# DW1000 DEVICE DRIVER APPLICATION PROGRAMMING INTERFACE (API) GUIDE

## USING API FUNCTIONS TO CONFIGURE AND PROGRAM THE DW1000 UWB TRANSCEIVER

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# 1 INTRODUCTION AND OVERVIEW

The DW1000 IC is a radio transceiver IC implementing the UWB physical layer defined in IEEE 802.15.4-2011 standard [3]. For more details of this device the reader is referred to:

- The DW1000 Data Sheet [1]
- The DW1000 User Manual [2]

This document, "*DW1000 Device Driver - Application Programming Interface (API) Guide*" is a guide to the device driver software developed by Decawave to drive Decawave's DW1000 UWB radio transceiver IC.

The device driver is essentially a set of low-level functions providing a means to exercise the main features of the DW1000 transceiver without having to deal with the details of accessing the device directly through its SPI interface register set.

The device driver is provided as source code to allow it to be ported to any target microprocessor system with an SPI interface[1]. The source code employs the C programming language.

The DW1000 device driver is controlled through its Application Programming Interface (API) which is comprised of a set of functions. This document is predominately a guide to the device driver API describing each of the API functions in detail in terms of its parameters, functionality and utility.

This document relates to: `"DW1000 Device Driver Version 03.00.xx"`

The device driver version information may be found in source code file "deca_version.h".

[1] Since the DW1000 is controlled through its SPI interface, an SPI interface is a mandatory requirement for the system.

# 2 GENERAL FRAMEWORK

Figure 1 shows the general framework of the software system encompassing the DW1000 device driver. The DW1000 device driver controls the DW1000 IC through its SPI interface. The DW1000 device driver abstracts the target SPI device by calling it through generic functions *writetospi()* and *readfromspi()*. In porting the DW1000 device driver to different target hardware, the body of these SPI functions are written/re-written/provided to drive the target microcontroller device's physical SPI hardware. The initialisation of the physical SPI interface mode and data rate is considered to be part of the target system outside the DW1000 device driver.

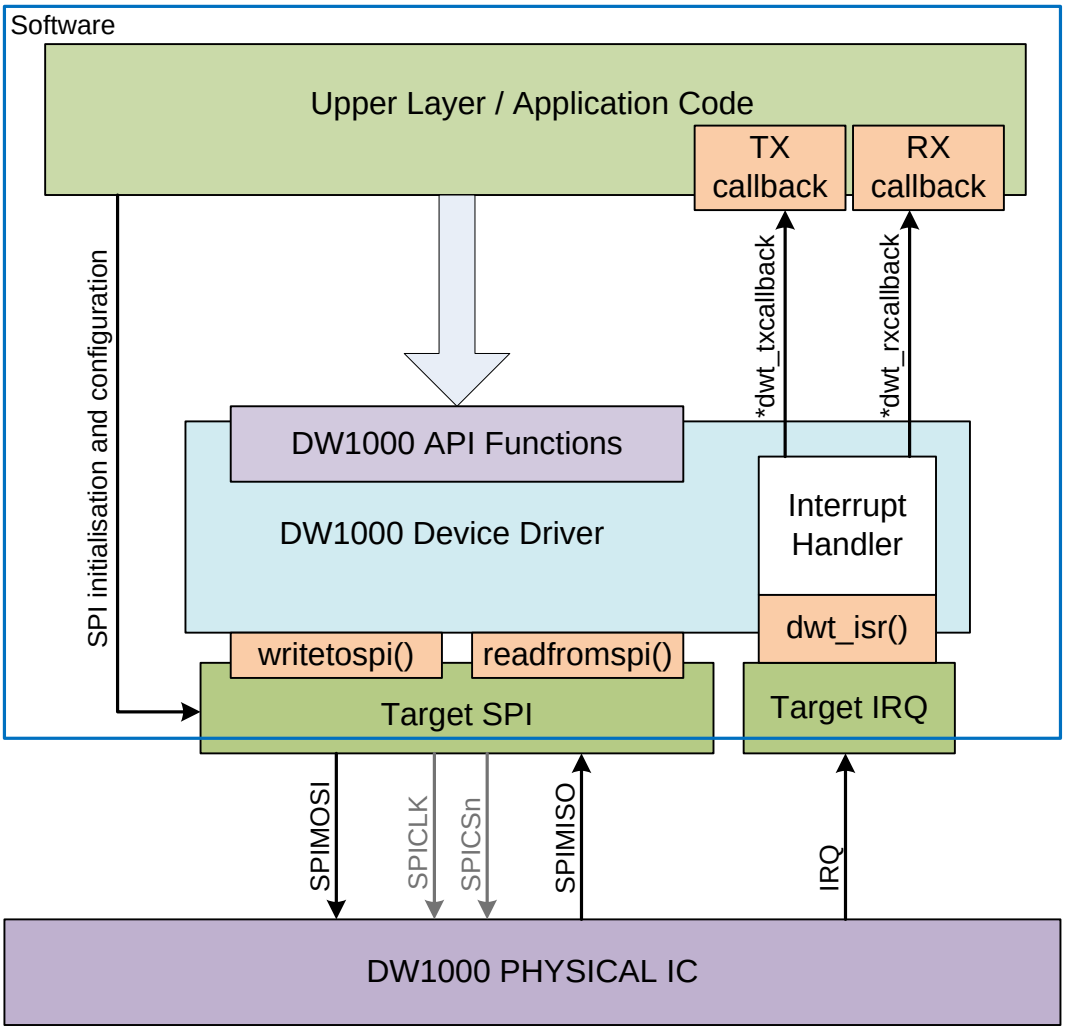


**Figure 1: General software framework of DW1000 device driver**

The control of the DW1000 IC through the DW1000 device driver software is achieved via a set of API functions, documented in section 5 *– API function descriptions* below, and called from the upper layer application code.

The IRQ interrupt line output from the DW1000 IC (assuming interrupts are being employed) is connected to the target microcontroller system's interrupt handling logic. Again this is considered to be outside the DW1000 device driver. It is assumed that the target systems interrupt handling logic and its associated target specific interrupt handling software will correctly identify the assertion of

the DW1000's IRQ and will as a result call the DW1000 device driver's interrupt handling function *dwt_isr()* to process the interrupt.

The DW1000 device driver's *dwt_isr()* function, processes the DW1000 interrupts and calls TX and RX call-back functions in the upper layer application code. This is done via function pointers **dwt_txcallback()* and **dwt_rxcallback()* which are configured to call the upper layer application code's own call-back functions via the *dwt_setcallbacks()* API function.

Using interrupts is recommended, but it is possible to drive the DW1000 without employing interrupts. In this case the background loop can periodically call the DW1000 device driver's *dwt_isr()* function, which will poll the DW1000 status register and process any events that are active.

**The following is IMPORTANT:**

**Note *background* application activity invoking API functions employing the SPI interface can conflict with *foreground* interrupt activity also needing to employ the SPI interface.**

The DW1000 device driver's interrupt handler accesses the DW1000 IC through the *writetospi()* and *readfromspi()* functions, and, it is generally expected that the call-back functions will also access the DW1000 IC through the DW1000 device driver's API functions which ultimately also call the *writetospi()* and *readfromspi()* functions.

**This means that the *writetospi()* and *readfromspi()* functions need to incorporate protection against *foreground* activity occurring when they are being used in the *background*. This is achieved by incorporating calls to *decamutexon()* and *decamutexoff()* within the *writetospi()* and *readfromspi()* functions to disable interrupts from the DW1000 from being recognised while the *background* SPI access is in progress.**

Examples of be *decamutexon()*and *decamutexoff()* within the *writetospi()* and *readfromspi()* functions found in source code file "deca_irq.c" and the definitions of the *writetospi()* and *readfromspi()* functions in "deca_spi.c" source file.

Other than the provisions for interrupt handling, the DW1000 device driver and its API functions are not written to be re-entrant or for simultaneous use by multiple threads. The design in general assumes a single caller that allows each function to complete before it is called again.

# 3 TYPICAL SYSTEM START-UP

Figure 2 shows the typical flow of initialisation of the DW1000 in a microprocessor system.

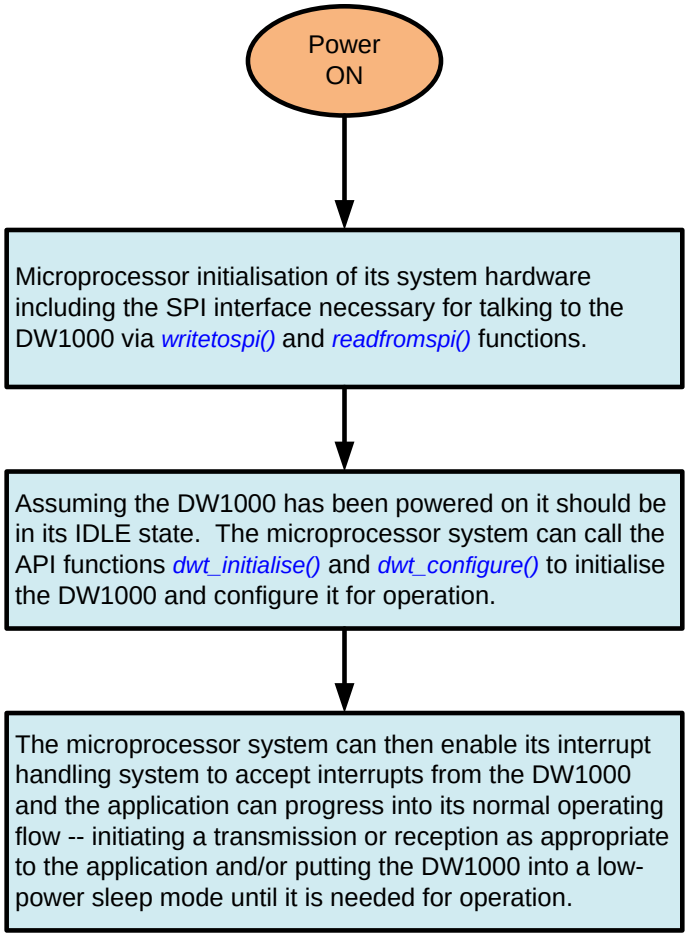


**Figure 2: Typical flow of initialisation**

# 4 INTERRUPT HANDLING

Figure 3 shows how the DW1000 interrupts should be processed by the microcontroller system. Once the interrupt is active, the microcontroller's target specific interrupt handler for that interrupt line should get called. This in turn calls the DW1000 device driver's interrupt handler service routine, the *dwt_isr()* API function, which processes the event that triggered the interrupt.

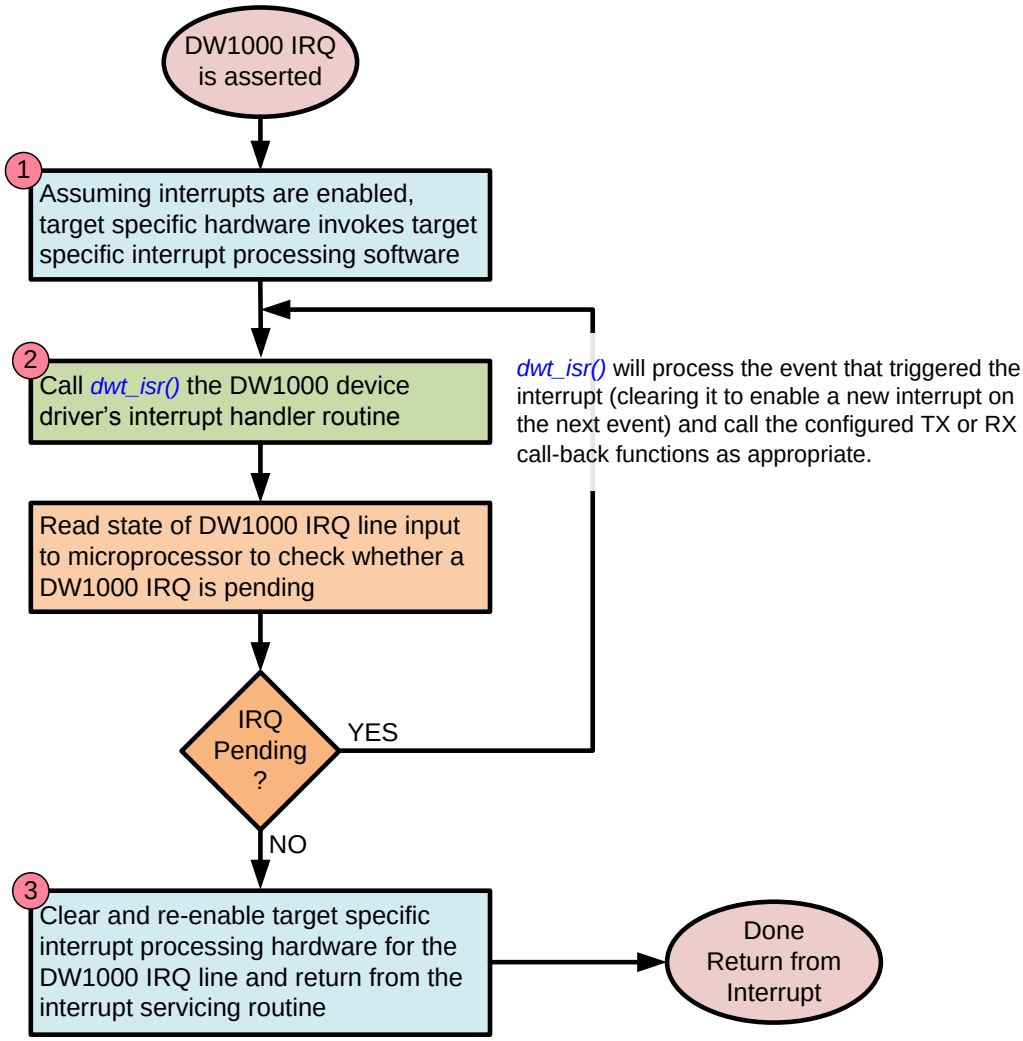


**Figure 3: Interrupt handling**

The flow shown above, with the rechecking of DW1000 to check for continued IRQ line activation and calling the *dwt_isr()* API function again, is only required for edge sensitive interrupts. This is done in case another interrupt becomes pending during the processing of the first interrupt, in this case if all interrupt sources are not cleared the IRQ line will not be de-asserted and edge sensitive interrupt processing hardware will not see another edge. For proper level sensitive interrupts only steps numbered 1, 2, and 3 are required – any still pending interrupt should cause the interrupt handler to be re-invoked as soon as it finishes processing the first interrupt.

More information about individual interrupt events and associated processing is shown in Figure 4.

# 5 API FUNCTION DESCRIPTIONS

This section describes DW1000 device driver's API function calls. The API functions are provided to aid developers in driving the DW1000 (Decawave's ScenSor IEEE 802.15.4 UWB transceiver IC).

These functions are implemented in the device driver source code file "deca_device.c", written in the 'C' programming language.

The device driver code interacts with the DW1000 IC using simple SPI read and write functions. These are abstracted from the physical hardware, and are easily ported to any specific SPI implementation of the target system. There are two SPI functions: *writetospi()* and *readfromspi()* these prototypes are defined in the source code file "deca_spi.c".

The functions of the device driver are covered below in individual sub-sections.

## 5.1 dwt_readdevid

**uint32 dwt_readdevid(void);**

This function returns the device identifier (DEV_ID) register value (32 bit value). It reads the DEV_ID register (0x00) and returns the result to the caller. This may be used for instance by the application to verify the DW IC is connected properly over the SPI bus and is running.

**Parameters:**

none

**Return Parameters:**

| type | description |
|---|---|
| uint32 | 32-bit device ID value, e.g. for DW1000 the device ID is 0xDECA0130. |

**Notes:**

This function can be called any time to read the device ID value. A return value of 0xFFFFFFFF indicates an error unless the device is in DEEP_SLEEP or SLEEP mode.

**Example code:**

```
uint32 devID = dwt_readdevid();
```

## 5.2 dwt_getpartid

**uint32 dwt_getpartid(void);**

This function returns the part identifier as programmed in the factory during device test and qualification.

**Parameters:**

none

**Return Parameters:**

| type | description |
|---|---|
| uint32 | 32-bit part ID value. |

**Notes:**

This function can be called any time to read the locally stored value which will be valid after device initialisation is done by a call to the *dwt_initalise()* function.

**Example code:**

```
uint32 partID = dwt_getpartid();
```

## 5.3 dwt_getlotid

**uint32 dwt_getlotid(void);**

This function returns the lot identifier as programmed in the factory during device test and qualification.

