces the value equal to “1” activates the index input signal. If this integer value is equal to “0” the external *ENCx_I* signal is not applied to reset the encoder counter.
In the .NET interface the value equal to *On* indicates active index input; *Off* indicates that the index input is deactivated.

5.8.3 IdxInvert

C interface	***unsigned int IdxInvert***	
.NET interface	***IdxActiveState IdxInvert***	
Simulink interface	***EncoderIdxInvert***	output of the read S-function
	SetEncodeIdxInvert	input of the send S-function

DESCRIPTION
This flag determines the active level of the index input.

In the C and Simulink interfaces the value equal to "0" determines that the "1" level of the index signal is active. If this integer value is equal to "1" the active level of the *ENCx_I* signal is "0".
In the .NET interface the value equal to *On* indicates that the active level of the *ENCx_I* signal is "0".; *Off* indicates that "1" level is active.
In fact the reset signal generated from the index input is always '1' and the *IdxInvert* is applied to invert the input (see Fig. 5.11).

5.8.4 Counter

C interface	***long int Counter***	
.NET interface	***uint Counter***	
Simulink interface	***EncoderCounter***	output of the read S-function

DESCRIPTION
32-bit value of the encoder counter. This field is read-only.

5.8.5 Example

Reset the ENC2 encoder, activate the index input, start counting and read the encoder counter.

C language

```
RTDACUSB2BufferType   RTDACUSBBuffer;
int NoOfDetectedUSBDevices;
int BoardIdx;
int Result;

NoOfDetectedUSBDevices = USB2NumOfDevices( );
if( NoOfDetectedUSBDevices < 1 ) {
  printf ( "Can not detect any RT-DAC/USB2 device\n");
  return;
}
BoardIdx = USB2Open( );
if( BoardIdx < 0 ) {
  printf(  "Can not open the RT-DAC/USB2 device\n" );
  return;
}
if( CommandRead_0103( BoardIdx, &RTDACUSBBuffer ) < 0 ) {
  printf(  "Can not read the RT-DAC/USB2 device\n" );
  return;
}

// Activate index and reset the encoder counter
RTDACUSBBuffer.Encoder[ 2 ].IdxActive = 1;
```

```
RTDACUSBBuffer.Encoder[ 2 ].IdxInvert = 0;
RTDACUSBBuffer.Encoder[ 2 ].Reset     = 1;
CommandSend_0103( BoardIdx, &RTDACUSBBuffer );

// Start counting – disable reset signal
RTDACUSBBuffer.Encoder[ 2 ].Reset = 0;
CommandSend_0103( BoardIdx, &RTDACUSBBuffer );

// wait ….

CommandRead_0103( BoardIdx, &RTDACUSBBuffer );
Result = RTDACUSBBuffer.Encoder[ 2 ].Counter;
printf("Encoder value %d\n", Result );

USB2Close( BoardIdx );
```

C# language

```
RTDACUSB2_0103 brd = new RTDACUSB2_0103();
if (brd.Open() < 0)
{
  MessageBox.Show("Can not open the device.", "Encoder example",
                  MessageBoxButtons.OK, MessageBoxIcon.Exclamation);
  return;
}
brd.ReadUSBFrame();

// Activate index and reset the encoder counter
brd.EncoderI(2).IdxActive = EncoderIClass.IdxActiveState.On;
brd.EncoderI(2).IdxInvert = EncoderIClass.IdxInvertState.Off;
brd.EncoderI(2).Reset = EncoderIClass.ResetState.On;
brd.SendUSBFrame();

// Start counting – disable reset signal
brd.EncoderI(2).Reset = EncoderIClass.ResetState.Off;
brd.SendUSBFrame();

// wait ….

brd.ReadUSBFrame();
String sAux;
sAux = "Enc2 counter: " +
       String.Format("{0:D}", brd.EncoderI(2).Counter);
MessageBox.Show(sAux, "Encoder example", MessageBoxButtons.OK);
```

5.9 Frequency meter

The RT-DAC/USB2 board includes eight frequency meter blocks. The blocks are applied to measure number of external pulses within a given counting period. The operation principle is presented in Fig. 5.12. A measurement can be started by a program or by an external input. The measurements can be gated by an external signal.

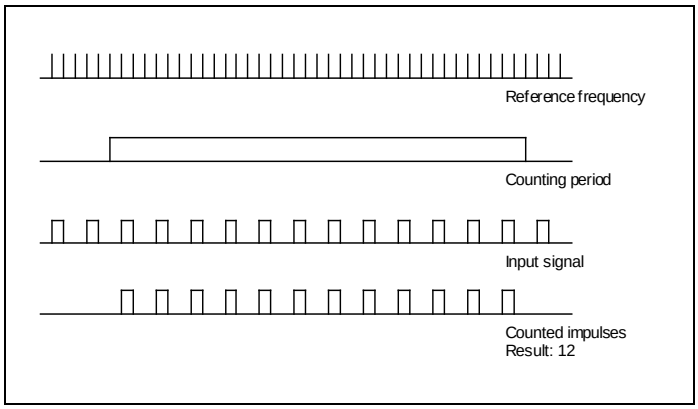

Fig. 5.12. Principle of the frequency operating mode

Each block uses three external input signals (*x* is a number from 0 to 7 and means the number of the block):

- *FrxI* – input signal; the block counts pulses from this input,
- *FrxSt* – external start counting signal,
- *FrxG* – external gate signal.

The algorithm of the frequency meter block can be described as follow:

1. the block operates only if the *Enable* parameter is '1'; if this parameter is '0' the *Ready* and the *Pending* flags are set to low. The *Pending* flag is an internal parameter of the block and can not be accessible from outside,
2. if the *SwHwGateStart* flag is set to '0' the *Start* and *Gate* signals are equal to *SwStart* and *SwGate* parameters respectively (it means that the software is the source of the *SwStart* and *SwGate* signals); if the *SwHwGateStart* flag is set to '1' the *Start* and *Gate* signals are equal to *Frx_St* and *Frx_G* inputs,
3. if the *GateInv* parameter is set to '1' the *Gate* signal is inverted,
4. if the *StartInv* parameter is set to '1' the *Start* signal is inverted,
5. if the *InputInv* parameter is set to '1' the *Fr_I* input signal is inverted,
6. if the block detects a rising edge of the *Start* signal the following actions are performed: the *Ready* parameter is set to '0', the *Pending* flag is set to '1', the *Timer* input parameter is used to determine the duration of the counting period. The resolution of the counting period is 25 ns,
7. the rising edges of the *Frx_I* signal (or falling edges when the *InputInv* is set) are counted only when the *Pending* flag is '1' or if the *InfiniteFlag* parameter is set to '1'; the number of *Frx_I* pulses is stored in the *Result* counter,
8. the *Pending* flag is set to '0' when the counting period terminates – it indicates the termination of the measurement cycle,
9. the *Gate* input signal can be applied to stop the counting of the pulses of the input signal as well as to stop the counting of the counting period. If the *Gate* signal is equal to '1' the *Result* counter does not count pulses of the *Fr_I* input; if the *GateMode* parameter is set to '1' and the *Gate* signal is equal to 1 also the counter which determines the counting period is stopped. Fig. 5.13 illustrates the influence of the *Gate* signal when the *GateMode* parameter is set to '0'.

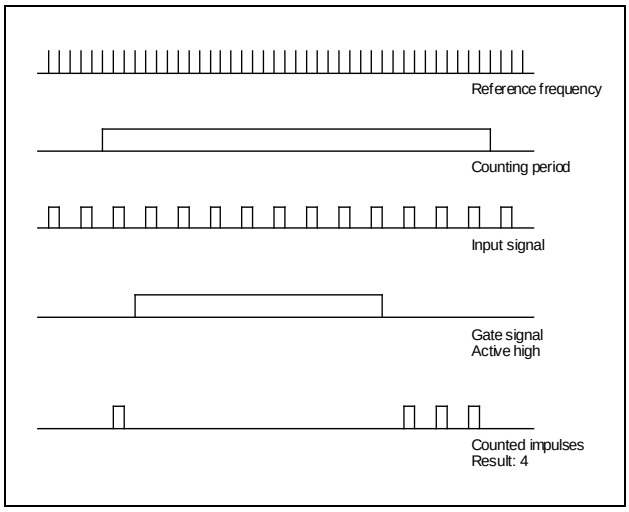

Fig. 5.13. Principle of the gate signal

In the C language interface the features of the frequency meter channels are controlled by the `FreqMType` structure. The main structure of the `RTDACUSB2BufferType` type contains the array:

```
FreqMType      FreqM[ 8 ];
```

that is applied to communicate with the blocks.
In the .NET interface the state of the frequency meter blocks are described in the `FreqMClass` class.

5.9.1 EnableBlock

C interface	**`unsigned int EnableBlock`**	
.NET interface	**`EnableState Enable`**	
Simulink interface	**`FreqMEnable`**	output of the read S-function
	`SetFreqMEnable`	input of the send S-function

DESCRIPTION
The field sets/means the enable state of the block. The block operates (responds to inputs and parameters) if it is enabled. In disable state the frequency meter block does not react to inputs.
In the C and Simulink interfaces the "1" value enables the block. If this integer value is equal to "0" the block is disabled.
In the .NET interface the value equal to `On` indicates enable state; `Off` disables the block.