**Parameters:**

none

**Return Parameters:**

| type | description |
|---|---|
| uint32 | 32-bit lot ID value. |

**Notes:**

This function can be called any time to read the locally stored value which will be valid after device initialisation is done by a call to the *dwt_initalise()* function.

**Example code:**

```
uint32 lotID = dwt_getlotid();
```

## 5.4 dwt_otprevision

**uint8 dwt_otprevision(void) ;**

This function returns OTP revision as read while DW1000 was initialised with a call to dwt_initialise. This location is suggested for customer programming, (and is used in Decawave's evaluation board products to identify different/changes in usage of the OTP area).

**Parameters:**

none

**Return Parameters:**

| type | description |
|---|---|
| uint8 | 8-bit OTP revision value. |

**Notes:**

## 5.5 dwt_softreset

**void dwt_softreset(void) ;**

This function performs a software controlled reset of DW1000. All of the IC configuration will be reset back to default. Please refer to the DW1000 User Manual [2] for details of IC default configuration register values.

**Parameters:**

none

**Return Parameters:**

none

**Notes:**

This function is used to reset the IC, e.g. before applying new configuration to clear all of the previously set values. After reset the DW1000 will be in the IDLE state, and all of the registers will have default values. Any values programmed into the always on (AON) low-power configuration array store will also be cleared.

Note: DW1000 RSTn pin can also be used to reset the device. Host microprocessor can use this pin to reset the device instead of calling *dwt_softreset()* function. The pin should be driven low (for 10 ns) and then left in open-drain mode. **It should never be driven high.**

## 5.6 dwt_rxreset

**void dwt_rxreset(void) ;**

This function performs a software controlled reset of DW1000 receiver.

**Parameters:**

none

**Return Parameters:**

none

**Notes:**

This function is used to reset the IC, e.g. before applying new configuration to clear all of the previously set values. After reset the DW1000 will be in the IDLE state, and all of the registers will have default values. Any values programmed into the always on (AON) low-power configuration array store will also be cleared.

## 5.7 dwt_initalise

**int dwt_initialise(uint16 config);**

This function initialises the DW1000 transceiver and sets up values in an internal static data structure used within the device driver functions, which is private data for use in the device driver implementation. The *dwt_initalise()* function also kicks off loading of LDE microcode, if *config* parameter has DWT_LOADUCODE bit set, (from the IC ROM into its runtime location) so that it is available to for future receiver use. If this is not configured the automatic execution of LDE (LDERUNE bit) will be disabled. The LDE algorithm is responsible for generating an accurate RX timestamp and calculating some signal quality statistics related to the received packet.

**Parameters:**

| type | name | description |
|---|---|---|
| int | config | This is a bitmask which specifies which configuration to load from OTP as part of initialisation. Table 1 shows the values of individual bit fields. |

**Return Parameters:**

| type | description |
|---|---|
| int | Return values can be either DWT_SUCCESS = 0 or DWT_ERROR = -1. |

**Notes:**

**NB: the SPI frequency has to be set to < 3 MHz before a call to this function.**

This *dwt_initalise()* function is the first function that should be called to initialise the device, e.g. after the power has been applied. It reads the device ID to verify the IC is one supported by this software (e.g. DW1000 32-bit device ID value is 0xDECA0130). Then it does some initial once only device configurations (e.g. configures the clocks for normal TX/RX functionality) needed for use. It also reads some data from OTP:

- LDO tune and crystal trim values which are applied directly if they are valid.

- Device's Part ID and Lot ID which are stored in driver's local structure for future access.

If the DWT_DECA_ERROR is returned by *dwt_initalise()* then further configuration and operation of the IC is not advised, as the IC will not be functioning properly.

**Table 1: Config parameter to dwt_initialise() function**

| Mode | Mask Value | Description |
|---|---|---|
| DWT_LOADNONE | 0x0 | Do not load any data from OTP. |
| DWT_LOADUCODE | 0x1 | Loads LDE microcode (from the IC ROM into its runtime location) so that it is available to for future receiver use. The LDE algorithm is responsible for generating an accurate RX timestamp and calculating some signal quality statistics related to the received packet. |

**Notes:**

For more details of the OTP memory programming please refer to section *dwt_otpwriteandverify()*. **Programming OTP memory is a one-time only activity, any values programmed in error cannot be corrected. Also, please take care when programming OTP memory to only write to the designated areas – programming elsewhere may permanently damage the DW1000's ability to function normally.**

## 5.8 dwt_configure

**int dwt_configure(dwt_config_t *config, uint16 use_otpconfigvalues);**

This function is responsible for setting up the channel configuration parameters for use by both the Transmitter and the Receiver. The settings are specified by the *dwt_config_t* structure passed into the function, see notes below. (Note also there is a separate function *dwt_configuretxrf()* for setting certain TX parameters. This is described in section 5.9 below).

**Parameters:**

| type | name | description |
|---|---|---|
| dwt_config_t* | config | This is a pointer to the configuration structure, which contains the device configuration data. Individual fields are described in detail in the notes below. |

```
typedef struct
{
      uint8 chan ;              //!< channel number {1, 2, 3, 4, 5, 7}
      uint8 prf ;               //!< Pulse Repetition Frequency
                                //{DWT_PRF_16M or DWT_PRF_64M}
      uint8 txPreambLength;     //!< DWT_PLEN_64..DWT_PLEN_4096
      uint8 rxPAC ;             //!< Acquisition Chunk Size (Relates to RX
                                // preamble length)
      uint8 txCode ;            //!< TX preamble code
      uint8 rxCode ;            //!< RX preamble code
      uint8 nsSFD ;             //!< Boolean, use non-std SFD for better
                                // performance
```

```
        uint8 dataRate ;            //!< Data Rate {DWT_BR_110K, DWT_BR_850K or
                                    // DWT_BR_6M8}
        uint8 phrMode ;             //!< PHR mode:
                                          // 0x0 - standard DWT_PHRMODE_STD
                                          // 0x3 - extended frames
                                    DWT_PHRMODE_EXT
        uint16 sfdTO ;              //!< SFD timeout value (in symbols)

    } dwt_config_t ;
```

**Return Parameters:**

| type | description |
|---|---|
| int | Return values can be either DWT_DECA_SUCCESS = 0 or DWT_DECA_ERROR = -1. |

**Notes:**

The *dwt_configure()* function should be used to configure the DW1000 channel (TX/RX) parameters before receiver enable or before issuing a start transmission command. It can be called again to change configurations as needed, however before using *dwt_configure()*the DW1000 should be returned to idle mode using the *dwt_forcetrxoff()* API call.

The *config* parameter points to a *dwt_config_t* structure that has various fields to select and configure different parameters within the DW1000. The fields of the *dwt_config_t* structure are identified are individually described below:

| Fields | Description of fields within the *dwt_config_t* structure |
|---|---|
| *chan* | The *chan* parameter sets the UWB channel number, (defining the centre frequency and bandwidth). The supported channels are 1, 2, 3, 4, 5, and 7. |
| *txCode* and *rxCode* | The *txCode* and *rxCode* parameters select the preamble codes to use in the transmitter and the receiver – these are generally both set to the same values. For correct operation of the DW1000, the selected preamble code should follow the rules of IEEE 802.15.4-2011 UWB with respect to which codes are allowed in the particular channel and PRF configuration, this is shown in Table 2 below. |
| *prf* | The *prf* parameter allows selection of the nominal PRF (pulse repetition frequency) being used by the receiver which can be either 16 MHz or 64 MHz, via the symbolic definitions DWT_PRF_16M and DWT_PRF_64M. |

| Fields | Description of fields within the *dwt_config_t* structure |
|---|---|
| *nsSFD* | The *nsSFD* parameter enables the use of an alternate non-standard SFD (Start Frame Delimiter) sequence, which Decawave has found to be more robust than that specified in the IEEE 802.15.4 standard, and which therefore gives improved performance. |
| *dataRate* | The *dataRate* parameter specifies the data rate to be one of 110kbps, 850kbps or 6800kbps, via symbolic definitions DWT_BR_110K, DWT_BR_850K and DWT_BR_6M8. |
| *txPreambLength* | The *txPreambLength* parameter specifies preamble length which has a range of values given by symbolic definitions: DWT_PLEN_4096, DWT_PLEN_2048, DWT_PLEN_1536, DWT_PLEN_1024, DWT_PLEN_512, DWT_PLEN_256, DWT_PLEN_128, DWT_PLEN_64. Table 3 gives recommended preamble sequence lengths to use depending on the data rate. |
| *rxPAC* | The *rxPAC* parameter specifies preamble acquisition chunk size used (DWT_PAC8, DWT_PAC16, DWT_PAC32 or DWT_PAC64). Table 4 below gives the recommended PAC size to use in the receiver depending on the preamble length being used in the transmitter. |
| *phrMode* | The *phrMode* parameter selects between either the standard or extended PHR mode is set, either DWT_PHRMODE_STD for standard length frames 5 to 127 octets long or non-standard DWT_PHRMODE_EXT allowing frames of length 5 to 1023 octets long. |
| *sfdTO* | The *sfdTO* parameter sets the SFD timeout value. The purpose of the SFD detection timeout is to recover from the occasional false preamble detection events that may occur. By default this value is 4096+64+1 symbols, which is just longer the longest possible preamble and SFD sequence. This is the maximum value that is sensible. When it is known that a shorter preamble is being used then the value can be reduced appropriately. The function does not allow a value of zero. (If a 0 value is selected the default value of 4161 symbols (*DWT_SFDTOC_DEF*) will be used). |

The *dwt_configure()* function does not error check the input parameters unless the DWT_API_ERROR_CHECK code switch is defined. If this is defined it will return DWT_DECA_ERROR for error. If DWT_API_ERROR_CHECK switch is not defined the code always returns DWT_DECA_SUCCESS, meaning success.

NOTE: SFD timeout cannot be set to 0; if a zero value is passed into the function the default value will be programmed. To minimise power consumption in the receiver, the SFD timeout of the receiving device, *sfdTO* parameter, should be set according to the TX preamble length of the transmitting device. As an example if the transmitting device is using 1024 preamble length, the corresponding receiver should have *sfdTO* parameter set to 1089 (1024+64+1).

**Table 2: DW1000 supported UWB channels and recommended preamble codes**

| Channel number | Preamble Codes (16 MHz PRF) | Preamble Codes (64 MHz PRF) |
|---|---|---|
| 1 | 1, 2 | 9, 10, 11, 12 |
| 2 | 3, 4 | 9, 10, 11, 12 |
| 3 | 5, 6 | 9, 10, 11, 12 |
| 4 | 7, 8 | 17, 18, 19, 20 |
| 5 | 3, 4 | 9, 10, 11, 12 |
| 7 | 7, 8 | 17, 18, 19, 20 |

In addition to the preamble codes in shown in

Table 2 above, for 64 MHz PRF there are eight additional preamble codes, (13 to 16, and 21 to 24), available for use on all channels. These should only be selected as part of implementing dynamic preamble selection (DPS). Please refer to the IEEE 802.15.4-2011 standard [3] for more details of the dynamic preamble selection technique.

The preamble sequence used on a particular channel is the same at all data rates, however its length, (i.e. the number of symbol times for which it is repeated), has a significant effect on the operational range. Table 3 gives some recommended preamble sequence lengths to use depending on the data rate. In general, a longer preamble gives improved range performance and better first path time of arrival information while a shorter preamble gives a shorter air time and saves power. When operating a low data rate for long range, then a long preamble is needed to achieve that range. At higher data rates the operating range is naturally shorter so there is no point in sending an overly long preamble as it wastes time and power for no added range advantage.

**Table 3: Recommended preamble lengths**

| Data Rate | Recommended preamble sequence length |
|---|---|
| 6.8Mbps | 64 or 128 or 256 |
| 850kbps | 256 or 512 or 1024 |
| 110kbps | 1024 or 1536, or 2048 |

The preamble sequence is detected by cross-correlating in chunks which are a number of preamble symbols long. The size of chunk used is selected by the PAC size configuration, which should be selected depending on the expected preamble size. A larger PAC size gives better performance when the preamble is long enough to allow it. But if the PAC size is too large for the preamble length then receiver performance will reduce, or fail to work at the extremes – (e.g. a PAC of 64 will never receive frames with just 64 preamble symbols). Table 4 below gives the recommended PAC size configuration to use in the receiver depending on the preamble length being used in the transmitter.

**Table 4: Recommended PAC size**

| Expected preamble length of frames being received | Recommended PAC size |
|---|---|
| 64 | 8 |
| 128 | 8 |
| 256 | 16 |
| 512 | 16 |
| 1024 | 32 |
| 1536 | 64 |
| 2048 | 64 |
| 4096 | 64 |

**See also:** *dwt_configuretxrf()* for setting certain TX parameters

*dwt_setrxmode()* for setting certain RX (preamble hunt) operating mode.

## 5.9 dwt_configuretxrf

**void dwt_configuretxrf(dwt_txconfig_t *config);**

The *dwt_configuretxrf()* function is responsible for setting up the transmit RF configuration parameters. One is the pulse generator delay value which sets the width of transmitted pulses effectively setting the output bandwidth. The other value is the transmit output power setting.

**Parameters:**

| type | name | description |
|---|---|---|

| | | |
|---|---|---|
| dwt_txconfig_t* | config | This is a pointer to the TX parameters configuration structure, which contains the device configuration data. Individual fields are described in detail below. |

```
typedef struct
{
              uint8  PGdly;              //Pulse generator delay value
              uint32 power;              //the TX power - 4 bytes

} dwt_txconfig_t ;
```

**Return Parameters:**

none

**Notes:**

This function can be called any time and it will configure the DW1000 spectrum parameters. The *config* parameter points to a *dwt_txconfig_t* structure (shown below) with fields to configure the pulse generator delay (*PGdly*) and TX power (*power*). Recommended values for *PGdly* are given in Table 5 below.

**Table 5: PGdly recommended values**

| TX Channel | recommended PGdly value |
|---|---|
| 1 | 0xC9 |
| 2 | 0xC2 |
| 3 | 0xC5 |
| 4 | 0x95 |
| 5 | 0xC0 |
| 7 | 0x93 |

**Table 6: TX power recommended values (when *smart power* is disabled)**

| TX Channel | recommended TX power value 16 MHz | recommended TX power value 64 MHz |
|---|---|---|
| 1 | 0x75757575 | 0x67676767 |
| 2 | 0x75757575 | 0x67676767 |
| 3 | 0x6F6F6F6F | 0x8B8B8B8B |
| 4 | 0x5F5F5F5F | 0x9A9A9A9A |
| 5 | 0x48484848 | 0x85858585 |
| 7 | 0x92929292 | 0xD1D1D1D1 |

Table 6 above includes the recommended TX power spectrum vales, for use in the case of *smart power* being disabled using the *dwt_setsmarttxpower()* API function, while Table 7 below applies when *smart power* is enabled.

**Table 7: TX power recommended values (when *smart power* is enabled)**

| TX Channel | recommended TX power value 16 MHz | recommended TX power value 64 MHz |
|---|---|---|
| 1 | 0x15355575 | 0x07274767 |
| 2 | 0x15355575 | 0x07274767 |
| 3 | 0x0F2F4F6F | 0x2B4B6B8B |
| 4 | 0x1F1F3F5F | 0x3A5A7A9A |
| 5 | 0x0E082848 | 0x25456585 |
| 7 | 0x32527292 | 0x5171B1D1 |

NB: The values in Table 6 and Table 7 have been chosen to suit Decawave's EVB1000 evaluation boards. For other hardware designs the values here may need to be changed as part of the transmit power calibration activity, and there is a location in OTP memory where the calibrated values can be stored and then read as part of device initialisation (see function *dwt_initalise()*). Please consult with Decawave's applications support team for details of transmit power calibration procedures and considerations.

## 5.10 dwt_setsmarttxpower

**void dwt_setsmarttxpower(int enable);**

This function enables or disables smart TX power functionality of DW1000.

**Parameters:**

| type | name | description |
|---|---|---|
| int | enable | 1 to enable, 0 to disable the smart TX power feature. |

**Return Parameters:**

none

**Notes:**

This function enables or disables smart TX power functionality.

Regional power output regulations typically specify the transmit power limit as -41 dBm in each 1 MHz of channel bandwidth, and generally measure this using a 1 ms dwell time in each 1 MHz segment. When sending short frames at 6.8 Mbps it is possible for a single frame to be sent in a fraction of a millisecond, and then as long as the transmitter does not transmit again within that same millisecond the power of that transmission can be increased and still comply with the regulations. This power increase will increase the transmission range. To make use of this the DW1000 includes functionality we call "Smart Transmit Power Gating" which automatically boosts the TX power for a transmission when the frame is short.

Smart TX power control acts at the 6.8 Mbps data rate. When sending short data frames at this rate (and providing that the frame transmission rate is at most 1 frame per millisecond) it is possible to increase the transmit power and still remain within regulatory power limits which are typically specified as average power per millisecond.

NB: When enabling/disabling smart TX power, the TX power values programmed via the *dwt_configuretxrf()* function also need to be set accordingly. When smart TX power is disabled the appropriate value from Table 6 should be used, and when smart TX power is enabled the appropriate value from Table 7 should be used. The values in Table 6 and Table 7 have been chosen to suit Decawave's evaluation boards. For other hardware designs the values here may need to be changed as part of the transmit power calibration activity. Please consult with Decawave's applications support team for details of transmit power calibration procedures and considerations.

## 5.11 dwt_setrxantennadelay

**void dwt_setrxantennadelay(uint16 antennaDelay);**

This function sets the RX antenna delay. The *antennaDelay* value passed is programmed into the RX antenna delay register. This needs to be set so that the RX timestamp is correctly adjusted to account for the time delay between the antenna and the internal digital RX timestamp event. This is determined by a calibration activity. Please consult with Decawave applications support team for details of antenna delay calibration procedures and considerations.

**Parameters:**

| type | name | description |
|---|---|---|
| uint16 | antennaDelay | The delay value is in DWT_TIME_UNITS (15.65 picoseconds ticks) |

**Return Parameters:**

none

**Notes:**

This function is used to program the RX antenna delay.

## 5.12 dwt_settxantennadelay

**void dwt_settxantennadelay(uint16 antennaDelay);**

This function sets the TX antenna delay. The *antennaDelay* value passed is programmed into the TX antenna delay register. This needs to be set so that the TX timestamp is correctly adjusted to account for the time delay between internal digital TX timestamp event and the signal actually leaving the antenna. This is determined by a calibration activity. Please consult with Decawave applications support team for details of antenna delay calibration procedures and considerations.

**Parameters:**

| type | name | description |
|---|---|---|
| uint16 | antennaDelay | The delay value is in DWT_TIME_UNITS (15.65 picoseconds ticks) |

**Return Parameters:**

none

**Notes:**

This function is used to program the TX antenna delay.

## 5.13 dwt_writetxdata

**int dwt_writetxdata(uint16 txFrameLength, uint8 *txFrameBytes, uint16 txBufferOffset) ;**

This function is used to write the TX message data into the DW1000 TX buffer.

**Parameters:**

| type | name | description |
|---|---|---|
| uint16 | txFrameLength | This is the total frame length, including the two byte CRC. |
| uint8* | txFrameBytes | Pointer to the user's buffer containing the data to send. |
| uint16 | txBufferOffset | This specifies an offset in the DW1000's TX Buffer at which to start writing data. |

**Return Parameters:**

| type | description |
|---|---|
| int | Return values can be either DWT_DECA_SUCCESS = 0 or DWT_DECA_ERROR = -1. |

**Notes:**

This function writes two bytes less than the specified *txFrameLength* from the memory, pointed to by the *txFrameBytes* parameter, into the DW1000 IC's transmit data buffer, starting at the specified offset (*txBufferOffset*). During transmission the DW1000 will automatically add the 2 CRC bytes to complete the TX frame to its full *txFrameLength.* NB: If the length + the offset is greater than the IC TX buffer length 1024 the function will return DWT_DECA_ERROR.

NOTE: standard PHR mode allows frames of up to 127 bytes. For longer lengths non-standard PHR mode DWT_PHRMODE_EXT needs to be set in the *phrMode* configuration passed into the *dwt_configure()* function.

The *dwt_writetxdata()* function does not error check the *txFrameLength* input parameter unless the DWT_API_ERROR_CHECK code switch is defined. If this is defined it will return DWT_DECA_ERROR if length is longer than the permitted frame length for the configured *phrMode* setting.

**Example code:**

Typical usage is to write the data, configure the frame control with starting buffer offset and frame length and then enable transmission as follows:

```
dwt_writetxdata(frameLength,DataBufferPtr,0);  // write the frame data at
                                               // offset 0
dwt_writetxfctrl(frameLength,0);               // set the frame control
```

```
                                                    // register
dwt_starttx(DWT_START_TX_IMMEDIATE);                // send the frame
```

## 5.14 dwt_writetxfctrl

**int dwt_writetxfctrl(uint16 txFrameLength, uint16 txBufferOffset) ;**

This function is used to configure the TX frame control register.

**Parameters:**

| type | name | description |
|---|---|---|
| uint16 | txFrameLength | This is the total frame length, including the two byte CRC. |
| uint16 | txBufferOffset | This specifies an offset in the DW1000's TX Buffer at which to start writing data. |

**Return Parameters:**

| type | description |
|---|---|
| int | Return values can be either DWT_DECA_SUCCESS = 0 or DWT_DECA_ERROR = -1. |

**Notes:**

This function configures the TX frame control register parameters, namely the length of the frame and the offset in the DW1000 IC's transmit data buffer where the data starts.

The *dwt_writetxfctrl()* function does not error check the *txFrameLength* input parameter unless the DWT_API_ERROR_CHECK code switch is defined. If this is defined it will return -1 if length is longer than the permitted frame length for the configured *phrMode* setting.

**Example code:**

Typical usage is to write the data, configure the frame control with starting buffer offset and frame length and then enable transmission as follows:

```
dwt_writetxdata(frameLength,DataBufferPtr,0);  // write the frame data at
                                               // offset 0
dwt_writetxfctrl(frameLength,0);               // set the frame control
                                               // register
dwt_starttx(DWT_START_TX_IMMEDIATE);           // send the frame
```

## 5.15 dwt_starttx

**int dwt_starttx(uint8 mode) ;**

This function initiates transmission of the frame. The *mode* parameter is described below.

**Parameters:**

| type | name | description |
|---|---|---|

| | | |
|---|---|---|
| uint8 | mode | This is a bit mask defining the operation of the function, see notes and Table 8 below. |

**Return Parameters:**

| type | description |
|---|---|
| int | Return values can be either DWT_DECA_SUCCESS = 0 or DWT_DECA_ERROR = -1. |

**Notes:**

This function is called to start the transmission of a frame.

Transmission begins immediately if the *mode* parameter is zero. When the *mode* parameter is 1 transmission begins when the system time reaches the *starttime* specified in the call to the *dwt_setdelayedtrxtime()* function described below. The *mode* parameter, when 2 or 3, is used to turn the receiver on immediately after the TX event is complete (see table below). This is used to make sure that there are no delays in turning on the receiver and that the DW1000 can start receiving data (e.g. ACK/response) which might come within 12 symbol times from the end of transmission. It returns 0 for success, or -1 for error.

In performing a delayed transmission, if the host microprocessor is late in invoking the *dwt_starttx()* function, (i.e. so that the DW1000's system clock has passed the specified *starttime* and would have to complete almost a whole clock count period before the start time is reached), then the transmission is aborted (transceiver off) and the *dwt_starttx()* function returns the -1 error indication.

**Table 8: Mode parameter to dwt_starttx() function**

| Mode | Mask Value | Description |
|---|---|---|
| DWT_START_TX_IMMEDIATE | 0x0 | The transmitter starts sending frame immediately. |
| DWT_START_TX_DELAYED | 0x1 | The transmitter will start sending a frame once the programmed *starttime* is reached.<br>See *dwt_setdelayedtrxtime().* |
| DWT_RESPONSE_EXPECTED | 0x2 | Response is expected, once the frame is sent the transceiver will enter receive mode to wait for response message. See *dwt_setrxaftertxdelay().* |
| DWT_START_TX_DELAYED + DWT_RESPONSE_EXPECTED | 0x3 | The transmitter will start sending a frame once the programmed delayed TX time is reached, see *dwt_setdelayedtrxtime(),* and once the frame is sent the transceiver will enter receive mode to wait for response message. |

**Example code:**

Typical usage is to write the data, configure the frame control with starting buffer offset and frame length and then enable transmission as follows:

```
dwt_writetxdata(frameLength,DataBufferPtr,0);  // write the frame data at
                                               // offset 0
dwt_writetxfctrl(frameLength,0);               // set the frame control
                                               // register
dwt_starttx(DWT_START_TX_IMMEDIATE);           // send the frame
```

## 5.16 dwt_setdelayedtrxtime

**void dwt_setdelayedtrxtime (uint32 starttime) ;**

This function sets a send time to use in delayed send or the time at which the receiver will turn on (a delayed receive). This function should be called to set the required send time before invoking the *dwt_starttx()* function (above) to initiate the transmission (in *DELAYED_TX* mode), or *dwt_rxenable()* (below) with *delayed* parameter set to 1.

**Parameters:**

| type | name | description |
|---|---|---|
| uint32 | starttime | The TX or RX start time. The 32-bit value is the high 32-bits of the system time value at which to send the message, or at which to turn on the receiver. The low order bit of this is ignored. This essentially sets the TX or RX time in units of approximately 8 ns. (or more precisely 512/(499.2e6*128) seconds)<br>For transmission this is the raw transmit timestamp not including the antenna delay, which will be added. For reception it specifies the time to turn the receiver on. |

**Return Parameters:**

none

**Notes:**

This function is called to program the delayed transmit or receive start time. The *starttime* parameter specifies the time at which to send/start receiving, when the system time reaches this time (minus the times it needs to send preamble etc.) then the sending of the frame begins. The actual time at which the frame's RMARKER transits the antenna (the standard TX timestamp event) is given by the *starttime* + the transmit antenna delay. If the application wants to embed this time into the message being sent it must do this calculation itself.

The system time counter is 40 bits wide, giving a wrap period of 17.20 seconds.

NOTE: Typically delayed sending might be used to give a fixed response delay with respect to an incoming message arrival time, or, because the application wants to embed the message send time into the message itself. The delayed receive might be used to save power and turn the receiver on only when response message is expected.

**Example code:**

Typical usage is to write the data, configure the frame control with starting buffer offset and frame length and then enable transmission as follows:

In this example the previous frame's TX timestamp time is read and new TX time calculated by adding 100 ms to it. The full 40-bit representation of 100ms would be 0x17CDC0000, however as the code is operating on just the high 32 bits a value of 0x17CDC00 is used. (The TX timestamp value should be read after a TX done interrupt triggers.)

```
uint32 dlyTxTime ;
```

```
dlyTxTime = dwt_readtxtimestamphi32() ;         // read last TX time
dlyTxTime = dlyTxTime + 0x17CDC00;              // add 100ms
dwt_writetxdata(frameLength,dataBufferPtr,0);  // write the frame data at
                                                // offset 0
dwt_writetxfctrl(frameLength,0);                // set the frame control
                                                // register
dwt_setdelayedtrxtime(dlyTxTime);               // set previously calculated
                                                // TX time
r = dwt_starttx(DWT_START_TX_DELAYED);          // send the frame at
                                                // appropriate time
if (r != DWT_SUCCESS)
{
    // start TX was late, TX has been aborted.
    // Application should take appropriate recovery activity
}
```

## 5.17 dwt_readtxtimestamp

**void dwt_readtxtimestamp(uint8* timestamp);**

This function reads the actual time at which the frame's RMARKER transits the antenna (the standard TX timestamp event). This time will include any TX antenna delay if programmed via the *dwt_settxantennadelay()* API function. The function returns a 40-bit timestamp value in the buffer passed in as the input parameter.

**Parameters:**

| type | name | description |
|---|---|---|
| uint8* | timestamp | The pointer to the buffer into which the timestamp value is read. (The buffer needs to be at least 5 bytes long.) The low order byte is the first element. |

**Return Parameters:**

none

**Notes:**

This function can be called after the transmission complete event, DWT_INT_TFRS (see *dwt_isr()* function).

## 5.18 dwt_readtxtimestamplo32

**uint32 dwt_readtxtimestamplo32(void);**

This function returns the low 32-bits of the 40-bit transmit timestamp.

**Parameters:**

none

**Return Parameters:**

| type | description |
|---|---|
| uint32 | Low 32-bits of the 40-bit transmit timestamp. |

**Notes:**

This function can be called after the transmission complete event, DWT_INT_TFRS (see *dwt_isr()* function).

## 5.19 dwt_readtxtimestamphi32

**uint32 dwt_readtxtimestamphi32(void);**

This function returns the high 32-bits of the 40-bit transmit timestamp.

**Parameters:**

none

**Return Parameters:**

| type | description |
|---|---|
| uint32 | High 32-bits of the 40-bit transmit timestamp. |

**Notes:**

This function can be called after the transmission complete event, DWT_INT_TFRS (see *dwt_isr()* function).

## 5.20 dwt_readrxtimestamp

**void dwt_readrxtimestamp(uint8* timestamp);**

This function returns the time at which the frame's RMARKER is received, including the antenna delay adjustments if this is programmed via the *dwt_setrxantennadelay()* API function. The function returns a 40-bit value.

**Parameters:**

| type | name | description |
|---|---|---|
| uint8* | timestamp | The pointer to the buffer into which the timestamp value is read. (The buffer needs to be at least 5 bytes long.) The low order byte is the first element. |

**Return Parameters:**

none

**Notes:**

This function can be called after the frame received event, DWT_INT_RFCG (see *dwt_isr()* function).

## 5.21 dwt_readrxtimestamplo32

**uint32 dwt_readrxtimestamplo32(void);**

This function returns the low 32-bits of the 40-bit received timestamp.

**Parameters:**

none

**Return Parameters:**

| type | description |
|---|---|
| uint32 | Low 32-bits of the 40-bit received timestamp. |

**Notes:**

This function can be called after the frame received event, DWT_INT_RFCG (see *dwt_isr()* function).

## 5.22 dwt_readrxtimestamphi32

**uint32 dwt_readrxtimestamphi32(void);**

This function returns the high 32-bits of the 40-bit received timestamp.

**Parameters:**

none

**Return Parameters:**

| type | description |
|---|---|
| uint32 | High 32-bits of the 40-bit received timestamp. |

**Notes:**

This function can be called after the frame received event, DWT_INT_RFCG (see *dwt_isr()* function).

## 5.23 dwt_readsystime

**void dwt_readsystime(uint8* timestamp);**

This function returns the system time. The function returns a 40-bit value.

**Parameters:**

| type | name | description |
|---|---|---|
| uint8* | timestamp | The pointer to the buffer into which the timestamp value is read. (The buffer needs to be at least 5 bytes long.) The low order byte is the first element. The low order 9 bits will always be 0, as the |

| type | name | description |
|---|---|---|
| | | system timer runs in units of approximately 8 ns. (more precisely 512/(499.2e6*128) seconds or 63.8976GHz). |

**Return Parameters:**

none

**Notes:**

This function can be called to read the DW1000 system time.

## 5.24 dwt_readsystimestamphi32

**uint32 dwt_readsystimestamphi32(void);**

This function returns the high 32-bits of the 40-bit system time.

**Parameters:**

none

**Return Parameters:**

| type | description |
|---|---|
| uint32 | High 32-bits of the 40-bit system timestamp. |

**Notes:**

This function can be called to read the DW1000 system time.

## 5.25 dwt_forcetrxoff

**void dwt_forcetrxoff(void);**

This function may be called at any time to disable the active transmitter or the active receiver and put the DW1000 back into idle mode (transceiver off).

**Parameters:**

none

**Return Parameters:**

none

**Notes:**

The *dwt_forcetrxoff()* function can be called any time and it will disable the active transmitter or receiver and put the device in IDLE mode. It issues a transceiver off command to the DW1000 IC and also clears status register event flags, so that there should be no outstanding/pending events for processing.

## 5.26 dwt_syncrxbufptrs

**void dwt_syncrxbufptrs(void);**

This function synchronizes RX buffer pointers. This is needed to make sure that the host and DW1000 buffer pointers are aligned before starting RX.

**Parameters:**

none

**Return Parameters:**

none

**Notes:**

The function is called as part of *dwt_rxenable()* and *dwt_forcetrxoff()*, to make sure the buffers are synchronized as the receiver is switched off or switched on. For more information see *dwt_setdblrxbuffmode*() function below.