5.9.2 SwHwGateStartFlag

C interface	**`unsigned int SwHwGateStartFlag`**	
.NET interface	**`SwHwGateStartState SwHwGateStart`**	
Simulink interface	**`SwHwGateStartFlag`**	output of the read S-function
	`SetSwHwGateStartFlag`	input of the send S-function

DESCRIPTION
The field sets the source of the *Start* and *Gate* signals. The signals can come from the hardware inputs *FRxSt* and *FrxG* or can be set by the software as the *SwStart* and *SwGate* parameters.
In the C and Simulink interfaces the value of "0" indicates the software signal sources. If this integer value is equal to "1" the block takes the signal from hardware inputs at CN1 connector.
In the .NET interfaces the value equal to `Software` indicates the software source; `Hardware` indicates the hardware signal sources.

5.9.3 SwStart

C interface	***unsigned int SwStart***	
.NET interface	***SwStartState SwStart***	
Simulink interface	***FreqMSwStart***	output of the read S-function
	SetFreqMSwStart	input of the send S-function

DESCRIPTION
The field sets the software *Start* signal. If there is selected the software source of the *Start* signal then the rising edge of this parameter starts a measurement.
In C and Simulink the “0” and “1” values are available. A change from “0” to “1” starts a measurement.
In .NET the *On* and *Off* values are available. A change from *On* to *Off* starts a measurement.

5.9.4 StartInv

C interface	***unsigned int StartInv***	
.NET interface	***StartInvState StartInv***	
Simulink interface	***FreqMStartInv***	output of the read S-function
	SetFreqMStartInv	input of the send S-function

DESCRIPTION
The field is applied to invert *Start* signal (either software or hardware). If the *Start* signal is inverted its falling edge starts the measurement.
In C and Simulink the “0” and “1” values are available. The “1” value inverts the *Start* signal.
In .NET the *On* and *Off* values are available. The value *On* inverts the *Start* signal.

5.9.5 SwGate

C interface	***unsigned int SwGate***	
.NET interface	***SwGateState SwGate***	
Simulink interface	***FreqMSwGate***	output of the read S-function
	SetFreqMSwGate	input of the send S-function

DESCRIPTION
The field sets the software *Gate* signal. If there is selected the software source of the *Gate* signal then this signal gates measurements.
In C and Simulink the “0” and “1” values are available. The “1” value gates measurements.
In .NET the *On* and *Off* values are available. The *On* value may be applied to gate measurements.

5.9.6 GateInv

C interface	***unsigned int GateInv***	
.NET interface	***GateInvState GateInv***	
Simulink interface	***FreqMGateInv***	output of the read S-function
	SetFreqMGateInv	input of the send S-function

DESCRIPTION
The field is applied to invert *Gate* signal (either software and hardware). If the *Gate* signal is inverted its low state gates measurements.
In C and Simulink the “0” and “1” values are available. The “1”value inverts the *Gate* signal.
In the .NET interface the *On* and *Off* values are available. The *On* value inverts the *Gate* signal.

5.9.7 InputInv

C interface	***unsigned int InputInv***	
.NET interface	***InputInvState InputInv***	
Simulink interface	***FreqMInputInv***	output of the read S-function
	SetFreqMInputInv	input of the send S-function

DESCRIPTION
The field is applied to invert input *FrxI* signal. If the signal is inverted the block counts falling edges of the *FrxI* input.
In C and Simulink the “0” and “1” values are available. The “1” value inverts the *FrxI* signal.
In .NET the *On* and *Off* values are available. The *ON* value inverts the *FrxI* signal.

5.9.8 GateMode

C interface	***unsigned int GateMode***	
.NET interface	***GateModeState GateMode***	
Simulink interface	***FreqMGateMode***	output of the read S-function
	SetFreqMGateMode	input of the send S-function

DESCRIPTION
Selects the gating mode. Two modes are available:

- when the *Gate* is active only the input signals are not counted. The timer counter operates until a counting period terminates,
- when the *Gate* is active the input signals are not counted and as well the timer counter stops.

In C and Simulink the“0” and “1” values are available. The “0” value stops counting of the *FrxI* input signal. If “1” is selected both the input signal and timer pulses are gated.
In .NET the *Input* and *TimeAndInput* values are available. The *Input* value gates only the *FrxI* signal. The TimeAnd*Input* value gates the *FrxI* and timer signals.

5.9.9 InfiniteFlag

C interface	***unsigned int InfiniteFlag***	
.NET interface	***InfiniteFlagState InfiniteFlag***	
Simulink interface	***FreqMInfiniteFlag***	output of the read S-function
	SetFreqMInfiniteFlag	input of the send S-function

DESCRIPTION
The counting of the input *FrxI* signal is usually terminated when a counting period terminates. If the *InfiniteFlag* is selected the counting of the input signal edges operates in continuous mode.
In C and Simulink the “0” and “1” values are available. The “1” value switches on the continuous counting.
In .NET the *On* and *Off* values are available. The *On* value switches on the continuous counting.

5.9.10 Mode

C interface	***unsigned int Mode***	
.NET interface	***ModeState Mode***	
Simulink interface	***FreqMMode***	output of the read S-function
	SetFreqMMode	input of the send S-function

DESCRIPTION
There are available two measurement modes:

- when the *Start* trigger edge appears a single measurement is started. During a measurement period the *Result* register remains equal to zero and the *Counting* register shows the current number of counted pulses. When the measurement terminates (it means when *Ready* flag is active) the *Counter* register is stored in the *Result* register, so the *Result* register contains the result of the measurement,
- the *Start* trigger start a series of measurements. When a measurement cycle terminates a new measurement is started immediately. The *Result* register always contain the result of the last measurement.

In C and Simulink values of "0" and "1" are available. The value of "0" allows to start a single measurement. The value of "1" prepares a block to start a series of measurements.
In .NET the *Single* and *Continous* values are available which start a single of a series of measurements respectively.

5.9.11 Timer

C interface	***unsigned int Timer***	
.NET interface	***uint Timer***	
Simulink interface	***FreqMTimer***	output of the read S-function

DESCRIPTION
The 30-bit value that determines the duration of the counting period. The duration of the period is given as the number of 25ns pulses. This field is read-only.

5.9.12 Ready

C interface	***unsigned int Ready***	
.NET interface	***ReadyState Ready***	
Simulink interface	***FreqMReady***	output of the read S-function
	SetFreqMReady	input of the send S-function

DESCRIPTION
Determines if the *Result* register contains the result of the measurements. In single mode it informs that register is ready to read. In multiple measurements mode it informs that result register contains a ready to read result of a last measurement.
In C and Simulink values of "0" and "1" indicate not ready to read and ready to read states respectively.
In .NET the *On* value indicates ready to read data. The *Off* value informs that data are not ready jet.

5.9.13 Counter

C interface ***unsigned int Counter***

DESCRIPTION
32-bit counter that contains the number of currently counted pulses. The field is read-only.

5.9.14 Result

C interface ***unsigned int Result***
.NET interface ***uint Result***
Simulink interface ***FreqMResult*** output of the read S-function

DESCRIPTION
32-bit result of the last measurement. The field is read-only.
The field contains valid data only when the *Ready* flag is set.

5.9.15 Example

Apply the *PWM0* output as the inputs signal for the frequency meter channel 0 (*Fr0I* signal).
Both signals, *PWM0* and *Fr0I*, are located at the same pin of the CN1 connector (pin number 5 - see Table 1). This pin is shared with the *DIO2* general purpose digital signal. To run the test the following steps have to be performed:

- set parameters of the *PWM0* block,
- set the mode of *DIO2* to allow the *PWM0* generation at the output,
- set the direction of *DIO2* as the output,
- set parameters of the *Fr0* block. Start a measurement and read the result.

C language

```
RTDACUSB2BufferType   RTDACUSBBuffer;
int NoOfDetectedUSBDevices;
int BoardIdx;

NoOfDetectedUSBDevices = USB2NumOfDevices( );
if( NoOfDetectedUSBDevices < 1 ) {
  printf ( "Can not detect any RT-DAC/USB2 device\n");
  return;
}
BoardIdx = USB2Open( );
if( BoardIdx < 0 ) {
  printf(  "Can not open the RT-DAC/USB2 device\n" );
  return;
}
CommandRead_0103( BoardIdx, &RTDACUSBBuffer );

// Set PWM0 parameters
RTDACUSBBuffer.PWM[0].Mode = 0;  // 8-bit PWM mode
RTDACUSBBuffer.PWM[0].Prescaler = 3;
RTDACUSBBuffer.PWM[0].Width = 64;

// Set pin mode and direction to allow PWM0 output
RTDACUSBBuffer.CN1PinMode |= 0x00000004;
RTDACUSBBuffer.CN1Direction &= 0x0FFFFFFB;
```

```
// Setups of the Fr0
RTDACUSBBuffer.FreqM[0].EnableBlock = 1;
RTDACUSBBuffer.FreqM[0].Mode = 0;  // Single measurement
RTDACUSBBuffer.FreqM[0].InfiniteFlag = 0;
RTDACUSBBuffer.FreqM[0].StartInv = 0;
RTDACUSBBuffer.FreqM[0].GateInv = 0;
RTDACUSBBuffer.FreqM[0].SwGate = 0;
RTDACUSBBuffer.FreqM[0].SwHwGateStartFlag  =  0;  //  Software  START
source
RTDACUSBBuffer.FreqM[0].GateMode = 0;
RTDACUSBBuffer.FreqM[0].InputInv = 0;
RTDACUSBBuffer.FreqM[0].Timer = 400000;

// Send setups and generate rising edge of the software START
RTDACUSBBuffer.FreqM[0].SwStart = 0;
CommandSend_0103( BoardIdx, &RTDACUSBBuffer );
RTDACUSBBuffer.FreqM[0].SwStart = 1;
CommandSend_0103( BoardIdx, &RTDACUSBBuffer );

// Wait for the rumination of the measurement
for(;;) {
  CommandRead_0103( BoardIdx, &RTDACUSBBuffer );
  if( RTDACUSBBuffer.FreqM[0].Ready ) break;
}

printf("Result: %d\n", RTDACUSBBuffer.FreqM[0].Result );

// Change PWM frequency and restart the measurement
RTDACUSBBuffer.PWM[0].Prescaler = 7;

RTDACUSBBuffer.FreqM[0].SwStart = 0;
CommandSend_0103( BoardIdx, &RTDACUSBBuffer );
RTDACUSBBuffer.FreqM[0].SwStart = 1;
CommandSend_0103( BoardIdx, &RTDACUSBBuffer );

for(;;) {
  CommandRead_0103( BoardIdx, &RTDACUSBBuffer );
  if( RTDACUSBBuffer.FreqM[0].Ready ) break;
}
printf("Result: %d\n", RTDACUSBBuffer.FreqM[0].Result );

USB2Close( BoardIdx );
```

C# language

```
RTDACUSB2_0103 brd = new RTDACUSB2_0103();
if (brd.Open() < 0)
{
  MessageBox.Show("Can not open the device.", "Encoder example",
                  MessageBoxButtons.OK, MessageBoxIcon.Exclamation);
  return;
}
brd.ReadUSBFrame();

// Set PWM0 parameters
brd.PWM(0).Mode = PWMClass.PWMMode.PWM8BitMode;
brd.PWM(0).Prescaler = 3;
brd.PWM(0).Width = 64;

// Set pin mode and direction to allow PWM0 output
```

```
brd.DigitalIO.CN1PinMode |= 0x00000004;
brd.DigitalIO.CN1Direction &= 0x0FFFFFFB;

// Setups of the Fr0
brd.FreqM(0).Enable = FreqMClass.EnableState.On;
brd.FreqM(0).Mode = FreqMClass.ModeState.Single;
brd.FreqM(0).InfiniteFlag = FreqMClass.InfiniteFlagState.Off;
brd.FreqM(0).StartInv = FreqMClass.StartInvState.Off;
brd.FreqM(0).GateInv = FreqMClass.GateInvState.Off;
brd.FreqM(0).SwGate = FreqMClass.SwGateState.Off;
brd.FreqM(0).SwHwGateStart = FreqMClass.SwHwGateStartState.Software;
brd.FreqM(0).GateMode = FreqMClass.GateModeState.Input;
brd.FreqM(0).InputInv = FreqMClass.InputInvState.Off;
brd.FreqM(0).Timer = 400000;

// Send setups and generate rising edge of the software START
brd.FreqM(0).SwStart = FreqMClass.SwStartState.Off;
brd.SendUSBFrame();
brd.FreqM(0).SwStart = FreqMClass.SwStartState.On;
brd.SendUSBFrame();

// Wait for the rumination of the measurement
for (; ; )
{
  brd.ReadUSBFrame();
  if (brd.FreqM(0).Ready == FreqMClass.ReadyState.On) break;
}
String sAux;
sAux = "Result 1: " +
       String.Format("{0:D}", brd.FreqM(0).Result);
MessageBox.Show(sAux, "Frequency meter example",
                      MessageBoxButtons.OK);

// Change PWM frequency and restart the measurement
brd.PWM(0).Prescaler = 7;

brd.FreqM(0).SwStart = FreqMClass.SwStartState.Off;
brd.SendUSBFrame();
brd.FreqM(0).SwStart = FreqMClass.SwStartState.On;
brd.SendUSBFrame();

for (; ; )
{
  brd.ReadUSBFrame();
  if (brd.FreqM(0).Ready == FreqMClass.ReadyState.On) break;
}
sAux = "Result 2: " +
       String.Format("{0:D}", brd.FreqM(0).Result);
MessageBox.Show(sAux, "Frequency meter example",
                       MessageBoxButtons.OK);
```

5.10 Chronometer

The chronometer block counts the time span between the start and stop conditions. The resolution of the time measurement is 25 ns. The block contains two main 32-bit registers: *Counter* and *Result*. The *Counter* register counts 25ns pulses between the start and stop conditions. This register value changes when the measurement is pending. When the stop condition occurs the *Counter* register value is stored into the *Result* register. The value of the *Result* register remains constant until the next measurement terminates.

The chronometer block is implemented as a Finite State Machine (FSM). The FSM contains five states: *Disabled*, *ReadyToArm*, *Armed*, *Counting* and *Terminated*. The state flow is shown below.

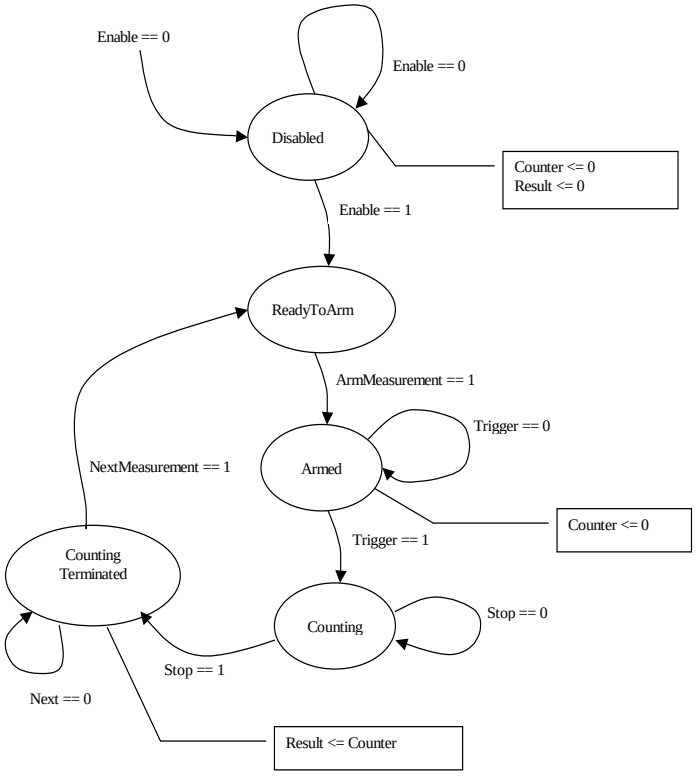

Fig. 5.14. State machine of the chronometer block

There are three operating modes of the block determined by the 2-bit *Mode* parameter. They are described in the following table.

Table 4. Operating modes of the chronometer block.

Value of the *Mode* parameter	Start measurement condition	Stop measurement condition
00	Rising edge of the *StartStop* signal	Falling edge of the *StartStop* signal
01	Rising edge of the *StartStop* signal	Rising edge of the *StartStop* signal
10	Rising edge of the *StartStop* signal	Rising edge of the *Stop* signal
11	Not used	Not used

The operation algorithm of the chronometer block can be described as follow:

1. there are three input signals of the chronometer block: *StartStop*, *Stop* and *Gate*. If the *StartStopInv* parameter is set to '1' the *StartStop* signal is inverted. If the *StopInv* parameter is set to '1' the *Stop* input is inverted. If the *GateInv* parameter flag is set to '1' the *Gate* signal is inverted,
2. if the *Enable* input flag is set to 0 the block moves to the *Disabled* state and remains in this state until the *Enable* flag is set to 1. In the *Disabled* state the *Counter* and the *Result* registers are set to zero. The block changes the state from *Disabled* to *ReadyToArm* when the *Enable* flag changes to 1,
3. the block remains in the *ReadyToArm* state until the *Arm* flag is set to 1,
4. in the *Armed* state the block waits for the start measurement condition. In all measurement modes the rising edge of the *StartStop* signal generates start measurement action (if the *StartStopInv* parameter is set in fact the falling edge of the *StartStop* input starts the measurement cycle). In the *Armed* state the *Counter* register is cleared. When the start measurement event occurs the block is moved to the *Counting* state,
5. in the *Counting* state the block counts 25ns pulses until the stop measurement condition occurs. The number of counted pulses is stored in the *Counter* register. The counting may be gated. If the *Gate* signal is 1 the block does not count reference clock pulses.
6. when the stop measurement condition occurs the state of the block changes to the *Terminated* and the *Counter* register is stored in the *Result* register. This register can be read to determine the time span between the start and stop conditions,
7. when the *NextMeasurement* flag is set the state immediately changes to *ReadyToArm*. If also the *Arm* flag is set a new measurement is armed automatically.