## 5.27 dwt_rxenable

**int dwt_rxenable(int delayed);**

This function turns on the receiver to wait for a receive frame. The delayed parameter allows for delayed RX where RX is turned on at the specific time, set via *dwt_setdelayedtrxtime()*, this is a lower power option then turning RX on immediately if we know the message will not come for a while.

**Parameters:**

| type | name | description |
|---|---|---|
| int | delayed | If non zero this means that the receiver will be turned on when the time reaches the delayed start time as set through the *dwt_setdelayedtrxtime()* function. |

**Return Parameters:**

| type | description |
|---|---|
| int | Return values can be either DWT_DECA_SUCCESS = 0 or DWT_DECA_ERROR = -1. |

**Notes:**

This function can be called any time to enable the receiver. The device should be initialised and have its RF configuration configured.

In performing a delayed reception, if the host microprocessor is late in invoking the *dwt_rxenable()* function, (i.e. so that the DW1000's system clock has passed the *starttime* specified in the call to the *dwt_setdelayedtrxtime()* function and would have to complete almost a whole clock count period before the start time is reached), then the delayed reception is aborted (transceiver off) and the receiver is immediately enabled. An error flag is returned in this case indicating that the RX on was late. It is up to the application whether this behaviour is acceptable, e.g. the application may issue a

*dwt_forcetrxoff()* call to turn off the receiver if some other remedial action is needed other than the immediate RX enabling.

## 5.28 dwt_setrxmode

**void dwt_setrxmode(int mode, uint8 rxON, uint8 rxOFF);**

This function configures different operational modes for preamble detection in the receiver, i.e. Normal mode or SNIFF. In normal mode the receiver in preamble hunt mode is continuously active looking for the preamble sequence. *SNIFF mode* is a lower power preamble hunt mode, also known as pulsed preamble detection mode (PPDM), where the receiver (RF and digital) is sequenced on and off rather than being on all the time. These on and off times are configurable via parameters to this function. Using *SNIFF mode* causes a reduction in sensitivity depending on the ratio and durations of the on and off periods.

**Parameters:**

| type | name | description |
|---|---|---|
| int | mode | See Table 9 below. |
| uint8 | rxON | The receiver ON time in PACs (as per the *rxPAC* parameter in the *dwt_config_t* structure parameter to the *dwt_configure()* API function call) the minimum number of PACs that should be used for the *ppmON* parameter is 2. |
| uint8 | rxOFF | The receiver OFF time in us (actually in 1.0256 µs, (512/499.2MHz) units). |

**Table 9: Mode parameter to dwt_setrxmode() function**

| Mode | Description |
|---|---|
| DWT_RX_NORMAL | normal RX – When the receiver is in preamble hunt mode it is continuously active looking for the preamble sequence |
| DWT_RX_SNIFF | SNIFF mode – When the receiver is in preamble hunt mode it is alternating between looking for the preamble sequence and returning to idle mode (reducing the power drain). The duty cycle of these ON and OFF states is defined by the PPM ON/OFF times. |

**Return Parameters:**

none

**Notes:**

This function can be called as part of device receiver configuration.

By default the DW1000 will be in Normal mode. If this is changed to SNIFF mode it will be maintained until a reset or it is re-configured by a call to this *dwt_setrxmode()* function. The setting is not changed by the *dwt_configure()* function.

## 5.29 dwt_setautorxreenable

**void dwt_setautorxreenable (int enable);**

This function enables automatic re-enable of the receiver. The receiver will exit receive mode only on receiver frame wait timeout or a good frame reception. Error frames are ignored and the receiver is re-enabled.

**Parameters:**

| type | name | description |
|---|---|---|
| int | enable | 1 to enable, 0 to disable the auto RX re-enable feature. |

**Return Parameters:**

none

**Notes:**

This function is called to configure the receiver with auto re-enable functionality. What this does depends also on whether the DW1000 is in single or double buffered mode, (see *dwt_setdblrxbuffmode*() function below). By default this is disabled, and the IC will not automatically re-enable the receiver but will stop receiving and return to idle mode whenever any receive events happen. This includes receiving a frame but also failing to receive a frame because of some error condition, for example and error in the PHY header. In such cases if the host wants to re-enable the receiver it must do it explicitly. The operation when RX auto re-enable is enabled is as follows:

(a) Double-buffered mode: After a frame reception event or failure (except a frame wait timeout), the receiver will re-enable to receive another frame.

(b) Single-buffered mode: After a frame reception failure (except a frame wait timeout), the receiver will re-enable to re-attempt reception.

In double-buffered mode when automatic frame acknowledgement is enabled the receiver will be re-enabled after the ACK frame has been transmitted. See *dwt_enableautoack()* function described in section 5.48 below.

## 5.30 dwt_setdblrxbuffmode

**void dwt_setdblrxbuffmode (int enable);**

This function enables double buffered receive mode. It is expected that this is only done when the auto RX re-enable feature also turned on. This means when a good frame is received, the receiver will automatically re-enable and start receiving the next good frame into the second receive buffer.

**Parameters:**

| type | name | description |
|---|---|---|
| int | enable | 1 to enable, 0 to disable the double buffer RX feature. |

**Return Parameters:**

none

**Notes:**

The *dwt_setdblrxbuffmode()* function is used to configure the receiver in double buffer mode. This should not be done when the receiver is enabled. It should be selected in idle mode before the *dwt_rxenable()* function is called.

## 5.31 dwt_setrxtimeout

**void dwt_setrxtimeout (uint16 time) ;**

The *dwt_setrxtimeout()* function sets the receiver to timeout (and disable) when no frame is received within the specified time (*time*). This function should be called before the *dwt_rxenable()* function is called to turn on the receiver. The time parameter used here is in 1.0256 us (512/499.2 MHz) units. The maximum RX timeout is ~ 65 ms.

**Parameters:**

| type | name | description |
|---|---|---|
| uint16 | time | Timeout time in micro seconds (1.0256 us). If this is 0, the timeout will be disabled. |

**Return Parameters:**

none

**Notes:**

If RX timeout is being employed then this function should be called before *dwt_rxenable()* to configure the frame wait timeout time, and enable the frame wait timeout.

## 5.32 dwt_setpreambledetecttimeout

**void dwt_setpreambledetecttimeout (uint16 time);**

This function sets the receiver to timeout (and disable) when no preamble is received within the specified time. This function should be called before the *dwt_rxenable()* function is called to turn on the receiver. The time parameter units are PACs (as per the *rxPAC* parameter in the *dwt_config_t* structure parameter to the *dwt_configure()* API function call).

**Parameters:**

| type | name | description |
|---|---|---|
| uint16 | time | This is the preamble detection timeout duration, if no preamble is detected within this time from the time the receiver is enabled, the receiver will be turned off. The units are PACs. A value of 0 disables the timer and timeout. |

**Return Parameters:**

none

**Notes:**

If preamble detection timeout is being employed then this function should be called before *dwt_rxenable()* is called.

## 5.33 dwt_loadopsettabfromotp

**void dwt_loadopsettabfromotp (uint8 tab);**

The *dwt_loadopsettabfromotp()* function selects which Operational Parameter Set table to load from OTP memory. The DW1000 receiver has the capability of operating with specific parameter sets that relate to how it acquires the preamble signal and decodes the data. Three distinct operating parameter sets are defined within the IC for selection by the host system designer depending on system characteristics. Table 10 below lists and defines these operating parameter sets indicating their recommended usages.

**Parameters:**

| type | name | description |
|---|---|---|
| uint8 | tab | This specifies the table to use, see Table 10 above. |

**Return Parameters:**

none

**Table 10: Tab parameter to dwt_loadopsettabfromotp() function**

| Mode | Mask Value | Description |
|---|---|---|
| DWT_OPSET_64LEN | 0x0 | This operating parameter set is designed to give good performance for very short preambles, i.e. the length 64 preamble. However this performance optimization comes at a cost, which is that it cannot tolerate large crystal offsets. In order to use this operating parameter set the total clock offset from transmitter to receiver needs to be kept below ±15 ppm. |
| DWT_OPSET_TIGHT | 0x1 | This operating parameter set maximises the operating range of the system. However this performance optimization again comes at a cost, which is that the total crystal offset must be kept very tight, at or below about ±1 ppm. This might be done for example by using very high quality 0.5 ppm TCXO in both the transmitter and the receiver. |
| DWT_OPSET_DEFLT | 0x2 | This is the default operating parameter set. This parameter set is designed to work at all data rates and can tolerate crystal offsets of the order of ±40 ppm (e.g. 20ppm XTAL in transmitter and receiver) between the transmitter and receiver. It is however not optimum for the very short preamble. |

**Notes:**

**NB: the SPI frequency has to be set to < 3 MHz before a call to this function.**

## 5.34 dwt_configuresleepcnt

**void dwt_configuresleepcnt (uint16 sleepcnt);**

The *dwt_configuresleepcnt()* function configures the sleep counter to a new value.

**Parameters:**

| type | name | description |
|---|---|---|
| uint16 | sleepcnt | This is the sleep count value to set. The high 16-bits of 28-bit counter. See note below for details of units and code example for configuration detail. |

**Return Parameters:**

none

**Notes:**

**NB: the SPI frequency has to be set to < 3 MHz before a call to this function.**

The units of the *sleepcnt* parameter depend on the oscillating frequency of the IC's internal L-C oscillator, which is between approximately 7,000 and 13,000 Hz depending on process variations within the IC and on temperature and voltage. This frequency can be measured using the *dwt_calibratesleepcnt()* function so that sleep times can be more accurately set.

The *sleepcnt* is actually setting the upper 16 bits of a 28-bit counter, i.e. the low order bit is equal to 4096 counts. So, for example, if the L-C oscillator frequency is 9500 Hz then programming the *sleepcnt* with a value of 24 would yield a sleep time of 24 × 4096 ÷ 9500, which is approximately 10.35 seconds.

**Example code:**

This example shows how to calibrate the low-power oscillator and set the sleep time to 10 seconds.

```
double t;
uint32 sleep_time = 0;
uint16 lp_osc_cal = 0;
uint16 sleepTime16;

// MUST SET SPI <= 3 MHz for this calibration activity.

setspibitrate(SPI_3MHz);   // target platform function to set SPI rate to 3
                           // MHz

// Measure low power oscillator frequency

lp_osc_cal = dwt_calibratesleepcnt();

// calibrate low power oscillator
// the lp_osc_cal value is number of XTAL/2 cycles in one cycle of LP OSC
// to convert into seconds (38.4 MHz/2 = 19.2 MHz (XTAL/2) => 1/19.2 MHz ns)
// so to get a sleep time of 10s we need a value of:
// 10 / period and then >> 12 as the register holds upper 16-bits of 28-bit
// counter

t = ((double) 10.0 / ((double) lp_osc_cal/19.2e6));
sleep_time = (int) t;
```

```
sleepTime16 = sleep_time >> 12;

dwt_configuresleepcnt(sleepTime16);      //configure sleep time

// CAN restore/increase SPI clock up to its maximum after the calibration
// activity.

setspibitrate(SPI_20MHz);               // target platform function to set
                                        // SPI rate to 20 MHz
```

## 5.35 dwt_calibratesleepcnt

**uint16 dwt_calibratesleepcnt (void);**

The *dwt_calibratesleepcnt()* function calibrates the low-power oscillator. It returns the number of XTAL/2 cycles per one low-power oscillator cycle.

**Parameters:**

none

**Return Parameters:**

| type | description |
|---|---|
| uint16 | This is number of XTAL/2 cycles per one low-power oscillator cycle. |

**Notes:**

**NB: the SPI frequency has to be set to < 3 MHz before a call to this function.**

The DW1000's internal L-C oscillator has an oscillating frequency which is between approximately 7,000 and 13,000 Hz depending on process variations within the IC and on temperature and voltage. To do more precise setting of sleep times its calibration is necessary. See also example code given under the *dwt_configuresleepcnt()* function.

## 5.36 dwt_configuresleep

**void dwt_configuresleep(uint16 mode, uint8 wake);**

The *dwt_configuresleep()* function may be called to configure the activity of DW1000 DEEPSLEEP or SLEEP modes. Note TX and RX configurations are maintained in DEEPSLEEP and SLEEP modes so that upon "waking up" there is no need to reconfigure the devices before initiating a TX or RX, although as the TX data buffer is not maintained the data for transmission will need to be written before initiating transmission.

**Parameters:**

| Type | name | description |
|---|---|---|
| uint16 | mode | A bit mask which configures which configures the SLEEP parameters, see Table 11. |
| uint8 | wake | A bit mask that configures the wakeup event. |

**Return Parameters:**

none

**Notes:**

This function is called to configure the DW1000 sleep and on wake parameters.

**Table 11: Bitmask values for dwt_configuresleep() *mode* bit mask**

| Event | Bit mask | Description |
|---|---|---|
| DWT_PRESRV_SLEEP | 0x0100 | Preserves sleep. When this is set to these sleep controls are not cleared upon wakeup, so that the DW1000 can be returned to sleep without needing to call configuresleep again. |
| DWT_LOADOPSET | 0x0080 | On Wake-up load the receiver operating parameter When the bit is 0 the receiver operating parameter set reverts to its power-on-reset value (the default operating parameter set) when the DW1000 wakes from SLEEP or DEEP-SLEEP. |
| DWT_CONFIG | 0x0040 | Restore saved configurations. |
| DWT_LOADEUI | 0x0008 | On Wake-up load the EUI value from OTP memory into register 0x1. The 64-bit EUI value will be stored in register 0x1 when the DW1000 wakes from DEEPSLEEP or SLEEP states. |
| DWT_GOTORX | 0x0002 | On Wake-up turn on the receiver. With this bit it is possible to make the IC transition into RX automatically as part of IC wake up. |
| DWT_TANDV | 0x0001 | On Wake-up run the (temperature and voltage) ADC. Setting this bit will cause the automatic initiation of temperature and input battery voltage measurements when the DW1000 wakes from DEEPSLEEP or SLEEP states. The sampled temperature value may be accessed using the *dwt_readwakeuptemp()* function and, the sampled battery voltage value may be accessed using the *dwt_readwakeupvbat()* function. |

**Table 12: Bitmask values for dwt_configuresleep() *wake* bit mask**

| Event | Bit mask | Description |
|---|---|---|
| DWT_WAKE_SLPCNT | 0x8 | Wake up after sleep count expires. By default this configuration is set enabling the sleep counter as a wake-up signal. Setting this configuration bit to 0 will mean that the sleep counter cannot awaken the DW1000 form SLEEP. |
| DWT_WAKE_CS | 0x4 | Wakeup on chip select, SPICSn, line. |
| DWT_WAKE_WK | 0x2 | Wake up on WAKEUP line. |
| DWT_SLP_EN | 0x1 | This is the sleep enable configuration bit. This needs to be set to enable DW1000 SLEEP/DEEPSLEEP functionality. |

The DEEPSLEEP state is the lowest power state except for the OFF state. In DEEPSLEEP all internal clocks and LDO are off and the IC consumes approximately 100 nA. To wake the DW1000 from DEEPSLEEP an external pin needs to be activated for the “power-up duration” approximately 300 to 500 µs .This can be either be the SPICSn line pulled low or the WAKEUP line driven high. The duration

quoted here is dependent on the frequency of the low power oscillator (enabled as the DW1000 comes out of DEEPSLEEP) which will vary between individual DW1000 IC and will also vary with changes of battery voltage and different temperatures. To ensure the DW1000 reliably wakes up it is recommended to either apply the wakeup signal until the 500 µs has passed, or to use the SLP2INIT event status bit (in Register file: 0x0F – System Event Status Register) to drive the IRQ interrupt output line high to confirm the wake-up. Once the DW1000 has detected a "wake up" it progresses into the WAKEUP state. While in DEEPSLEEP power should not be applied to GPIO, SPICLK or SPIMISO pins as this will cause an increase in leakage current.

There are three mechanisms to awaken the DW1000:

a) By driving the WAKEUP pin (pin 23) of the DW1000 high for a period > 500 µs (as per DW1000 Data Sheet [1])
b) Driving SPICSn low for a period > 500 µs. This can also be achieved by an SPI read (of register 0, offset 0) of sufficient length
c) If the DW1000 is sleeping using its own internal sleep counter it will be awoken when the timer expires. This is configured by setting the *wake* parameter to 0x8 (+ 0x1 – to enable sleep).