In the basic mode the block counts the pulses of the reference signal which period is equal to 25ns. To allow measurements of longer time periods the reference frequency can be divided. The 30-bit *Divider* register contains the division factor. The reference frequency is divided by the (*Divider + 1)* value (zero *Divider* value means no division).

The board contains eight chronometer blocks. Each block uses three external input signals (*x* is a number from 0 to 7 and means the number of the block):

- *ChxG* – gating signal,
- *ChxSt* – external *Start* signal,
- *ChxStSt* – external *Start/Stop* signal.

In the C language interface the features of the chronometer channels are controlled by the `ChronoType` structure. The main structure of the `RTDACUSB2BufferType` type contains the array:

```
ChronoType  Chrono[ 8 ]
```

that is applied to communicate with the blocks.
In the .NET interface the state of the chronometers are described in the `ChronoClass` class.

5.10.1 EnableBlock

C interface	**`unsigned int EnableBlock`**	
.NET interface	**`EnableState Enable`**	
Simulink interface	**`ChronoEnable`**	output of the read S-function
	`SetChronoEnable`	input of the send S-function

DESCRIPTION
The field sets/means the enable state of the block. The block operates (responds to inputs and parameters) if it is enabled. In disable state the chronometer block does not react to inputs and timer pulses.
In the C and Simulink interfaces the value of "1" enables the block. If this integer value is equal to "0" the block is disabled.
In the .NET interfaces the value equal to `On` indicates enable state; `Off` disables the block.

5.10.2 TriggerMode

C interface	***unsigned int TriggerMode***	
.NET interface	***TriggerModeState TriggerMode***	
Simulink interface	***ChronoTriggerMode***	output of the read S-function
	SetChronoTriggerMode	input of the send S-function

DESCRIPTION
2-bit field that determines the operating condition that starts and terminates the measurement cycle.
In the C and Simulink interfaces the values of the operating modes are given in Table 4.
In the .NET interfaces the values of this field can be set to *StartStop_IsH*, *StartStop_RigingEdges* and *StartStop_Stop_RisingEdges* that reflect respectively to values 00, 01 and 10 from Table 4.

5.10.3 EnableGate

C interface	***unsigned int EnableGate***	
.NET interface	***EnableGateState EnableGate***	
Simulink interface	***ChronoEnableGate***	output of the read S-function
	SetChronoEnableGate	input of the send S-function

DESCRIPTION
Flag that enables/disables gate signal. If the flag is set and the *ChxG* signal is 1 the block does not count reference clock pulses.
In the C and Simulink interfaces the value of "1" enables gating. If this integer value is equal to "0" the *GATE* signal is disabled.
In the .NET interfaces the value equal to `On` indicates enable state; `Off` disables gating.

5.10.4 InvertStartStop

C interface	***unsigned int InvertStartStop***	
.NET interface	***InvertStartStopState InvertStartStop***	
Simulink interface	***ChronoInvertStartStop***	output of the read S-function
	SetChronoInvertStartStop	input of the send S-function

DESCRIPTION
Flag that allows to invert the *ChxStSt* input. If the flag is active the *ChxStSt* signal is inverted at the input of the chronometer block. It evokes the block to start and terminate measurements as a reaction on falling edges of the *ChxStSt* signal.
In the C and Simulink interfaces the value of "1" inverts the signal. The value of "0" does not change the level of the input signal.
In the .NET interfaces the value equal to `On` indicates inverting of the input; `Off` disables inverting.

5.10.5 InvertStop

C interface	***unsigned int InvertStop***	
.NET interface	***InvertStopState InvertStop***	
Simulink interface	***ChronoInvertStop***	output of the read S-function
	SetChronoInvertStop	input of the send S-function

DESCRIPTION

The flag that allows to invert the *ChxSt* input. If the flag is active the *ChxSt* signal is inverted at the input of the chronometer block. It evokes the block terminate measurements as a reaction on falling edges of the *ChxSt* signal.
In the C and Simulink interfaces the "1" value inverts the signal. The "0" value does not change the level of the input signal.
In the .NET interfaces the value equal to `On` indicates inverting of the input; `Off` disables inverting.

5.10.6 InvertGate

C interface	**`unsigned int InvertGate`**	
.NET interface	**`InvertGateState InvertGate`**	
Simulink interface	**`ChronoInvertGate`**	output of the read S-function
	`SetChronoInvertGate`	input of the send S-function

DESCRIPTION
The flag that allows to invert the *ChxG* input. If the flag is active the *ChxG* signal is inverted at the input of the chronometer block. If the flag is set and the *ChxG* signal is 0 the block does not count reference clock pulses.
In the C and Simulink interfaces the "1" value inverts the signal. The "0" value does not change the level of the input signal.
In the .NET interfaces the value equal to `On` indicates to invert the input; `Off` disables inverting.

5.10.7 ArmMeasurement

C interface	**`unsigned int ArmMeasurement`**	
.NET interface	**`ArmMeasurementState ArmMeasurement`**	
Simulink interface	**`ChronoArmMeasurement`**	output of the read S-function
	`SetChronoArmMeasurement`	input of the send S-function

DESCRIPTION
The state of the *ArmMeasurement* flag. If the block remains in the *ReadyToArm* state and the flag is set the state of the block is changed to *Armed*. In the *Armed* state the block waits for the start measurement trigger signal.
In the C and Simulink interfaces the "1" value sets the flag. The "0" value clears the flag.
In the .NET interfaces the value equal to `On` indicates that the flag is set; `Off` clears the flag.

5.10.8 NextMeasurement

C interface	**`unsigned int NextMeasurement`**	
.NET interface	**`NextMeasurementState NextMeasurement`**	
Simulink interface	**`ChronoNextMeasurement`**	output of the read S-function
	`SetChronoNextMeasurement`	input of the send S-function

DESCRIPTION
The state of the *NextMeasurement* flag. When a measurement terminates and the *NextMeasurement* flag is set the state of the block immediately changes to *ReadyToArm*. If also the *ArmMeasurement* flag is set a new measurement is armed automatically. If both flags: *ArmMeasurement* and *NextMeasurement* are set the measurements are rearmed automatically.
In the C and Simulink interfaces the "1" value sets the flag. The "0" value clears the flag.
In the .NET interfaces the value equal to `On` indicates that the flag is set; `Off` clears the flag.

5.10.9 Armed

C interface	***unsigned int BlockState_Armed***	
.NET interface	***BlockStatusState BlockStatus***	
Simulink interface	***ChronoStateArmed***	output of the read S-function

DESCRIPTION
The flag that indicates that the block remains in the *Armed* state.
The field is read-only.
In the C and Simulink interfaces the "1" value indicates the *Armed* state of the block. The "0" value indicates other states.
In the .NET interfaces the *BlockStatus* property value equal to `Armed` indicates the *Armed* state of the block.

5.10.10 Pending

C interface	***unsigned int BlockState_Pending***	
.NET interface	***BlockStatusState BlockStatus***	
Simulink interface	***ChronoStatePending***	output of the read S-function

DESCRIPTION
The flag that indicates that the block remains in the *Counting* state.
The field is read-only.
In the C and Simulink interfaces the "1" value indicates the *Counting* state of the block. The "0" value indicates other states.
In the .NET interfaces the *BlockStatus* property value equal to `Counting` indicates the *Counting* state of the block.

5.10.11 Ready

C interface	***unsigned int BlockState_Ready***	
.NET interface	***BlockStatusState BlockStatus***	
Simulink interface	***ChronoStateReady***	output of the read S-function

DESCRIPTION
The flag that indicates that the block remains in the *Counting Terminated* state.
The field is read-only.
In the C and Simulink interfaces the "1" value indicates the *Counting Terminated* state of the block. The "0" value indicates other states.
In the .NET interfaces the *BlockStatus* property value equal to `CntTerminated` indicates the *Counting Terminated* state of the block.

5.10.12 ClkDivider

C interface	***unsigned int ClkDivider***	
.NET interface	***uint Divider***	
Simulink interface	***ChronoClkDivider***	output of the read S-function
	SetChronoClkDivider	input of the send S-function

DESCRIPTION
In the basic mode the block counts the pulses of the reference signal which period is equal to 25ns. To allow measurements of longer time periods the reference frequency can be divided. The 30-bit *Divider* register contains the division factor. The reference frequency is divided by the (*Divider + 1)* value (zero *Divider* value means no division).

5.10.13 Counter

C interface ***unsigned int Counter***
.NET interface ***uint Counter***

DESCRIPTION
The 32-bit *Counter* register counts 25ns pulses between the start and stop conditions. The value of this register changes when the measurement is pending. When the stop condition occurs the value of the *Counter* register is stored into the *Result* register.
The field is read-only.

5.10.14 Result

C interface ***unsigned int Result***
.NET interface ***uint Result***
Simulink interface ***ChronoResult*** output of the read S-function

DESCRIPTION
32-bit register. The result of the last measurement cycle. The result is ready-to-read when the *Ready* flag is set (see section 5.10.11)
The field is read-only.

5.10.15 Example

Generate a pulse of the H logical state at the *DIO2* output. The *DIO2* signal is shared with *Ch0StSt*. Measure the duration of the generated pulse at the *Ch0* chronometer.

C language

```
RTDACUSB2BufferType   RTDACUSBBuffer;
int NoOfDetectedUSBDevices;
int BoardIdx;

NoOfDetectedUSBDevices = USB2NumOfDevices( );
if( NoOfDetectedUSBDevices < 1 ) {
  printf ( "Can not detect any RT-DAC/USB2 device\n");
  return;
}
BoardIdx = USB2Open( );
if( BoardIdx < 0 ) {
  printf(  "Can not open the RT-DAC/USB2 device\n" );
  return;
}
CommandRead_0103( BoardIdx, &RTDACUSBBuffer );


// Set pin mode as general-purpose for all signals
RTDACUSBBuffer.CN1PinMode = 0;
// Set direction of the Ch0StSt to be output
RTDACUSBBuffer.CN1Direction &= 0x0FFFFFFB;

// Setups of the Ch0
RTDACUSBBuffer.Chrono[0].EnableBlock = 1;
RTDACUSBBuffer.Chrono[0].InvertStartStop = 0;
RTDACUSBBuffer.Chrono[0].InvertStop = 0;
RTDACUSBBuffer.Chrono[0].InvertGate = 0;
RTDACUSBBuffer.Chrono[0].EnableGate = 0;
// Duration of the H state at the Ch0StSt
RTDACUSBBuffer.Chrono[0].TriggerMode = 0;
RTDACUSBBuffer.Chrono[0].ArmMeasurement = 1;
RTDACUSBBuffer.Chrono[0].NextMeasurement = 1;
RTDACUSBBuffer.Chrono[0].ClkDivider = 0;  // Maximum resolution

// Generate the pulse
RTDACUSBBuffer.CN1Output &= 0x0FFFFFFB;  // Set DIO2 to L
CommandSend_0103( BoardIdx, &RTDACUSBBuffer );
RTDACUSBBuffer.CN1Output |= 0x00000004; // Set DIO2 to H
CommandSend_0103( BoardIdx, &RTDACUSBBuffer );
RTDACUSBBuffer.CN1Output &= 0x0FFFFFFB; // Set DIO2 to L
CommandSend_0103( BoardIdx, &RTDACUSBBuffer );

CommandRead_0103( BoardIdx, &RTDACUSBBuffer );
printf("Result: %d\n", RTDACUSBBuffer.Chrono[0].Result);

USB2Close( BoardIdx );
```

C# language

```
RTDACUSB2_0103 brd = new RTDACUSB2_0103();
if (brd.Open() < 0)
{
  MessageBox.Show("Can not open the device.", "Encoder example",
                  MessageBoxButtons.OK, MessageBoxIcon.Exclamation);
  return;
}
brd.ReadUSBFrame();

// Set pin mode as general-purpose for all signals
brd.DigitalIO.CN1PinMode = 0;
// Set direction of the Ch0StSt to be output
brd.DigitalIO.CN1Direction &= 0x0FFFFFFB;

// Setups of the Ch0
brd.Chrono(0).Enable = ChronoClass.EnableState.On;
brd.Chrono(0).InvertStartStop = ChronoClass.InvertStartStopState.Off;
brd.Chrono(0).InvertStop = ChronoClass.InvertStopState.Off;
brd.Chrono(0).InvertGate = ChronoClass.InvertGateState.Off;
brd.Chrono(0).EnableGate = ChronoClass.EnableGateState.Off;
brd.Chrono(0).TriggerMode =
                  ChronoClass.TriggerModeState.StartStop_IsH;
brd.Chrono(0).Arm = ChronoClass.ArmState.On;
brd.Chrono(0).Next = ChronoClass.NextState.On;
brd.Chrono(0).Divider = 0;  // Maximum resolution

// Generate the pulse
brd.DigitalIO.CN1Output &= 0x0FFFFFFB;  // Set DIO2 to L
brd.SendUSBFrame();
brd.DigitalIO.CN1Output |= 0x00000004; // Set DIO2 to H
brd.SendUSBFrame();
brd.DigitalIO.CN1Output &= 0x0FFFFFFB; // Set DIO2 to L
brd.SendUSBFrame();

brd.ReadUSBFrame();
String sAux;
sAux = "Result: " +
       String.Format("{0:D}", brd.Chrono(0).Result);
MessageBox.Show(sAux, "Chronometer example",
                MessageBoxButtons.OK);
```

5.11 A/D conversion

The RT-DAC/USB2 board is equipped with the 12-bit successive approximation A/D converter that gives the 5 mV resolution within input range ±10V. A finer resolution can be achieved by the gain definition using the analog amplifier. The A/D conversion time of the RT-DAC/USB2 board is equal to 5.4 μs. The board logic automatically starts the A/D conversions from all analog inputs when the PC host requires data from the RT-DAC/USB2 device. There is possible to select individually the analog gain for each analog input channel.

The A/D conversion functions are not active in the digital version of the board.

In the C language interface the features of the frequency meter channels are controlled by the `ADType` structure. The main structure of the `RTDACUSB2BufferType` type contains the array:

```
ADType      AD[ 16 ];
```

that is applied to communicate with the A/D converters and the gain amplifier.
In the .NET interface the state of A/D conversion channels are described in the `ADClass` class.

5.11.1 Gain

C interface	**`unsigned int Gain`**	
.NET interface	**`GainState ADGain`**	
Simulink interface	**`ADGain`**	output of the read S-function
	`SetADGain`	input of the send S-function

DESCRIPTION
The field defines the gain of the analog inputs. The amplifications of 1, 2, 4, 8 and 16 are available.
In C and Simulink the *Gain* is a 3-bit number. The values of 0, 1, 2, 3 and 4 define the gains of 1, 2, 4, 8 and 16 respectively.
In the .NET values of *x1*, *x2*, *x4*, *x8* and *x16* define the gains of 1, 2, 4, 8 and 16.

5.11.2 Result

C interface	**`unsigned int Result`**	
.NET interface	**`GainState ADGain`**	
Simulink interface	**`ADResult`**	output of the read S-function

DESCRIPTION
The A/D conversion result. This field is read-only.

In C and Simulink the result of the A/D conversion given in the form of a 12-bit U2 coded number. The number stored in *Result* can be transferred to voltage value following the formula:

```
if ( Result  > 2047 ) Result = Result –4096;
Voltage = (10*Result/2048);        // [V]
```

The calculated voltage has to be multiplied by the number defined as the *Gain* property.
In .NET the *ADResult* field gives a voltage value at the analog input.

5.11.3 Example

Set the gain of the third A/D2 input channel to 1 and read the conversion result.

C language

```
RTDACUSB2BufferType   RTDACUSBBuffer;
int NoOfDetectedUSBDevices;
int BoardIdx;
int Result;
double AnalogSignal;

NoOfDetectedUSBDevices = USB2NumOfDevices( );
if( NoOfDetectedUSBDevices < 1 ) {
  printf ( "Can not detect any RT-DAC/USB2 device\n");
  return;
}
BoardIdx = USB2Open( );
if( BoardIdx < 0 ) {
  printf(  "Can not open the RT-DAC/USB2 device\n" );
  return;
}
if( CommandRead_0103( BoardIdx, &RTDACUSBBuffer ) < 0 ) {
  printf(  "Can not read the RT-DAC/USB2 device\n" );
  return;
}

// Set the gain of the third A/D channel to 1
RTDACUSBBuffer.AD[2].Gain = 0;
CommandSend_0103( BoardIdx, &RTDACUSBBuffer );

CommandRead_0103( BoardIdx, &RTDACUSBBuffer );
Result = RTDACUSBBuffer.AD[ 2 ].Result;
printf("Input of the third A/D2 channel: %d\n", Result );
if ( Result  > 2047 ) Result = Result -4096;
AnalogSignal = (10*Result/2048);      // [V]
printf("Input of the A/D2 channel in [V]: %f\n",
       (float)AnalogSignal);

USB2Close( BoardIdx );
```

C# language

```
RTDACUSB2_0103 brd = new RTDACUSB2_0103();
if (brd.Open() < 0)
{
  MessageBox.Show("Can not open the device.", "Encoder example",
                  MessageBoxButtons.OK, MessageBoxIcon.Exclamation);
  return;
}
brd.ReadUSBFrame();

// Set the gain of the third A/D channel to 1
brd.AD(2).ADGain = ADClass.GainState.x1;
brd.SendUSBFrame();

brd.ReadUSBFrame();
String sAux;
sAux = "Input of the third A/D 2 channel: " +
       String.Format("{0:D}", brd.AD(2).ADValue + "\n" +
       "Input of the A/D 2 channel in [V]: " +
       brd.AD(2).ADVoltage.ToString() );
MessageBox.Show(sAux, "A/D example", MessageBoxButtons.OK);
```

5.12 D/A conversion

The board contains four 12-bits D/A converter channels connected to the A/O 0, A/O 1, A/O 2 and A/O 3 pins. All channels can be hardware configured to operate in the ±10V mode. Each analog output channel can sink up to 10 mA.