**Example code:**

This example shows how to configure the device to enter DEEPSLEEP mode after some event e.g. frame transmission. The mode parameter into the *dwt_configuresleep()* function has value 0x0940 which is a combination of parameters to load IC configurations, load LDE microcode, and preserve the sleep setting. The wake parameter value, 5, enables the sleeping with SPICSn as the wakeup signal.

```
dwt_configuresleep(0x0940, 0x5); //configure sleep and wake parameters

// then ... later... after some event we can instruct the IC to go into
// DEEPSLEEP mode

dwt_entersleep();                //go to sleep

/// then ... later ... when we want to wake up the device

dwt_spicswakeup(buffer, len);

// buffer is declared locally and needs to be of length (len) which must be
// sufficiently long keep the SPI CSn pin low for at least 500us this
// depends on SPI speed - see also dwt_spicswakeup() function
```

## 5.37 dwt_entersleep

**void dwt_entersleep(void);**

This function is called to put the device into DEEPSLEEP or SLEEP mode.

NOTE: *dwt_configuresleep()* needs to be called before calling this function to configure the sleep and on wake parameters.

(Before entering DEEPSLEEP, the device should be programmed for TX or RX, then upon "waking up" the TX/RX settings will be preserved and the device can immediately perform the desired action TX/RX see *dwt_configuresleep()*).

**Parameters:**

none

**Return Parameters:**

none

**Notes:**

This function is called to enable (put the device into) DEEPSLEEP mode. The *dwt_configuresleep()* should be called first to configure the sleep/wake parameters. (See code example on the *dwt_configuresleep()* function).

## 5.38 dwt_entersleepaftertx

**void dwt_entersleepaftertx (int enable);**

The *dwt_entersleepaftertx()* function configures the "enter sleep after transmission completes" bit. If this is set, the device will automatically go to DEEPSLEEP/SLEEP mode after a TX event.

**Parameters:**

| type | name | description |
|---|---|---|
| int | enable | If set the "enter DEEPSLEEP/SLEEP after TX" bit will be set, else it will be cleared. |

**Return Parameters:**

none

**Notes:**

When this mode of operation is enabled the DW1000 will automatically transition into SLEEP or DEEPSLEEP mode (depending on the sleep mode configuration set in *dwt_configuresleep()*) after transmission of a frame has completed so long as there are no unmasked interrupts pending. See *dwt_setinterrupt()* for details of controlling the masking of interrupts.

To be effective *dwt_entersleepaftertx()* function should be called before *dw_starttx()* function and then upon Tx event completion the device will enter sleep mode.

**Example code:**

This example shows how to configure the device to enter DEEP_SLEEP mode after frame transmission.

```
dwt_configuresleep(0x0940, 0x5);        //configure the on-wake parameters
                                        //(upload the IC config settings)

dwt_entersleepaftertx(1);               //configure the auto go to sleep
                                        //after TX

dwt_setinterrupt(DWT_INT_TFRS, 0);      //disable TX interrupt

// won't be able to enter sleep if any other unmasked events are pending

dwt_writetxdata(frameLength,DataBufferPtr,0);  // write the frame data at
                                               //offset 0

dwt_writetxfctrl(frameLength,0);        // set the frame control register
```

```
dwt_starttx(DWT_START_TX_IMMEDIATE);    // send the frame immediately

// when TX completes the DW1000 will go to sleep....then…..later...when we
// want to wake up the device

dwt_spicswakeup(buffer, len);

// buffer is declared locally and needs to be of length (len) which must be
// sufficiently long keep the SPI CSn pin low for at least 500us this
// depends on SPI speed – see also dwt_spicswakeup() function
```

## 5.39 dwt_spicswakeup

**void dwt_spicswakeup (uint8 *buff, uint16 length);**

The *dwt_spicswakeup()* function uses an SPI read to wake up the DW1000 from SLEEP or DEEPSLEEP.

**Parameters:**

| type | name | description |
|---|---|---|
| uint8* | buff | This is the pointer to a buffer where the data from SPI read will be read into. |
| uint16 | length | This is the length of the input buffer. |

**Return Parameters:**

none

**Notes:**

When the DW1000 is in DEEPSLEEP or SLEEP mode, this function can be used to wake it up, assuming SPICSn has been configured as a wakeup signal in the *dwt_configuresleep()*) call. This is done using an SPI read. The duration of the SPI read, keeping SPICSn low, has to be long enough to provide the low for a period > 500 µs.

See example code below.

**Example code:**

This example shows how to configure the device to enter DEEPSLEEP mode after frame transmission.

```
dwt_configuresleep(0x0940, 0x5); //configure sleep and wake parameters

// then ... later....after some event we can instruct the IC to go into
// DEEPSLEEP mode

dwt_entersleep();                //go to sleep

// then ... later ... when we want to wake up the device

dwt_spicswakeup(buffer, len);

// buffer is declared locally and needs to be of length (len) which must be
// sufficient to keep the SPI CSn pin low for at least 500us This depends
// on SPI speed
```

## 5.40 dwt_setcallbacks

**void dwt_setcallbacks(void (*txcallback)(const dwt_callback_data_t *), void (*rxcallback)(const dwt_callback_data_t *));**

This function is used to configure the TX/RX callback function pointers. These callback functions will be called when TX or RX events happen and the *dwt_isr()* is called to handle them (described below).

**Parameters:**

| type | name | description |
|---|---|---|
| void * | txcallback() | This is the function pointer for the txcallback function. The callback function takes one parameter of dwt_callback_data_t pointer type. |
| void * | rxcallback() | This is the function pointer for the rxcallback function. The callback function takes one parameter of dwt_callback_data_t pointer type. |

```
typedef struct{

       uint32 status;      //initial value of register as ISR is entered
       uint8  event;       //event type
       uint8  aatset;      //auto ACK TX bit is set
       uint16 datalength;  //length of frame
       uint8  fctrl[2];    //frame control bytes
       uint8  dblbuff ;    //set if double buffer is enabled

}dwt_callback_data_t;
```

**Return Parameters:**

none

**Notes:**

This function is used to set up the TX and RX call-back functions.

| Fields | Description of fields within the *dwt_callback_data_t* structure |
|---|---|
| *status* | The *status* parameter holds the initial value of the status (0xF) register which is read on entry into the ISR. |
| *event* | The *event* parameter notifies the application which event triggered the interrupt. The list of events is shown in Table 14 and<br>Table 15 below. |
| *aatset* | The *aatset* parameter notifies the application that the received frame has ACK request bit set. Value of 1 means that the ACK has been requested. |
| *datalength* | The *datalength* parameter specifies the length of the received frame. |
| *fctrl[2]* | The *fctrl* is the two byte array holding the two frame control bytes. |

| Fields | Description of fields within the *dwt_callback_data_t* structure |
|---|---|
| *dblbuff* | The *dblbuff* parameter specifies if double buffering is used. |

For more detailed information on interrupt events, see *dwt_isr()* function description below.

## 5.41 dwt_setinterrupt

**void dwt_setinterrupt( uint32 bitmask, uint8 enable);**

This function sets the events which will generate an interrupt. Here are the main events that can be enabled:

**Parameters:**

| type | name | description |
|---|---|---|
| uint32 | bitmask | This is the bitmask of the events that will generate the DW1000 interrupt, see<br><br>Table 13. |
| uint8 | enable | When the enable parameter is set to 1 the function enables the interrupt mask bits (specified in the bitmask parameter) allowing them to cause interrupts, otherwise the selected interrupt mask bits are cleared disallowing them to cause interrupts.<br><br>To disable particular interrupt or a set of interrupts enable needs to be set to 0. |

**Return Parameters:**

none

**Notes:**

This function is called to enable/set events which are going to generate interrupts.

For the transmitter it is sufficient to enable the SY_STAT_TFRS event which will trigger when a frame has been sent, and for the receiver it is sufficient to enable the good frame reception event and also any error events which will disable the receiver.

**Table 13: Bitmask values for dwt_setinterrupt() interrupt mask enabling/disabling**

| Event | Bit mask | Description |
|---|---|---|
| DWT_INT_TFRS | 0x00000080 | Transmit Frame Sent: This is set when the transmitter has completed the sending of a frame. |
| DWT_INT_RPHE | 0x00001000 | Receiver PHY Header Error: Reception completed, Frame Error |
| DWT_INT_RFCG | 0x00004000 | Receiver FCS Good: The CRC check has matched the transmitted CRC, frame should be good |

| Event | Bit mask | Description |
|---|---|---|
| DWT_INT_RFCE | 0x00008000 | Receiver FCS Error: The CRC check has not matched the transmitted CRC, frame has some error |
| DWT_INT_RFSL | 0x00010000 | Receiver Frame Sync Loss: The RX lost signal before frame was received, indicates excessive Reed Solomon decoder errors |
| DWT_INT_RFTO | 0x00020000 | Receiver Frame Wait Timeout: The RX_FWTO time period expired without a Frame RX. |
| DWT_INT_SFDT | 0x04000000 | SFD Timeout |
| DWT_INT_RXPTO | 0x00200000 | Preamble detection timeout |
| DWT_INT_ARFE | 0x20000000 | ARFE - frame rejection status |

## 5.42 dwt_isr

**void dwt_isr(void);**

This function processes device events, (e.g. frame reception, transmission). It is intended that this function be called as a result of an interrupt from the DW1000 – the mechanism by which this is achieved is target specific. Where interrupts are not supported this function can be called from a simple runtime loop to poll the DW1000 status register and take the appropriate action, but this approach is not as efficient and may result in reduced performance depending on system characteristics.

The *dwt_isr()* function makes use of call-back functions in the application to indicate that received data is available to the upper layers (application) or to indicate when frame transmission has completed.

The *dwt_isr()* function reads the DW1000 status register and recognises the following events:

**Table 14: List of TX events handled by the *dwt_isr()* function and signalled in TX call-back**

| Event | Activity |
|---|---|
| Transmit Frame Sent | It clears the event and signals “Frame Sent” (DWT_SIG_TX_DONE) to the application so that the transmit time stamp can be read and appropriate action taken. |

**Table 15: List of RX events handled by the *dwt_isr()* function and signalled in RX call-back**

| Event | Activity |
|---|---|
| Frame Received | Signals “Frame Received” (DWT_SIG_RX_OKAY). This means that a frame with a good CRC has been received and that the RX data and the frame receive time stamp can be read.<br>If a frame has been received with the ACK request bit set then the “ACK request” is signalled (*aatset* field of *dwt_callback_data_t* structure will be set). |
| Receive wait timeout | Signals “Receive timeout” (DWT_SIG_RX_TIMEOUT). |

| Event | Activity |
|---|---|
| SFD timeout | Signals “SFD timeout” (DWT_SIG_RX_SFDTIMEOUT). |
| RX Preamble Timeout | Signals “RXPTO timeout” (DWT_SIG_RX_PTOTIMEOUT). |
| Receiver PHY Header Error | Signals “PHY Header Error” (DWT_SIG_RX_PHR_ERROR). |
| RX Frame Sync Loss | Signals “Reed Solomon Error” (DWT_SIG_RX_SYNCLOSS). Sync Loss means excessive Reed Solomon decoder errors. |
| CRC Error | Signal RX error/ bad CRC” (DWT_SIG_RX_ERROR). |

When an event is recognised and processed the status register bit is cleared to clear the event interrupt. Figure 4 below shows the *dwt_isr()* function flow diagram.

**Parameters:**

none

**Return Parameters:**

none

**Notes:**

This function should be called from the microprocessor’s interrupt handler that is used to process the DW1000 interrupt.

It is recommended that the user reads DW1000 User Manual [2], especially chapters 3, 4, and 5 and familiarizes themselves with DW1000 events and their operation.

Also if the microprocessor is not fast enough and two events are set in the status register, the order they will be processed in is as shown in Figure 4 below which may not be the order in which they were triggered.

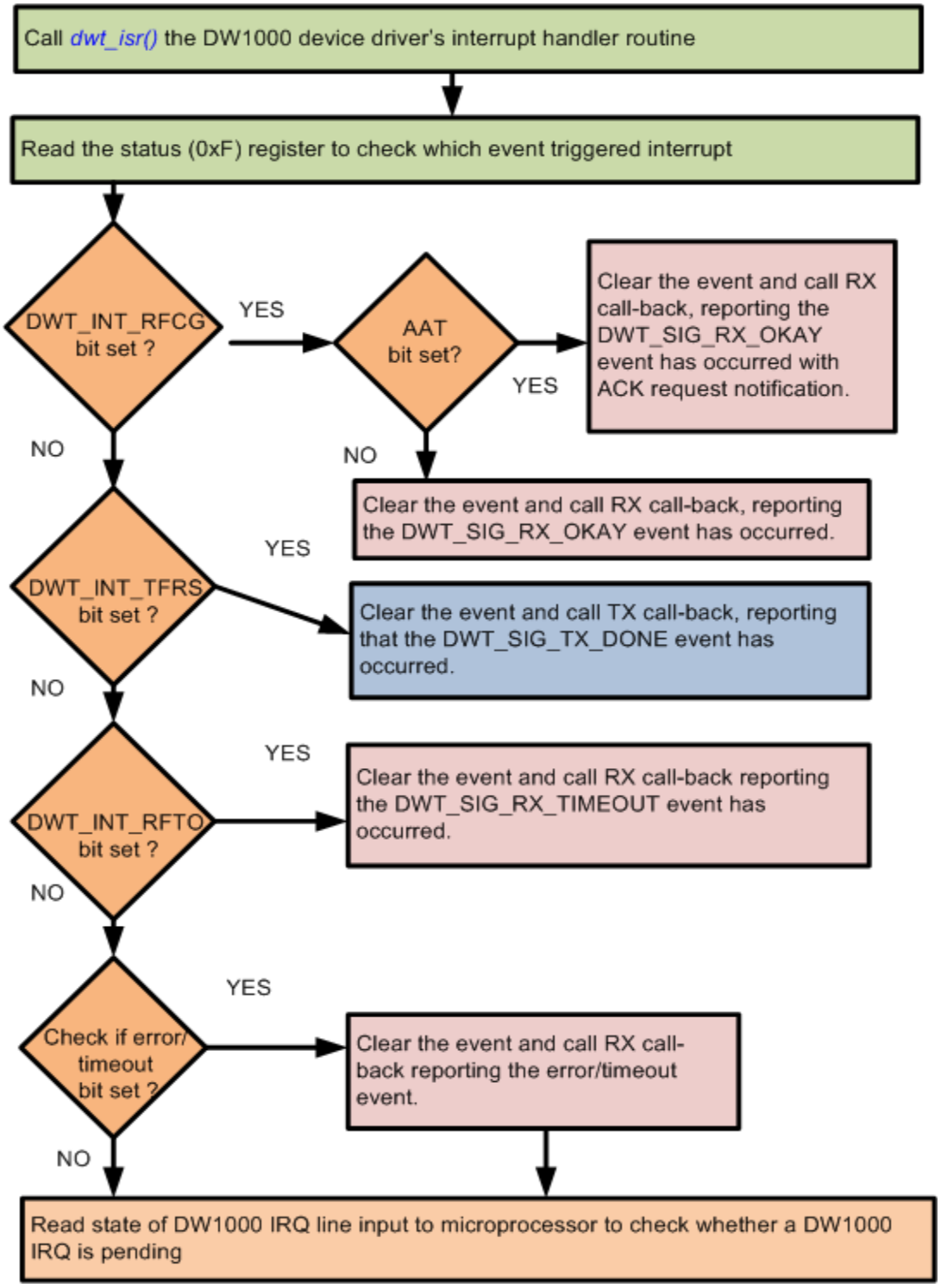


**Figure 4: Interrupt handling**

## 5.43 dwt_setpanid

**void dwt_setpanid(uint16 panID) ;**

This function sets the PAN ID value. These are typically assigned by the PAN coordinator when a node joins a network. This value is only used by the DW1000 for frame filtering. See the dwt_*enableframefilter()* function.

**Parameters:**

| type | name | description |
|---|---|---|
| uint16 | panID | This is the PAN ID. |

**Return Parameters:**

none

**Notes:**

This function can be called to set device's PANID for frame filtering use, it does not need to be set if frame filtering is not being used. Insertion of PAN ID in the TX frames is the responsibility of the upper layers calling the *dwt_writetxdata()* function.

## 5.44 dwt_setaddress16

**void dwt_setaddress16(uint16 shortAddress) ;**

This function sets the 16-bit short address values. These are typically assigned by the PAN coordinator when a node joins a network. This value is only used by the DW1000 for frame filtering. See the dwt_*enableframefilter()* function.