The D/A conversion functions are not active in the digital version of the board.

In the C language interface the D/A channels are controlled by the array:

```
unsigned int  DA[ 4 ]
```

In the .NET interface the state of the frequency meter blocks are described in the `DAClass` class.

5.12.1 D/A control

C interface	***unsigned int DA[4]***	
.NET interface	***uint DAValue***	
	double DAVoltage	
Simulink interface	***DA***	output of the read S-function
	SetDA	input of the send S-function
	SetDAterminate	input of the send S-function

DESCRIPTION
The field sets a value to the selected D/A channel.

In the C interface the value written to the field is a 14-bit number in the natural binary code and two least significant bits of the number are neglected. The value of the output signal (*Vout)* (expressed in volts) corresponds to the number sent to the D/A converter. The voltage value is calculated by the formula:

Vout = -10 + 20 DA[*] / 16384; [V].*

In the .NET interface the *DAValue* property corresponds to a binary number applied to control the D/A converter. The *DAVoltage* property corresponds to the output voltages,
In Simulink the inputs to the send S-function are in the range –10.0 to +10.0 and correspond to the output voltages.
In the Simulink send S-functions there are two inputs applied to set the D/A outputs. The first one, `SetDA`, is applied during each sampling period. The second input, `SetDATerminate`, is used when the simulation terminates to set safe voltages at the analog outputs.

5.12.2 Example

Set the output of the third A/D channel to 5V and set the output of the fourth A/D channel to –5V.

C language

```
RTDACUSB2BufferType   RTDACUSBBuffer;
int NoOfDetectedUSBDevices;
int BoardIdx;

NoOfDetectedUSBDevices = USB2NumOfDevices( );
if( NoOfDetectedUSBDevices < 1 ) {
  printf ( "Can not detect any RT-DAC/USB2 device\n");
  return;
}
BoardIdx = USB2Open( );
if( BoardIdx < 0 ) {
  printf(  "Can not open the RT-DAC/USB2 device\n" );
  return;
}
if( CommandRead_0103( BoardIdx, &RTDACUSBBuffer ) < 0 ) {
  printf( "Can not read the RT-DAC/USB2 device\n" );
  return;
}

// Set the levels of the D/A2 and D/A3
RTDACUSBBuffer.DA[2] = 0.75*16384;
RTDACUSBBuffer.DA[3] = 0.25*16384;
CommandSend_0103( BoardIdx, &RTDACUSBBuffer );

USB2Close( BoardIdx );
```

C# language

```
RTDACUSB2_0103 brd = new RTDACUSB2_0103();
if (brd.Open() < 0)
{
    MessageBox.Show("Can not open the device.", "Encoder example",
                    MessageBoxButtons.OK, MessageBoxIcon.Exclamation);
    return;
}
brd.ReadUSBFrame();

// Set the levels of the D/A2 and D/A3
brd.DA(2).DAValue = (uint)(0.75 * 16384);
brd.DA(3).DAValue = (uint)(0.25 * 16384);
brd.SendUSBFrame();
```

6. TEST APPLICATIONS

The software included to the RT-DAC/USB2 board contains eight short programs which allow to test all the functions of the board.
More than one program can be run simultaneously to perform more advanced tests. For example the outputs of the PWM waves can be observed by the program used to test digital I/O signals.

There are the following testing programs:

- Digital I/O test,
- Timer / Counter test,
- PWM test,
- Encoder test,
- Frequency Meter test,
- Chronometer test,
- A/D test and
- D/A test.

The usage of these programs is self-explained, simple and fully intuitive. However, a short operating instruction may be needed. It is assumed that a user is familiarised with the previous sections of this manual that describe the features of the I/O channels.

6.1 Digital IO test

The screen view of the program is given in Fig. 6.1. Information about the states of all digital input/outputs lines is placed in the screen. Also one can choose a direction of each line independently marking the appropriate checkbox.
The *Mode* column contains buttons which change the mode of the output pins shared between general-purpose digital outputs and the outputs of the specialised PWM blocks. Only the buttons associated with the signals shared between the general-purpose I/Os and PWM outputs are active. As it has been described in the section 5.5 the digital input/output lines named: DIO2/PWM0, DIO5/PWM1, DIO8/PWM2, DIO11/PWM3, DIO14/PWM4, DIO17/PWM5 DIO20/PWM6 and DIO23/PWM7 are shared with outputs of the PWM blocks. The radio buttons in the column *Output* allow to set the state of line if it works as the output. The column *Input* (read only) shows the state of the input lines. The column *Direction* allows to set the direction of the line.
The list box in the left upper corner of the application allows to select the board if more then one board is connected to the computer.

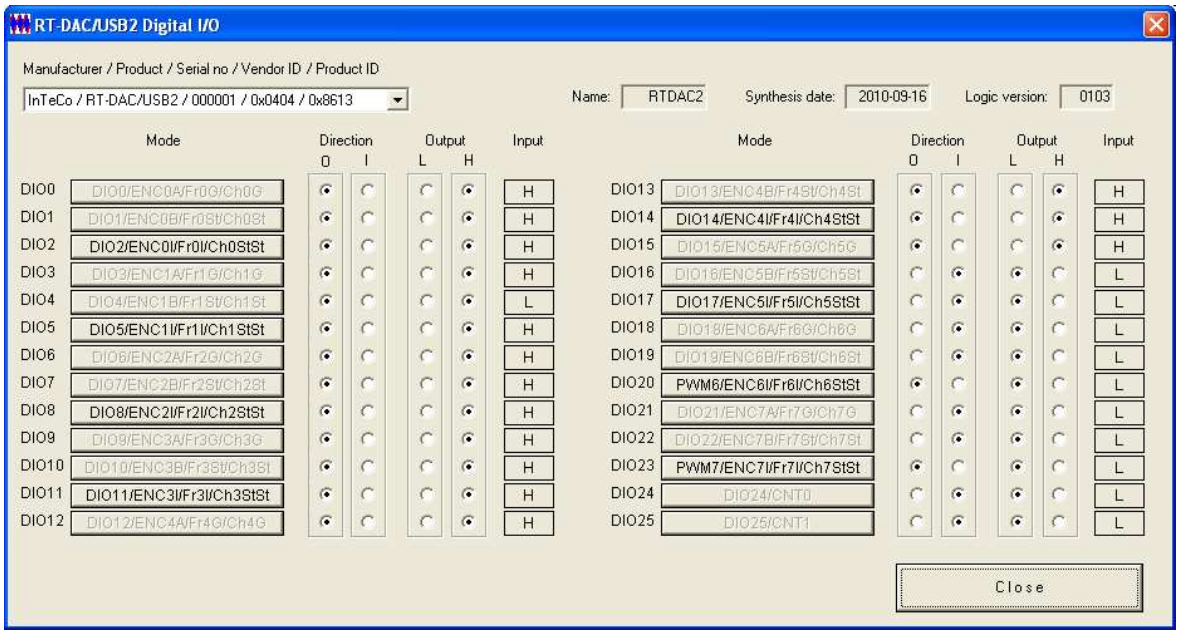

Fig. 6.1. The *Digital I/O* test window

The analysis of the presented screen will help us to understand the idea of the testing program. In the case illustrated in the figure all the digital I/O signals except DIO20 and DIO23 are the general-purpose I/Os. The signals are configured to be the outputs except DIO16-DIO19, DIO21, DIO22, DIO24 and DIO25 which are the inputs. The outputs from DIO0 to DIO15 are set to high. The remaining outputs are set to low. The states of DIO20 and DIO23 are controlled by the PWM6 and PWM7 blocks.

Table 5 presents the elements of the test application and the numbers of sections where the detailed description of the fields is given.

Table 5. Fields of the *Digital I/O* application.

Element of the test application window	**Description** **Section where the field/property is described**
Name	Name of the board Section 5.3.2
Synthesis date	Synthesis date of the FPGA configuration Section 5.3.3
Logic version	Logic version of the FPGA configuration Section 5.3.1
Mode column	Pin mode of the digital I/O signals Section 5.4
Direction column	Direction of the digital I/O signals Section 5.5.1
Output column	Output state of the digital I/O signals Section 5.5.3
Input column	Input states at the digital I/O inputs Section 5.5.2

6.2 Timer/Counter test

After calling the program the screen shown in Fig. 6.2 appears. The parameters of the timer/counter block can be selected within the *Timer/counter* frame. One can select the channel, set state of the *Reset* signal, select the operating mode and observe the value of the counter.
The list box at the top of the application allows to select the board if more then one board is connected to the computer.