**Parameters:**

| type | name | description |
|---|---|---|
| uint16 | shortAddress | This is the 16-bit address to set. |

**Return Parameters:**

none

**Notes:**

This function is called to set device's short (16-bit) address, it does not need to be set if frame filtering is not being used. Insertion of short (16-bit) address, in the TX frames is the responsibility of the upper layers calling the *dwt_writetxdata()* function.

## 5.45 dwt_seteui

**void dwt_seteui (uint8* eui) ;**

The *dwt_seteui()* function sets the 64-bit address.

**Parameters:**

| type | name | description |
|---|---|---|
| uint8* | eui | This is a pointer to the 64-bit address to set, arranged as 8 unsigned bytes. The low order byte comes first. |

**Return Parameters:**

none

**Notes:**

This function may be called to set a long (64-bit) address into the DW1000 internal register used for address filtering. If address filtering is not being used then this register does not need to be set.

It is possible for a 64-bit address to be programmed into the DW1000's one-time programmable memory (OTP memory) during customers' manufacturing processes and automatically loaded into this register on power-on reset or wake-up from sleep. *dwt_seteui()* may be used subsequently to change the value automatically loaded.

## 5.46 dwt_geteui

**void dwt_geteui (uint8* eui) ;**

The *dwt_geteui()* function gets the programmed 64-bit EUI value from the DW1000.

**Parameters:**

| type | name | description |
|---|---|---|
| uint8* | eui | This is a pointer to the 64-bit address to read, arranged as 8 unsigned bytes. The low order byte comes first. |

**Return Parameters:**

none

**Notes:**

This function may be called to get programmed the DW1000 EUI value. The value will be 0xFFFFFFFF00000000 if it has not been programmed into OTP memory or has not been set by a call to *dwt_seteui()* function.

It is possible for a 64-bit address to be programmed into the DW1000's one-time programmable memory (OTP memory) during customers' manufacturing processes and automatically loaded into this register on power-on reset or wake-up from sleep. *dwt_seteui()* may be used subsequently to change the value automatically loaded.

## 5.47 dwt_enableframefilter

**void dwt_enableframefilter(uint16 mask) ;**

This dwt_enableframefilter*()* function enables frame filtering according to the *mask* parameter.

**Parameters:**

| type | name | description |
|---|---|---|
| uint16 | mask | The bit mask which enables particular frame filter options, see Table 16. |

**Return Parameters:**

none

**Notes:**

This function is used to enable frame filtering, the device address and pan ID should be configured beforehand.

**Table 16: Bitmask values for frame filtering enabling/disabling**

| Definition | Value | Description |
|---|---|---|
| DWT_FF_NOTYPE_EN | 0x000 | no frame types allowed – frame filtering will be disabled |
| DWT_FF_COORD_EN | 0x002 | behave as coordinator (can receive frames with no destination address (PAN ID has to match)) |
| DWT_FF_BEACON_EN | 0x004 | beacon frames allowed |
| DWT_FF_DATA_EN | 0x008 | data frames allowed |
| DWT_FF_ACK_EN | 0x010 | ACK frames allowed |
| DWT_FF_MAC_EN | 0x020 | MAC command frames allowed |
| DWT_FF_RSVD_EN | 0x040 | reserved frame types allowed |

## 5.48 dwt_enableautoack

**void dwt_enableautoack(uint8 responseDelayTime) ;**

This function enables automatic ACK to be sent after a frame with ACK request is received. The ACK frame is sent after a specified responseDelayTime (in preamble symbols, max is 255).

**Parameters:**

| type | name | description |
|---|---|---|
| uint8 | responseDelayTime | The delay between the ACK request reception and ACK transmission. |

**Return Parameters:**

none

**Notes:**

This function is used to enable the automatic ACK response. It is recommended that the *responseDelayTime* is set as low as possible consistent with the ability of the frame transmitter to turn around and be ready to receive the response. If the host system is using the *RESPONSE_EXP* mode (with *rxDelayTime* in *dwt_setrxaftertxdelay*() function set to 0) in the *dwt_starttx()* function then the *responseDelayTime* can be set to 3 symbols (3 µs) without loss of preamble symbols in the receiver awaiting the ACK.

## 5.49 dwt_setrxaftertxdelay

**void dwt_setrxaftertxdelay(uint32 rxDelayTime) ;**

This function sets the delay in turning the receiver on after a frame transmission has completed. The delay, *rxDelayTime*, is in *UWB microseconds* (1 *UWB microsecond* is 512/499.2 microseconds). It is a 20-bit wide field. This should be set before start of frame transmission after which a response is

expected, i.e. before invoking the *dwt_starttx()* function (above) to initiate the transmission (in *RESPONSE_EXP* mode). E.g. transmission of a frame with an ACK request bit set.

**Parameters:**

| type | name | description |
|---|---|---|
| uint32 | rxDelayTime | The turnaround time, in UWB microseconds, between the TX completion and the RX enable. |

**Return Parameters:**

none

**Notes:**

This function is used to set the delay time before automatic receiver enable after a frame transmission. The smallest value that can be set is 0. If 0 is set the DW1000 will turn the RX on as soon as possible, which approximately takes 6.2 µs. So if setting a value smaller than 7 µs it will still take 6.2 µs to switch to receive mode.

## 5.50 dwt_readrxdata

**void dwt_readrxdata(uint8 *buffer, uint16 len, uint16 bufferOffset);**

This function reads a number, *len*, bytes of rx buffer data, from a given offset, *bufferOffset*, into the given buffer, *buffer*.

**Parameters:**

| type | name | description |
|---|---|---|
| uint8* | buffer | The pointer to the buffer into which the data will be read. |
| uint16 | len | The length of data to be read (in bytes). |
| uint16 | bufferOffset | The offset at which to start to read the data. |

**Return Parameters:**

none

**Notes:**

This function should be called on the reception of a good frame to read the received frame data. The offset might be used to skip parts of the frame that the application is not interested in, or has read previously.

## 5.51 dwt_readaccdata

**void dwt_readaccdata(uint8 *buffer, uint16 len, uint16 bufferOffset);**

This API function reads data from the DW1000 accumulator memory. This data represents the impulse response of the RF channel. Reading this data is not required in normal operation but it may be useful for diagnostic purposes. The accumulator contains complex values, a 16-bit real integer and a 16-bit

imaginary integer, for each tap of the accumulator, each of which represents a 1ns sample interval (or more precisely half a period of the 499.2 MHz fundamental frequency). The span of the accumulator is one symbol time. This is 992 samples for the nominal 16 MHz mean PRF, or, 1016 samples for the nominal 64 MHz mean PRF. The *dwt_readaccdata()* function reads, *len*, bytes of accumulator buffer data, from a given offset, *bufferOffset*, into the given destination buffer, *buffer*. The output data starts from *buffer[1]*. The first byte, *buffer[0]*, is dummy byte.

**Parameters:**

| type | name | description |
|---|---|---|
| uint8* | buffer | The pointer to the destination buffer into which the read accumulator data will be written. |
| uint16 | len | The length of data to be read (in bytes). Since each complex value occupies four octets, the value used here should naturally be a multiple of four. Maximum lengths are 3968 bytes (@ 16 MHz PRF) and 4064 bytes (@ 16 MHz PRF). |
| uint16 | bufferOffset | The offset at which to start to read the data. Offset 0 should be used when reading the full accumulator. Since each complex value is 4 octets, the offset should naturally be a multiple of 4. |

**Return Parameters:**

none

**Notes:**

*dwt_readaccdata()* may be called after frame reception to read the accumulator data for diagnostic purposes. The accumulator is not double buffered so this access must be done before the receiver is re-enabled since the accumulator data is overwritten during the reception of the next frame. The data returned in the buffer has the following format (for *bufferOffset* input of zero):

| buffer index | Description of elements within buffer |
|---|---|
| 0 | Dummy Octet |
| 1 | Low 8 bits of real part of accumulator sample index 0 |
| 2 | High 8 bits of real part of accumulator sample index 0 |
| 3 | Low 8 bits of imaginary part of accumulator sample index 0 |
| 4 | High 8 bits of imaginary part of accumulator sample index 0 |
| 5 | Low 8 bits of real part of accumulator sample index 1 |
| 6 | High 8 bits of real part of accumulator sample index 1 |
| 7 | Low 8 bits of imaginary part of accumulator sample index 1 |
| 8 | High 8 bits of imaginary part of accumulator sample index 1 |
| : | : |

In examining the CIR it is normal to compute the magnitude of the complex values.

## 5.52 dwt_readdiagnostics

**void dwt_readdiagnostics(dwt_diag_t * diagnostics);**

This function reads receiver frame quality diagnostic values.

**Parameters:**

| type | name | description |
|---|---|---|
| dwt_rxdiag_t* | diagnostics | Pointer to the diagnostics structure which will contain the read data. |

```
typedef struct
{
        uint16 maxNoise ;           // LDE max value of noise
        uint16 firstPathAmp1 ;      // Amplitude at floor(index FP) + 1
        uint16 stdNoise ;           // Standard deviation of noise
        uint16 firstPathAmp2 ;      // Amplitude at floor(index FP) + 2
        uint16 firstPathAmp3 ;      // Amplitude at floor(index FP) + 3
        uint16 maxGrowthCIR ;       // Channel Impulse Response max growth CIR
        uint16 rxPreamCount;        // count of preamble symbols accumulated
        uint16 firstPath ;          // First path index

}dwt_rxdiag_t ;
```

**Return Parameters:**

none

**Notes:**

This function is used to read the received frame diagnostic data. They can be read after a frame is received (e.g. after DWT_SIG_RX_OKAY event reported in the RX call-back function called from *dwt_isr()*).

| Fields | Description of fields within the ***dwt_rxdiag_t*** structure |
|---|---|
| *maxNoise* | The *maxNoise* parameter. |
| *firstPathAmp1* | First path amplitude is a 16-bit value reporting the magnitude of the leading edge signal seen in the accumulator data memory during the LDE algorithm's analysis. The amplitude of the sample reported in this *firstPathAmp* parameter is the value of the accumulator tap at index given by floor(*firstPath)* reported below. This amplitude value can be used in assessing the quality of the received signal and/or the receive timestamp produced by the LDE. |
| *firstPathAmp2* | Is a 16-bit value reporting the magnitude of signal at index floor (*firstPath)* +2. |
| *firstPathAmp3* | Is a 16-bit value reporting the magnitude of signal at index floor (*firstPath)* + 3. |
| *stdNoise* | The *stdNoise* parameter is a 16-bit value reporting the standard deviation of the noise level seen during the LDE algorithm's analysis of the accumulator data. This value can be used in assessing the quality of the received signal and/or the receive timestamp produced by the LDE. |

| Fields | Description of fields within the *dwt_rxdiag_t* structure |
|---|---|
| *maxGrowthCIR* | Channel impulse response max growth is a 16-bit value reporting a growth factor for the accumulator which is related to the receive signal power. This value can be used in assessing the quality of the received signal and/or the receive timestamp produced by the LDE. |
| *rxPreamCount* | This reports the number of symbols of preamble accumulated. This may be used to estimate the length of TX preamble received and also during diagnostics as an aid to interpreting the accumulator data. It is possible for this count to be a little larger than the transmitted preamble length, because of very early detection of preamble and because the accumulation count may include accumulation that continues through the SFD (until the SFD is detected). |
| *firstPath* | First path index is a 16-bit value reporting the position within the accumulator that the LDE algorithm has determined to be the first path. This value is set during the LDE algorithm's analysis of the accumulator data. This value may be of use during diagnostic graphing of the accumulator data, and may also be of use in assessing the quality of the received message and/or the receive timestamp produced by the LDE.<br><br>The first path (or leading edge) is a sub-nanosecond quantity. Each tap in the accumulator corresponds to a sample time, which is roughly 1 nanosecond (or 30 cm in terms of the radio signal's flight time through air). To report the position of the leading edge more accurately than this 1-nanosecond step size, the index value consist of a whole part and a fraction part. The 16-bits of *firstPath* are arranged in a fixed point "10.6" style value where the low 6 bits are the fractional part and the high 10 bits are the integer part. Essentially this means if the *firstPath* is read as a whole number, then it has to be divided by 64 to get the fractional representation. |

## 5.53 dwt_configeventcounters

**void dwt_configeventcounters (int enable) ;**

This function enables event counters (TX, RX, error counters) in the DW1000.

**Parameters:**

| type | name | description |
|---|---|---|
| int | enable | Set to 1 to clear and enable the DW1000's internal digital counters. Set to 0 to disable. |

**Return Parameters:**

none

**Notes:**

This function is used to enable internal counters, these count the number of frames transmitted, received, and also number of errors received/detected.

## 5.54 dwt_readeventcounters

**void dwt_readeventcounters (dwt_deviceentcnts_t *counters) ;**

This function reads the event counters (TX, RX, error counters) in the DW1000.

**Parameters:**

| type | name | description |
|---|---|---|
| dwt_deviceentcnts_t * | counters | Pointer to the device event counters structure. |

```
typedef struct
{
	uint16 PHE ;		//number of received header errors
	uint16 RSL ;		//number of received frame sync loss events
	uint16 CRCG ;		//number of good CRC received frames
	uint16 CRCB ;		//number of bad CRC (CRC error) received frames
	uint16 ARFE ;		//number of address filter errors
	uint16 OVER ;		//number of receiver overflows (used in double buffer
mode)
	uint16 SFDTO ;		//SFD timeouts
	uint16 PTO ;		//Preamble timeouts
	uint16 RTO ;		//RX frame wait timeouts
	uint16 TXF ;		//number of transmitted frames
	uint16 HPW ;		//half period warnings
	uint16 TXW ;		//power up warnings

} dwt_deviceentcnts_t ;
```

**Return Parameters:**

none

**Notes:**

**This function is used to read the internal counters. These count the number of frames transmitted, received, and also number of errors received/detected.**

| Fields | Description of fields within the *dwt_deviceentcnts_t* structure |
|---|---|
| *PHE* | PHR error counter is a 12-bit counter of PHY header errors. |
| *RSL* | RSE error counter is a 12-bit counter of the non-correctable error events that can occur during Reed Solomon decoding. |

| Fields | Description of fields within the *dwt_deviceentcnts_t* structure |
|---|---|
| *CRCG* | Frame check sequence good counter is a 12-bit counter of the frames received with good CRC/FCS sequence. |
| *CRCB* | Frame check sequence error counter is a 12-bit counter of the frames received with bad CRC/FCS sequence. |
| *ARFE* | Frame filter rejection counter is a 12-bit counter of the frames rejected by the receive frame filtering function. |
| *OVER* | RX overrun error counter is a 12-bit counter of receive overrun events. This is essentially a count of the reporting of overrun events, i.e. when using double buffer mode, and the receiver has already received two frames, and the host has not processed the first one. The receiver will flag an overrun when it starts receiving a third frame. |
| *SFDT* | SFD timeout errors counter is a 12-bit counter of SFD timeout error events. |
| *PTO* | Preamble detection timeout event counter is a 12-bit counter of preamble detection timeout events. |
| *RTO* | RX frame wait timeout event counter is a 12-bit counter of receive frame wait timeout events. |
| *TXF* | TX frame sent counter is a 12-bit counter of transmit frames sent events. This is incremented every time a frame is sent. |
| *HPW* | Half period warning counter is a 12-bit counter of “Half Period Warning” events. These relate to late invocation of delayed transmission or reception functionality. |
| *TXW* | TX power-up warning counter is a 12-bit counter of “Transmitter Power-Up Warning” events. These relate to a delayed sent time that is too short to allow proper power up of TX blocks before the delayed transmission. |

## 5.55 dwt_readtempvbat

**uint16 dwt_readtempvbat(uint8 fastSPI);**

This function reads the temperature and battery voltage.

**Parameters:**

| type | name | description |
|---|---|---|
| uint8 | fastSPI | Should be set to 1 if this function is called when SPI rate used is > 3 MHz. If this is set to 0, then the SPI rate has to be < 3 MHz and the DW1000 has to be in IDLE. |

**Return Parameters:**

| type | description |
|---|---|
| uint16 | The low 8-bits are voltage value, and the high 8-bits are temperature value. |

**Notes:**

This function can be called to read the battery voltage and temperature of DW1000. It enables the DW1000 internal convertors to sample the current IC temperature and battery.