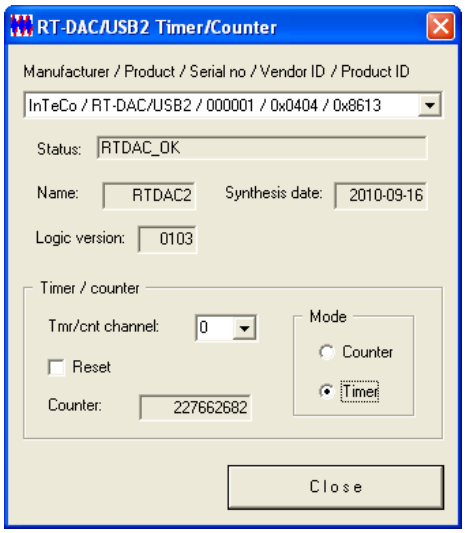

Fig. 6.2. The *Timer/Counter* test window

Table 6 presents the elements of the test application and the numbers of sections where the detailed description of the fields is given.

Table 6. Fields of the *Timer/Counter* application.

Element of the test application window	**Description** **Section where the field/property is described**
Status	Status of the last USB operation Section 5.2.1
Name	Name of the board Section 5.3.2
Synthesis date	Synthesis date of the FPGA configuration Section 5.3.3
Logic version	Logic version of the FPGA configuration Section 5.3.1
Reset	Reset state of the selected channel Section 5.6.2
Mode	Operation mode of the selected channel Section 5.6.1
Counter	Counter value of the selected channel Section 5.6.3

6.3 PWM test

The screen of this testing program is shown in Fig. 6.3.
The parameters of the PWM channels are visible within the *PWM* frame. One can select the channel, mode, prescaler and width.
The list box at the top of the application allows to select the board if more then one board is connected to the computer.

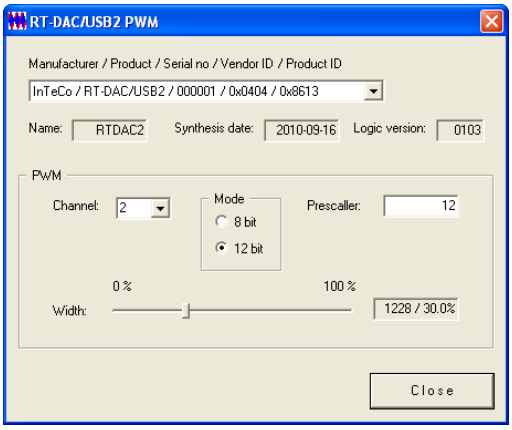

Fig. 6.3. The *PWM* test window

Table 6 presents the elements of the test application and the numbers of sections where the detailed description of the fields is given.

Table 7. Fields of the *PWM* application.

Element of the test application window	**Description** **Section where the field/property is described**
Status	Status of the last USB operation Section 5.2.1
Name	Name of the board Section 5.3.2
Synthesis date	Synthesis date of the FPGA configuration Section 5.3.3
Logic version	Logic version of the FPGA configuration Section 5.3.1
Mode	8-bit / 12-bit generation mode Section 5.7.1

Prescaler	Prescaler of the block (determines the PWM frequency) Section 5.7.2
Width	Duration of the H state of the PWM periods Section 5.7.3

6.4 Encoder test

The screens of this testing program are shown in Fig. 6.4. The windows present states of the ENC4 and ENC5 channels. The parameters of the encoder channels are given in the *Encoder* frames.

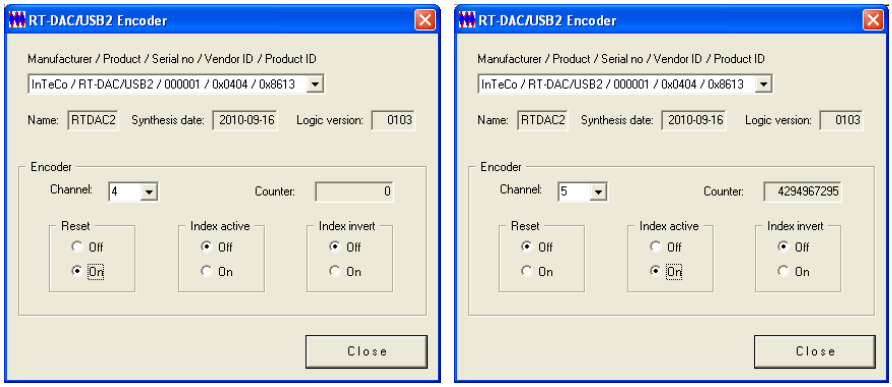

Fig. 6.4. The *Encoder* test windows

Table 8 presents the elements of the test application and the numbers of sections where the detailed description of the fields is given.

Table 8. Fields of the *Encoder* application.

Element of the test application window	**Description** **Section where the field/property is described**
Status	Status of the last USB operation Section 5.2.1
Name	Name of the board Section 5.3.2
Synthesis date	Synthesis date of the FPGA configuration Section 5.3.3
Logic version	Logic version of the FPGA configuration Section 5.3.1
Reset	State of the reset signal Section 5.8.1
Index active	State of the index active signal Section 5.8.2
Index invert	State of the index invert signal Section 5.8.3
Counter	Value of the encoder conter Section 5.8.4

6.5 Frequency meter test

The application presented in Fig. 6.5 sets the parameters of the frequency meter channels and presents the results of the frequency measurements.
The duration of the measurement window, given in the *Window* field, is presented in 25ns units.

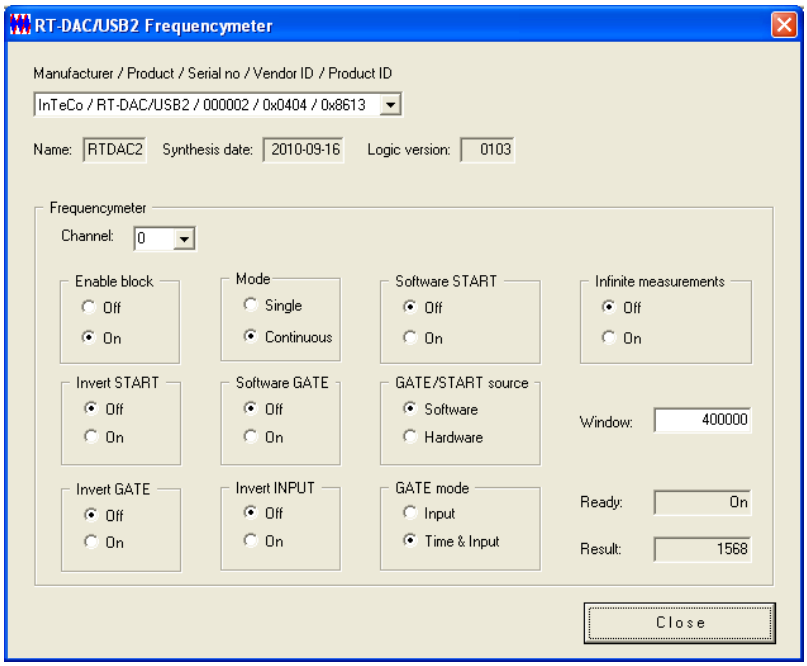

Fig. 6.5. The *Frequency meter* test window

Table 9 presents the elements of the test application and the numbers of sections where the detailed description of the fields is given.

Table 9. Fields of the *Frequency meter* application.

Element of the test application window	**Description** **Section where the field/property is described**
Status	Status of the last USB operation Section 5.2.1
Name	Name of the board Section 5.3.2
Synthesis date	Synthesis date of the FPGA configuration Section 5.3.3
Logic version	Logic version of the FPGA configuration Section 5.3.1
Enable block	State of the enable block flag Section 5.9.1
Mode	State of the mode flag Section 5.9.10
Software START	State of the software START signal Section 5.9.3
Infinite measurements	Value of the infinite measurement flag Section 5.9.9
Invert START	State of the START invert flag Section 5.9.4
Software GATE	State of the software GATE signal Section 5.9.5
GATE/START source	State of the GATE/START source flag Section 5.9.2
Invert GATE	State of the GATE invert signal Section 5.9.6
Invert INPUT	State of the INPUT invert flag Section 5.9.7
GATE mode	State of the GATE mode flag Section 5.9.8

Window	Value of the measurement window Section 5.9.11
Ready	State of the measurement ready flag Section 5.9.12
Result	Result of the measurement Section 5.9.14

To simplify the channel test the PWM output can be applied to measure the number of pulses within the measurement window. The output of the PWM0 channel and the inputs signal of the frequency meter channel 0 are located at the same pin. It is pin number 5 of the CN1 connector (see Table 1). Please set the digital I/O parameters as given in Fig. 6.6. Note that the direction and mode of DIO2 are set to the output and PWM0 respectively.