**To correctly read temperature and voltage values the DW1000 should be configured to use xtal clock and a SPI rate of < 3 MHz needs to be used. However if the application wants to read this e.g. while receiver is turned on or using fast SPI rate then the function will use a delay of 1 ms to stabilise the values being read.**

## 5.56 dwt_readwakeuptemp

**uint8 dwt_readwakeuptemp(void);**

This function reads the IC temperature sensor value that was sampled during IC wake-up.

**Parameters:**

none

**Return Parameters:**

| type | description |
|---|---|
| uint8 | The 8-bits are temperature value sampled at wakeup event. |

**Notes:**

This function may be used to read the temperature sensor value that was sampled by DW1000 on wake up, assuming the DWT_TANDV bit in the mode parameter was set in a call to *dwt_configuresleep()* before entering sleep mode. If the wakeup sampling of the temperature sensor was not enabled then the value returned by *dwt_readwakeuptemp()* will not be valid.

## 5.57 dwt_readwakeupvbat

**uint8 dwt_ readwakeupvbat (void);**

This function reads the battery voltage sensor value that was sampled during IC wake-up.

**Parameters:**

none

**Return Parameters:**

| type | description |
|---|---|
| uint8 | The 8-bits are voltage value sampled at wake up event. |

**Notes:**

This function may be used to read the battery voltage sensor value that was sampled by DW1000 on wake up, assuming the DWT_TANDV bit in the mode parameter was set in the call to *dwt_configuresleep()* before entering sleep mode. If the wakeup sampling of the battery voltage sensor was not enabled then the value returned by *dwt_readwakeupvbat()* will not be valid.

## 5.58 dwt_otpread

**void dwt_otpread(uint32 address, uint32 *array, uint8 length);**

This function is used to read a number (given by length) of 32-bit values from the DW1000 OTP memory, starting at given address. The given array will contain the read values.

**Parameters:**

| type | name | description |
|---|---|---|
| uint32 | address | This is starting address in the OTP memory from which to read |
| uint16* | array | This is the 32-bit array that will hold the read values. It should be of at least *length* 32-bit words long. |
| uint8 | length | The number of values to read |

**Return Parameters:**

none

**Notes:**

## 5.59 dwt_otpwriteandverify

**int dwt_otpwriteandverify(uint32 value, uint16 address);**

This function is used to program 32-bit value into the DW1000 OTP memory.

**Parameters:**

| type | name | description |
|---|---|---|
| uint32 | value | this is the 32-bit value to be programmed into OTP memory |
| uint16 | address | this is the 16-bit OTP memory address into which the 32-bit value is programmed |

**Return Parameters:**

| type | description |
|---|---|
| int | Return values can be either DWT_DECA_SUCCESS = 0 or DWT_DECA_ERROR = -1. |

**Notes:**

The DW1000 has a small amount of one-time-programmable (OTP) memory intended for device specific configuration or calibration data. Some areas of the OTP memory are used to save device calibration values determined during DW1000 testing, while other OTP memory locations are intended to be set by the customer during module manufacture and test.

**Programming OTP memory is a one-time only activity, any values programmed in error cannot be corrected. Also, please take care when programming OTP memory to only write to the designated areas – programming elsewhere may permanently damage the DW1000's ability to function normally.**

The OTP memory locations are as defined in Table 17. The OTP memory locations are each 32-bits wide, OTP addresses are word addresses so each increment of address specifies a different 32-bit word.

**Table 17: OTP memory map**

| OTP Address | Size (Used Bytes) | Byte [3] | Byte [2] | Byte [1] | Byte [0] | Programmed By |
|---|---|---|---|---|---|---|
| 0x000 | 4 | 64 bit EUID (These 64 bits get automatically copied over to *Register File 0x01:EUI* on each reset.) | | | | Customer |
| 0x001 | 4 | | | | | |
| 0x002 | 0 | - | - | - | - | Reserved |
| 0x003 | 0 | - | - | - | - | |
| 0x004 | 4 | 40 bit LDOTUNE_CAL (These 40 bits can be automatically copied over to *Sub Register File 0x28:30 LDOTUNE* on wakeup) | | | | Decawave Test |
| 0x005 | 1 | | | | | |
| 0x006 | 4 | {"0001,0000,0001", "CHIP ID (20 bits)"} | | | | Decawave Test |
| 0x007 | 4 | {"0001"", "LOT ID (28bits)"} | | | | DecaWaveTest |
| 0x008 | 2 | - | - | $V_{meas}$ @ 3.7 V | $V_{meas}$ @ 3.3 V | DecaWaveTest |
| 0x009 | 1 | - | - | $T_{meas}$ @ Ant Cal | $T_{meas}$ @ 23 °C | Customer/Deca-WaveTest |
| 0x00A | 0 | - | | | | Reserved |
| 0x00B | 4 | - | | | | Reserved |
| 0x00C | 2 | - | | | | Reserved |

| OTP Address | Size (Used Bytes) | Byte [3] | Byte [2] | Byte [1] | Byte [0] | Programmed By |
|---|---|---|---|---|---|---|
| 0x00D | 4 | - | | | | Reserved |
| 0x00E | 4 | - | | | | Reserved |
| 0x00F | 4 | - | | | | Reserved |
| 0x010 | 4 | CH1 TX Power Level PRF 16 | | | | Customer |
| 0x011 | 4 | CH1 TX Power Level PRF 64 | | | | Customer |
| 0x012 | 4 | CH2 TX Power Level PRF 16 | | | | Customer |
| 0x013 | 4 | CH2 TX Power Level PRF 64 | | | | Customer |
| 0x014 | 4 | CH3 TX Power Level PRF 16 | | | | Customer |
| 0x015 | 4 | CH3 TX Power Level PRF 64 | | | | Customer |
| 0x016 | 4 | CH4 TX Power Level PRF 16 | | | | Customer |
| 0x017 | 4 | CH4 TX Power Level PRF 64 | | | | Customer |
| 0x018 | 4 | CH5 TX Power Level PRF 16 | | | | Customer |
| 0x019 | 4 | CH5 TX Power Level PRF 64 | | | | Customer |
| 0x01A | 4 | CH7 TX Power Level PRF 16 | | | | Customer |
| 0x01B | 4 | CH7 TX Power Level PRF 64 | | | | Customer |
| 0x01C | 4 | TX/RX Antenna Delay - PRF 64 | | TX/RX Antenna Delay - PRF 16 | | Customer |
| 0x01D | 0 | - | - | - | - | Customer |
| 0x01E | 1 | - | - | OTP Revision | XTAL_Trim[4:0] | Customer |
| 0x01F | 0 | - | - | - | - | Customer |
| : | : | : | : | : | : | Reserved |
| 0x400 | 4 | SR Register (see below) | | | | Customer |

The SR ("Special Register") is a 32-bit segment of OTP that is directly readable via the register interface upon power up. To program the SR register follow the normal OTP programming method but set the OTP address to 0x400. The value of the SR register can be directly read back at address.

**For more information on OTP memory programming please consult the DW1000 User Manual** [2] **and Data Sheet [1].**

## 5.60 dwt_getrangebias

**double dwt_getrangebias(uint8 chan, float range, uint8 prf);**

This function is used to return the range bias correction that may be applied to a two-way ranging result.

**Parameters:**

| type | name | description |
|---|---|---|
| uint8 | chan | Specifies the operating channel (e.g. 1, 2, 3, 4, 5, 6 or 7) |
| float | range | The calculated distance before correction. |
| uint8 | prf | This is the PRF e.g. DWT_PRF_16M or DWT_PRF_64M. |

**Return Parameters:**

| type | description |
|---|---|
| double | Returns range correction needed in meters. |

**Notes:**

A small but potentially significant error in range measurement is observed when units are in close proximity. This gives a bias due to unequal growth of low and high powered signals in the accumulator. Depending on the application the bias correction given by this *dwt_getrangebias()* function may be used to return a more accurate ranging result estimate.

For more information on range bias please consult with Decawave.

## 5.61 dwt_setleds

**void dwt_setleds(uint8 value);**

This is used to set up Tx/Rx GPIOs which are then used to control (for example) LEDs. This is not completely IC dependent and requires that LEDs are connected to the DW1000 GPIO lines.

**Parameters:**

| type | name | description |
|---|---|---|
| uint8 | value | If value is set to 1 the LEDs will be enabled, if it is 0 the LED control is disabled. If value is 2 the LEDs will flash once after enable. |

**Return Parameters:**

none

**Notes:**

For more information on GPIO control and configuration please consult the DW1000 User Manual [2] and Data Sheet [1].

## 5.62 dwt_setGPIOforEXTTRX

**void dwt_setGPIOforEXTTRX (void);**

This is used to enable GPIO for external LNA or PA functionality - HW dependent, consult the DW1000 User Manual [2].

**Parameters:**

none

**Return Parameters:**

none

**Notes:**

For more information on GPIO control and configuration please consult the DW1000 User Manual [2] and Data Sheet [1].

## 5.63 dwt_setGPIOdirection

**void dwt_setGPIOdirection(uint32 gpioNum, uint32 direction);**

This is used to configure the direction of DW1000 GPIOs. The GPIOs can be used as either inputs (1) or outputs (0). Reader should study this functionality in the DW1000 User Manual [2].

**Parameters:**

| type | name | description |
|---|---|---|
| uint32 | gpioNum | This selects the GPIOs ports to configure. It is a bitmask, which allows for many ports to be configured simultaneously. The mask values (GxM0... GxM8) are defined in deca_regs.h |
| uint32 | direction | This sets the GPIOs direction. A value of zero is used to set the direction to output, and the appropriate direction mask value is used to set the port as input. This allows multiple ports to be configured simultaneously.<br>Any ports not selected by the gpioNum (mask) parameter are unchanged. |

**Return Parameters:**

none

**Notes:**

For more information on GPIO control and configuration please consult the DW1000 User Manual [2] and Data Sheet [1].

## 5.64 dwt_setGPIOvalue

**void dwt_setGPIOvalue(uint32 gpioNum, uint32 value);**

This is used to set GPIO output lines high (1) or low (0).

**Parameters:**

| type | name | description |
|---|---|---|
| uint32 | gpioNum | This selects the GPIOs ports to output on. It is a bitmask, which allows for many ports to be changed simultaneously. The mask values (GxM0... GxM8) are defined in deca_regs.h. |
| uint32 | value | This sets the GPIOs value. A value of zero outputs a low voltage, and the appropriate output mask value is used to set the port |

| | | |
|---|---|---|
| | | high. This allows multiple ports to be controlled simultaneously.<br>Any ports not selected by the gpioNum (mask) parameter or not configured as outputs by *dwt_setGPIOdirection* are unchanged. |

**Return Parameters:**

none

**Notes:**

For more information on GPIO control and configuration please consult the DW1000 User Manual [2] and Data Sheet [1].

## 5.65 dwt_xtaltrim

**void dwt_xtaltrim(uint8 value);**

This function writes the crystal trim value parameter into the DW1000 crystal trimming register.

**Parameters:**

| type | name | description |
|---|---|---|
| uint8 | value | Crystal trim value (in range 0x0 to 0x1F, 31 steps (~1.5ppm per step). |

**Return Parameters:**

none

**Notes:**

This function can be called any time to set the crystal trim register value. This is used to fine tune and adjust the XTAL frequency. Better long range performance may be achieved when crystals are more closely matched. Crystal trimming may allow this without using expensive TCXO devices. Please consult the DW1000 User Manual [2], Data Sheet [1] and application notes available on www.decawave.com.

## 5.66 dwt_configcwmode

**void dwt_configcwmode(uint8 chan);**

This function configures the device to transmit a Continuous Wave (CW) at a specified channel frequency. This may be of use as part of crystal trimming procedure. Please consult with Decawave's applications support team for details of crystal trimming procedures and considerations.

**Parameters:**

| type | name | description |
|---|---|---|

| | | |
|---|---|---|
| uint8 | chan | This sets the UWB channel number, (defining the centre frequency and bandwidth). The supported channels are 1, 2, 3, 4, 5, and 7. |

**Return Parameters:**

none

**Notes:**

Example code below of how to use this function in conjunction with *xtaltrim()* function (please also see Example 4a: continuous wave mode in section 6.3.7) :

**Example code:**

```
// The table below specifies the default TX spectrum configuration
// parameters... this has been tuned for DW EVK hardware units

const tx_struct tx_spectrumconfig[NUM_CH] =
{
    // Channel 1
    {
              0xc9,               //PG_DELAY
             {
                     0x75757575,  //16M prf power
                     0x67676767   //64M prf power
             }

    },
    // Channel 2
    {
// Add other channels here
    },
    // Channel 7
    {
             0x93,               //PG_DELAY
             {
                     0x92929292,  //16M prf power
                     0xd1d1d1d1   //64M prf power
             }
    }
};


void xtalcalibration(void)
{
       int i;
       uint8 chan = 2 ;
       uint8 prf = DWT_PRF_16M ;
       dwt_txconfig_t  configTx ;

       // MUST SET SPI <= 3 MHz for this calibration activity.

       setspibitrate(SPI_3MHz);   // target platform function to set SPI rate
                                  // to 3 MHz

       //
       //     reset device
       //
       dwt_softreset();

       //
       //     configure TX channel parameters
       //
```

```
        configTx.PGdly = tx_spectrumconfig[chan-1].PG_DELAY ;

        configTx.power = tx_spectrumconfig[chan-1].tx_pwr[prf - DWT_PRF_16M];

        dwt_configuretxrf(&configTx);

        dwt_configcwmode(chan);

        for(i=0; i<=0x1F; i++)
        {
               dwt_xtaltrim(i);
               // measure the frequency
               // Spectrum Analyser set:
               // FREQ to be channel default e.g. 3.9936 GHz for channel 2
               // SPAN to 10MHz
               // PEAK SEARCH
        } // end for

        // when the crystal trim has completed, the device should be reset
        // with a call to dwt_softreset()after which it can be programmed
        // using the API functions for desired operation


        return;
} // end xtalcalibration()
```

## 5.67 dwt_configcontinuousframemode

**void dwt_configcontinuousframemode(uint32 framerepetitionrate);**

This function configures the DW1000 in continuous frame mode. This facilitates measurement of the power in the transmitted spectrum.

**Parameters:**

| type | name | description |
|---|---|---|
| uint32 | framerepetitionrate | This is a 32-bit value that is used to set the interval between transmissions. The minimum value is 4. The units are approximately 8 ns. (or more precisely 512/(499.2e6*128) seconds)). |

**Return Parameters:**

none

**Notes:**

This function is used to configure continuous frame (transmit power spectrum test) mode, used in TX power spectrum measurements. This test mode is provided to help support regulatory approvals spectral testing. Please consult with Decawave's applications support team for details of regulatory approvals considerations. The *dwt_configcontinuousframemode()* function enables a repeating transmission of the data from the transmit buffer. To use this test mode, the operating channel, preamble code, data length, offset, etc. should all be set-up as if for a normal transmission.

The *framerepititionrate* parameter value is programmed in units of one quarter of the 499.2 MHz fundamental frequency, (~ 8 ns). To send one frame per millisecond, a value of 124800 or 0x0001E780 should be set. A value <4 will not work properly, and a time value less than the frame length will cause the frames to be sent back-to-back without any pause.

We expect there to be two use cases for the *dwt_configcontinuousframemode()* function:

(a) Testing to figure out the TX power/pulse width to meet the regulations.

(b) In the approvals house to enable the spectral test.

To end the test and return to normal operation the device can be rest with *dwt_softreset()* function.