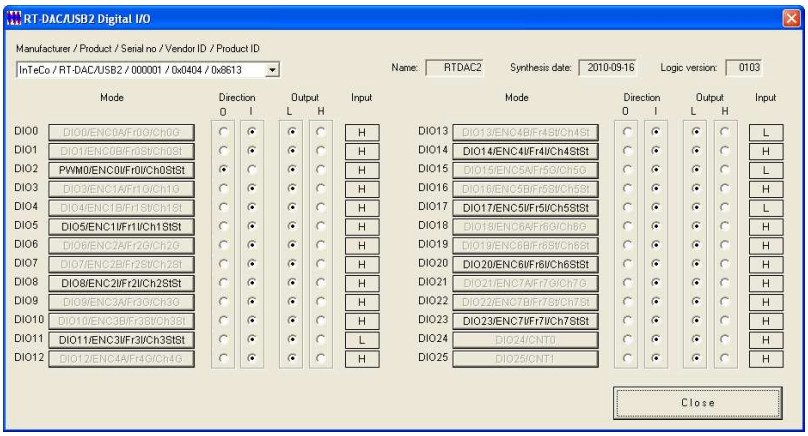

Fig. 6.6. Parameters of the digital I/O signals

Then set the parameters of the PWM0 channel as given in the Fig. 6.7.

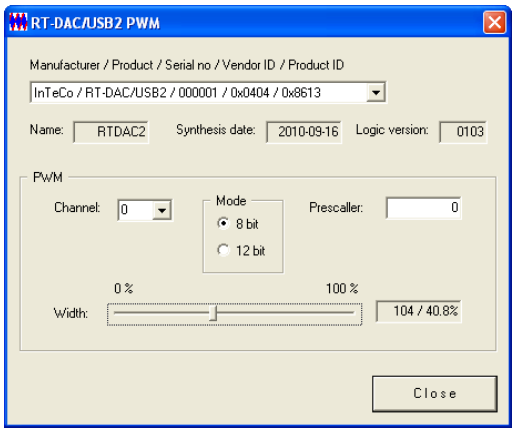

Fig. 6.7. Parameters of the PWM0 output

Finally, set the parameters of the frequency meter channel as shown in Fig. 6.5 and switch the *Software START* flag *ON* and *OFF*. The last operation starts the continuous measurement of PWM pulses generated within the measurement window. To change the result value one has to change the frequency of the PWM wave – it is done by entering a new value in the *Prescaler* field. As well changing the PWM mode from 8-bit to 12-bit changes the frequency.

6.6 Chronometer test

The application presented in Fig. 6.8 sets the parameters of the chronometer channels and presents the results of the measurement. The mode is selected as *"STARTSTOP is H"* so the block performed a single measurement of the duration of the H state at the *Ch0StSt* input.

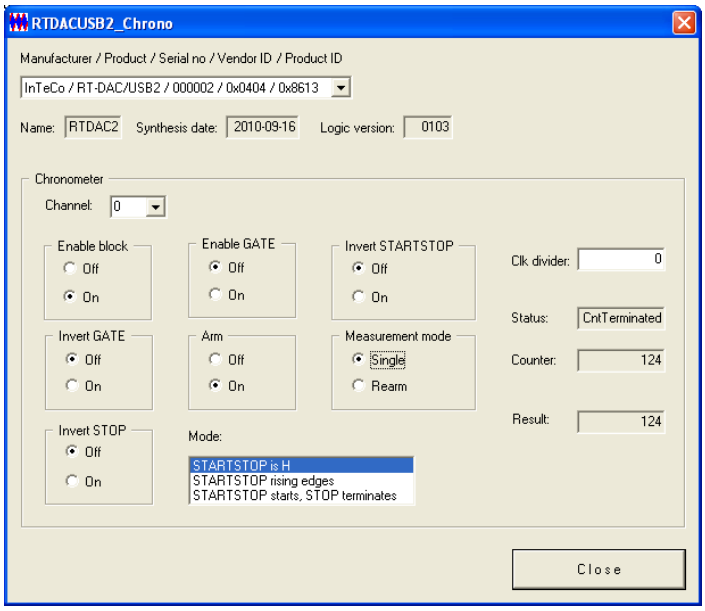

Fig. 6.8. The *Chronometer* test window

The *ChxStSt* and *PWMx* signals are located at the same pins of the CN1 connector. It allows to apply the PWM outputs to test the behaviour of the chronometer blocks. See previous section for more detailed description of a test scenario.

Table 10 presents the elements of the test application and the numbers of sections where the detailed description of the fields is given.

Table 10. Fields of the *Chronometer* application.

Element of the test application window	**Description** **Section where the field/property is described**
Status	Status of the last USB operation Section 5.2.1
Name	Name of the board Section 5.3.2
Synthesis date	Synthesis date of the FPGA configuration Section 5.3.3
Logic version	Logic version of the FPGA configuration Section 5.3.1
Enable block	Enable status of the block Section 5.10.1
Enable GATE	State of the enable GATE signal Section
Invert STARTSTOP	State of the invert STARTSTOP signal Section
Invert GATE	State of the invert GATE signal Section
Arm	State of the arm signal Section
Measurement mode	Measurement operation mode Section
Invert STOP	State of the invert STOP signal Section
Mode	Start/stop mode Section
Clk divider	Value of the clock divider Section
Status	Measurement status Section

Counter	Value of the counter Section
Result	Result of the last measurement Section

6.7 A/D conversion test

The application shown in Fig. 6.9 illustrates the levels of the analog signals at the analog inputs of the board. The levels are presented as values read from the A/D converters and as voltage values. Also one can set gains individually for each A/D channel.

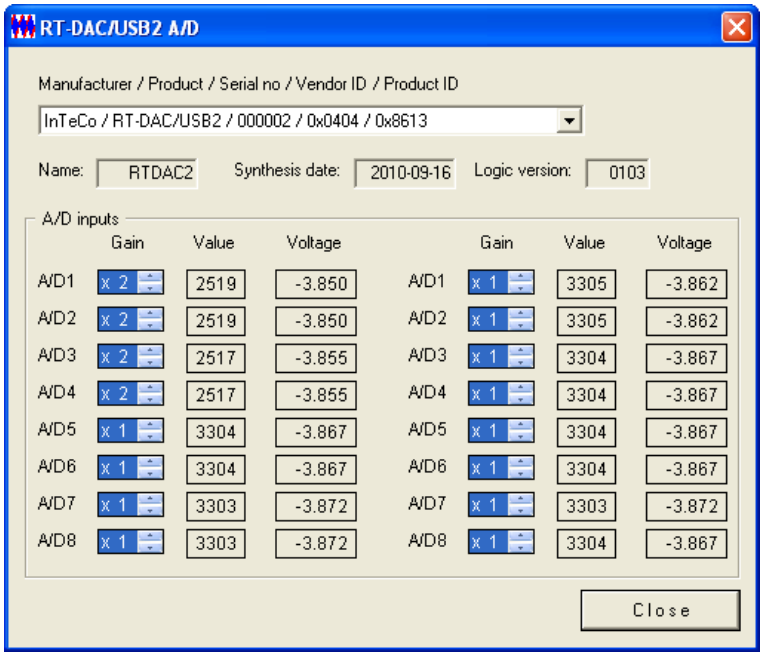

Fig. 6.9. The *A/D Conversion* test window

Table 11 presents the elements of the test application and the numbers of sections where the detailed description of the fields is given.

Table 11. Fields of the *A/D convertion* application.

Element of the test application window	**Description** **Section where the field/property is described**
Status	Status of the last USB operation Section 5.2.1
Name	Name of the board Section 5.3.2
Synthesis date	Synthesis date of the FPGA configuration Section 5.3.3
Logic version	Logic version of the FPGA configuration Section 5.3.1
Gain	Gain of the A/D channels Section 5.11.1
Value and voltage	Bit value and voltage at the A/D inputs Section 5.11.2

6.8 D/A conversion test

The screen snapshot of this testing program is shown in Fig. 6.10. Four sliders allow to set the voltage levels at the D/A outputs. The application presents the values applied to control the D/A converters as well as the levels of the signals at the analog outputs.

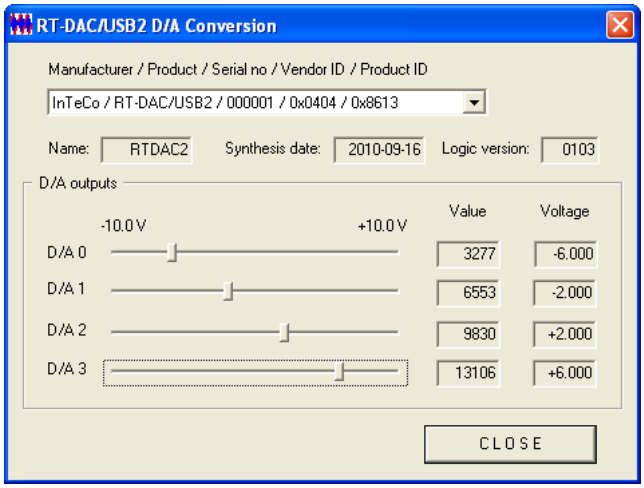

Fig. 6.10. The *D/A* test window

Table 12 presents the elements of the test application and the numbers of sections where the detailed description of the fields is given.

Table 12. Fields of the *D/A convertion* application.

Element of the test application window	**Description** **Section where the field/property is described**
Status	Status of the last USB operation Section 5.2.1
Name	Name of the board Section 5.3.2
Synthesis date	Synthesis date of the FPGA configuration Section 5.3.3
Logic version	Logic version of the FPGA configuration Section 5.3.1
D/A outputs	Output of the D/A channels (bit value and voltage) Section 5.12.1