Example code below of how to use this function (please also see Example 4b: continuous frame mode in section 6.3.8):

**Example code :**

```
// The table below specifies the default TX spectrum configuration
// parameters... this has been tuned for DW EVK hardware units

const tx_struct tx_s [NUM_CH] =
{
    {// Channel 1
              0xc9,               //PG_DELAY
             {
                     0x75757575,  //16M prf power
                     0x67676767   //64M prf power
             }

    },
    {// Channel 2
… Add other channels should be added here
    },
    {// Channel 7
             0x93,               //PG_DELAY
             {
                     0x92929292,  //16M prf power
                     0xd1d1d1d1   //64M prf power
             }
    }
};
int powertest(void)
{
       dwt_config_t    config ;
       dwt_txconfig_t  configTx ;

        uint8 msg[127]= "The quick brown fox jumps over the lazy dog."
                        "The quick brown fox jumps over the lazy dog."
                        "The quick brown fox jumps over the l";

        // MUST SET SPI <= 3 MHz for this calibration activity.

        setspibitrate(SPI_3MHz);  // target platform function to set SPI rate
                                  // to 3 MHz
        //     reset device

        dwt_softreset();

        //     configure channel parameters

        config.chan = 2;
        config.rxCode = 9;
        config.txCode = 9;
        config.prf = DWT_PRF_64M;
        config.dataRate = DWT_BR_110K;
        config.txPreambLength = DWT_PLEN_2048;
        config.rxPAC = DWT_PAC64;
        config.nsSFD = 1;

        dwt_configure(&config) ;

        configTx.PGdly = tx_s[config.chan-1].PG_DELAY ;
```

```
        configTx.power = tx_s[config.chan-1].tx_pwr[config.prf - DWT_PRF_16M];

        dwt_configuretxrf(&configTx);

        // the value here 0x1000 gives a period of 32.82 µs

        dwt_configcontinuousframemode(0x1000);

        dwt_writetxdata(127, (uint8 *)  msg, 0) ;
        dwt_writetxfctrl(127, 0);

        //to start the first frame - set TXSTRT

        dwt_starttx(DWT_START_TX_IMMEDIATE);

        //measure the channel power
        //Spectrum Analyser set:
        //FREQ to be channel default e.g. 3.9936 GHz for channel 2
        //SPAN to 1GHz
        //SWEEP TIME 1s
        //RBW and VBW 1MHz

        // After the power is measured, the values in configTx can be changed
        // to tune the spectrum. To stop the continuous frame mode, a call to
        // dwt_softreset()is needed, after which the device can be programmed
        // using the API functions for desired operation

        return DWT_SUCCESS ;
}
```

## 5.68 dwt_checkoverrun

**int dwt_checkoverrun(void);**

This is function returns the status of the RXOVRR bit in the status register.

**Parameters:**

none

**Return Parameters:**

| type | description |
|---|---|
| int | If the RXOVERR bit is set then the value returned is 1, else it is 0. |

**Notes:**

For more information on RXOVERR bit see the DW1000 User Manual [2].

## 5.69 SPI driver functions

These functions are platform specific SPI read and write functions, external to the DW1000 driver code, used by the device driver to send and receive data over the SPI interface to and from the DW1000. The DW1000 device driver abstracts the target SPI device by calling it through generic functions *writetospi()* and *readfromspi()*. In porting the DW1000 device driver, to different target hardware, the body of these SPI functions should be written, re-written, or provided in the target

specific code to drive the target microcontroller device's physical SPI hardware. The initialisation of the target host controller's physical SPI interface mode and its data rate is considered to be part of the target system and is done in the host code outside of the DW1000 device driver functions.

### 5.69.1 writetospi

**int writetospi (uint16 hLen, const uint8 *hbuff, uint32 bLen, const uint8 *buffer) ;**

This function is called by the DW1000 device driver code (from the *dwt_writetodevice()* function) when it wants to write to the DW1000's SPI interface (registers) over the SPI bus.

**Parameters:**

| type | name | description |
|---|---|---|
| uint16 | hLen | This is gives the length of the header buffer (*hbuff*) |
| uint8* | hbuff | This is a pointer to the header buffer byte array. The LSB is the first element. |
| uint32 | bLen | This is gives the length of the data buffer (*buffer*), to write. |
| uint8* | buffer | This is a pointer to the data buffer byte array. The LSB is the first element. This holds the data to write. |

**Return Parameters:**

| Type | description |
|---|---|
| int | Return values can be either DWT_DECA_SUCCESS = 0 or DWT_DECA_ERROR = -1. |

**Notes:**

The return values can be used to notify the upper application layer that there was a problem with SPI write. In DW1000 API *dwt_writetodevice()* function the return value from this function is returned. However it should be noted that the DW1000 device driver itself does not take any notice of success/error return value but instead assumes that SPI accesses succeed without error.

### 5.69.2 readfromspi

**int readfromspi (uint16 hLen, const uint8 *hbuff, uint32 bLen, uint8 *buffer) ;**

This function is called by the DW1000 device driver code (from the dwt_readfromdevice() function) when it wants to read from the DW1000's SPI interface (registers) over the SPI bus.

**Parameters:**

| type | name | description |
|---|---|---|

| | | |
|---|---|---|
| uint16 | hLen | This is gives the length of the header buffer (*hbuff*) |
| uint8* | hbuff | This is a pointer to the header buffer byte array. The LSB is the first element. |
| uint32 | bLen | This is gives the number of bytes to read. |
| uint8* | buffer | This is a pointer to the data buffer byte array. The LSB is the first element. This holds the data being read. |

**Return Parameters:**

| Type | description |
|---|---|
| int | Return values can be either DWT_DECA_SUCCESS = 0 or DWT_DECA_ERROR = -1. |

**Notes:**

The return values can be used to notify the upper application layer that there was a problem with SPI read. In DW1000 API dwt_readfromdevice*()* function the return value from this function is returned. However it should be noted that the DW1000 device driver itself does not take any notice of success/error return value but instead assumes that SPI accesses succeed without error.

## *5.70 Mutual-exclusion API functions*

The purpose of these functions is to provide for microprocessor interrupt enable/disable, which is used for ensuring mutual exclusion from critical sections in the DW1000 device driver code where interrupts and background processing may interact. The only use made of this is to ensure SPI accesses are non-interruptible.

The mutual exclusion API functions are *decamutexon()* and *decamutexoff().* These are external to the DW1000 driver code but used by the device driver when it wants to ensure mutual exclusion from critical sections. This usage is kept to a minimum and the disable period is also kept to a minimum (but is dependent on the SPI data rate). A blanket interrupt disable may be the easiest way to provide this mutual exclusion functionality in the target system, but at a minimum those interrupts coming from the DW1000 device should be disabled/re-enabled by this activity.

In implementing the *decamutexon()* and *decamutexoff()* functions in a particular microprocessor system, the implementer may choose to use #defines to map these calls transparently to the target system. Alternatively the appropriate code may be embedded in the functions provided in the deca_mutex.c source file.

### 5.70.1 decamutexon

**decaIrqStatus_t decamutexon (void) ;**

This function is used to turn on mutual exclusion (e.g. by disabling interrupts). **This is called at the start of the critical section of SPI access.** The *decamutexon()* function should operate to read the current system interrupt status in the target microcontroller system's interrupt handling logic with

respect to the handling of the DW1000's interrupt. Let's call this "IRQ_State" Then it should disable the interrupt relating to the DW1000, and then return the original IRQ_State.

**Parameters:**

none

**Return Parameters:**

| Type | Description |
|---|---|
| decaIrqStatus_t | This is the state of the target microcontroller's interrupt logic with respect to the handling the DW1000's interrupt, as it was on entry to the *decamutexon()* function before it did any interrupt disabling. |

```
typedef int decaIrqStatus_t ;
```

**Notes:**

The *decamutexon()* function returns the DW1000 interrupt status, which can be noted and appropriate action taken. The returned status is intended to be used in the call to *decamutexoff()* function to be used to restore the interrupt enable status to its original pre-*decamutexon()* state.

### 5.70.2 decamutexoff

**void decamutexoff (decaIrqStatus_t state) ;**

This function is used to restore the DW1000's interrupt state as returned by *decamutexon()* function. It is used to turn off mutual exclusion (e.g. by enabling interrupts if appropriate). **This is called at the end of the critical section of SPI access.** The *decamutexoff()* function should operate to restore the system interrupt status in the target microcontroller system's interrupt handling logic to the state indicated by the input "IRQ_State" parameter, *state*.

**Parameters:**

| type | name | description |
|---|---|---|
| decaIrqStatus_t | state | This is the state of the target microcontroller's interrupt logic with respect to the handling of the DW1000's interrupt, as it was on entry to the *decamutexon()* function before it did any interrupt disabling. |

**Return Parameters:**

none

**Notes:**

The state parameter passed into *decamutexoff()* function should be used to appropriately set/restore the system interrupt status in the target microcontroller system's interrupt handling logic.

## 5.71 Sleep function

The purpose of this function is to provide a platform dependent implementation of sleep feature, i.e. waiting for a certain amount of time before proceeding with the application's next step.

This is an external function used by DW1000 driver code to wait for the end of a process, e.g. the stabilization of a clock or the completion of a write command. This function is provided in the deca_sleep.c source file.

### 5.71.1 deca_sleep

**void deca_sleep (unsigned int time_ms) ;**

This function is used to wait for a given amount of time before proceeding to the next step of the calling function.

**Parameters:**

| type | name | description |
|---|---|---|
| unsigned int | time_ms | The amount of time to wait, expressed in milliseconds. |

**Return Parameters:**

None

**Notes:**

The implementation provided here is designed for a simple single-threaded system and is blocking, i.e. it will prevent the system from doing anything else during the waiting time.

## 5.72 Subsidiary functions

These functions are used to provide low level access to individually numbered registers and buffers (or register files). These may be needed to access IC functionality not included in the main API functions above.

### 5.72.1 dwt_writetodevice

**int dwt_writetodevice (uint16 regID, uint16 index, uint32 length, const uint8 *buffer) ;**

This function is used to write to the DW1000's registers and buffers. The *regID* specifies the main address of the register or parameter block being accessed, e.g. a *regID* of 9 selects the transmit buffer. The *index* parameter selects a sub-address within the register file. A *regID* value of 0 is used for most of the accesses employed in the device driver. The *length* parameter specifies the number of bytes to write, and the *buffer* parameter points at the bytes to actually write. The function returns 0 for success, or, -1 for error.

### 5.72.2 dwt_readfromdevice

**int dwt_readfromdevice (uint16 regID, uint16 index, uint32 length, uint8 *buffer) ;**

This function is used to read from the DW1000's registers and buffers. The parameters are the same as for the *dwt_writetodevice* function above except that the *buffer* parameter points at a location where the bytes being read are placed by the function call. The function returns 0 for success, or, -1 for error.

### 5.72.3 dwt_read32bitreg

```
uint32 dwt_read32bitreg(int regFileID) ;
```

This function is used to read 32-bit DW1000 registers.

### 5.72.4 dwt_read32bitoffsetreg

```
uint32 dwt_read32bitoffsetreg(int regFileID,int regOffset) ;
```

This function is used to read a 32-bit DW1000 register that is part of a sub-addressed block.

### 5.72.5 dwt_write32bitreg

```
int dwt_write32bitreg(int regFileID, uint32 regval);
```

This function is used to write a 32-bit DW1000 register. The function returns 0 for success, or, -1 for error.

### 5.72.6 dwt_write32bitoffsetreg

```
int dwt_write32bitoffsetreg(int regFileID,int regOffset,uint32 regval);
```

This function is used to write to a 32-bit DW1000 register that is part of a sub-addressed block. . The function returns 0 for success, or, -1 for error.

### 5.72.7 dwt_read16bitoffsetreg

```
uint16 dwt_read16bitoffsetreg(int regFileID,int regOffset) ;
```

This function is used to read a 16-bit DW1000 register that is part of a sub-addressed block.

### 5.72.8 dwt_write16bitoffsetreg

```
int dwt_write16bitoffsetreg(int regFileID, uint16 regval);
```

This function is used to write a 16-bit DW1000 register. The function returns 0 for success, or, -1 for error.

# 6 APPENDIX 1 – DW1000 API EXAMPLES APPLICATIONS

The DW1000 API package provides, along with the DW1000 driver itself, a set of simple example applications designed to show how to achieve a number of basic features of the DW1000 IC like sending a frame, receiving a frame, putting the DW1000 IC to sleep, etc.

All these examples have been designed to be as simple as possible. The main idea is to make the code self-explanatory and include the least possible amount of code not directly involved in the achievement of the example-related feature. One of the consequences of this design is that the examples output very little (or even no) debug information, and are designed so that the application flow can be followed using a debugger if the user wants to have more information about run-time operations.

On the hardware side, the examples have been designed to run on an EVB1000 board. The base layers included in this package (see detail below) provide specific implementations for this HW.

## 6.1 Package structure

The folder structure of the package is the following:

**Table 18: Document History**

| Folder | | Brief description |
|---|---|---|
| decadriver | | DW1000 device driver |
| examples | | Example applications |
| | example 1 | Specific code and CooCox project file for example application 1 |
| | example 2 | Specific code and CooCox project file for example application 2 |
| | … | … |
| Libraries | | ARM and STM32 low-level layers |
| | CMSIS | Hardware abstraction layer for ARM Cortex-M processors |
| | STM32F10x_StdPeriph_Driver | Hardware abstraction layer for ST STM32 F1 processors |
| Linkers | | Linker script for STM32F105RC processor |
| platform | | Platform dependent implementation of low-level features (IT management, mutex, sleep, etc.) |

All example applications are named after the feature or set of features they implement.

## 6.2 Building and running the examples

All examples provide a specific main.c source file and a CooCox project file. To build and run the code, the user just needs to unzip the source and open the *.coproj* project file corresponding to the example one wants to build.

CooCox IDE can be downloaded from: http://www.coocox.org/software.html. Please follow the "Read More" link and download version 1.7.8. These examples have been developed using version 1.7.8.

This code building guide assumes that the reader has ARM Toolchains installed and is familiar with building code using the CooCox IDE. Those examples have been developed using the GNU Tools ARM for Embedded.

As shown in Figure 5 the user should enter the path to ARM tools for embedded toolchain – e.g. "C:\GNUToolsARMEmbedded\4.8_2014q1\bin". GNU Tools ARM for Embedded can be found here: https://launchpad.net/gcc-arm-embedded

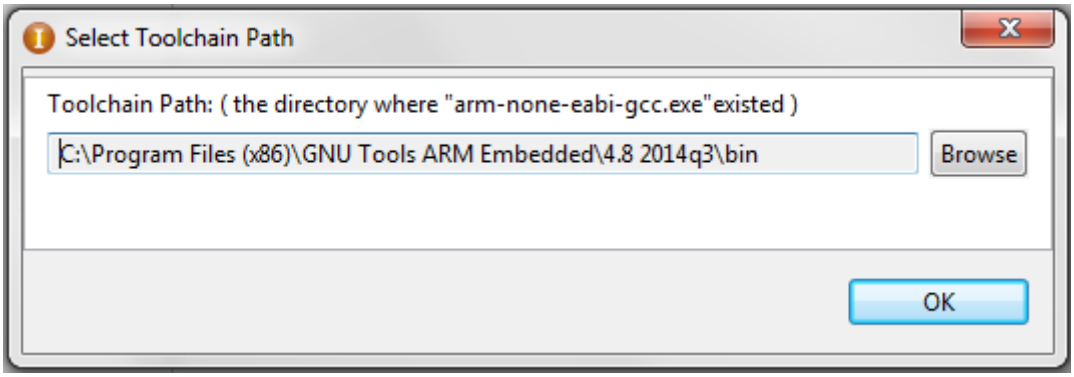


**Figure 5: Select toolchain path**

Please note that an ST-LINK/V2 probe will be needed to be able to program a board with an example application and observe the application flow using the debugger mode of CooCox.

## *6.3 Examples list*

As all examples have been designed to be self-explanatory and quite straightforward to read. The following is a list of all the examples provided with a brief description of the function of each.

### 6.3.1 Example 1a: simple TX

This example application repeatedly sends a hardcoded standard blink frame. Hardcoded delay between frames is 1 second.

### 6.3.2 Example 1b: TX with sleep

This is a variation of example 1a where the DW1000 is commanded to sleep and then awoken after the delay between each frame.

### 6.3.3 Example 1c: TX with auto sleep

This is a variation of example 1b where the DW1000 automatically goes to sleep after the transmission of a frame. DW1000 is still commanded to wake up after the desired sleep period has elapsed before sending the next frame.

### 6.3.4 Example 2a: simple RX

This example application waits indefinitely for an incoming frame. When a frame is received, it is read into a local buffer where it can be examined and then the application starts waiting for a frame again.

### 6.3.5 Example 3a: TX then wait for a response

This example application is a combination of examples 1a and 2a: it sends a frame then waits for a response (with receive timeout enabled). If a response is received, it is stored in a local buffer for examination and then proceeds to the transmission of the next frame. If not, the timeout will trigger and the application can proceed to the next transmission.

### 6.3.6 Example 3b: RX then send a response

This example application is the complement of example 3a: it waits indefinitely for a frame. When a frame is received, it is stored in a local buffer. If the frame is the one transmitted by the example 3a application, a response is sent. In any case, this application starts waiting again when the received frame is processed.

### 6.3.7 Example 4a: continuous wave mode

This example application activates continuous wave mode for 2 minutes with a predefined configuration. On a correctly configured spectrum analyser (use configuration values on the picture below), the output should look like this:

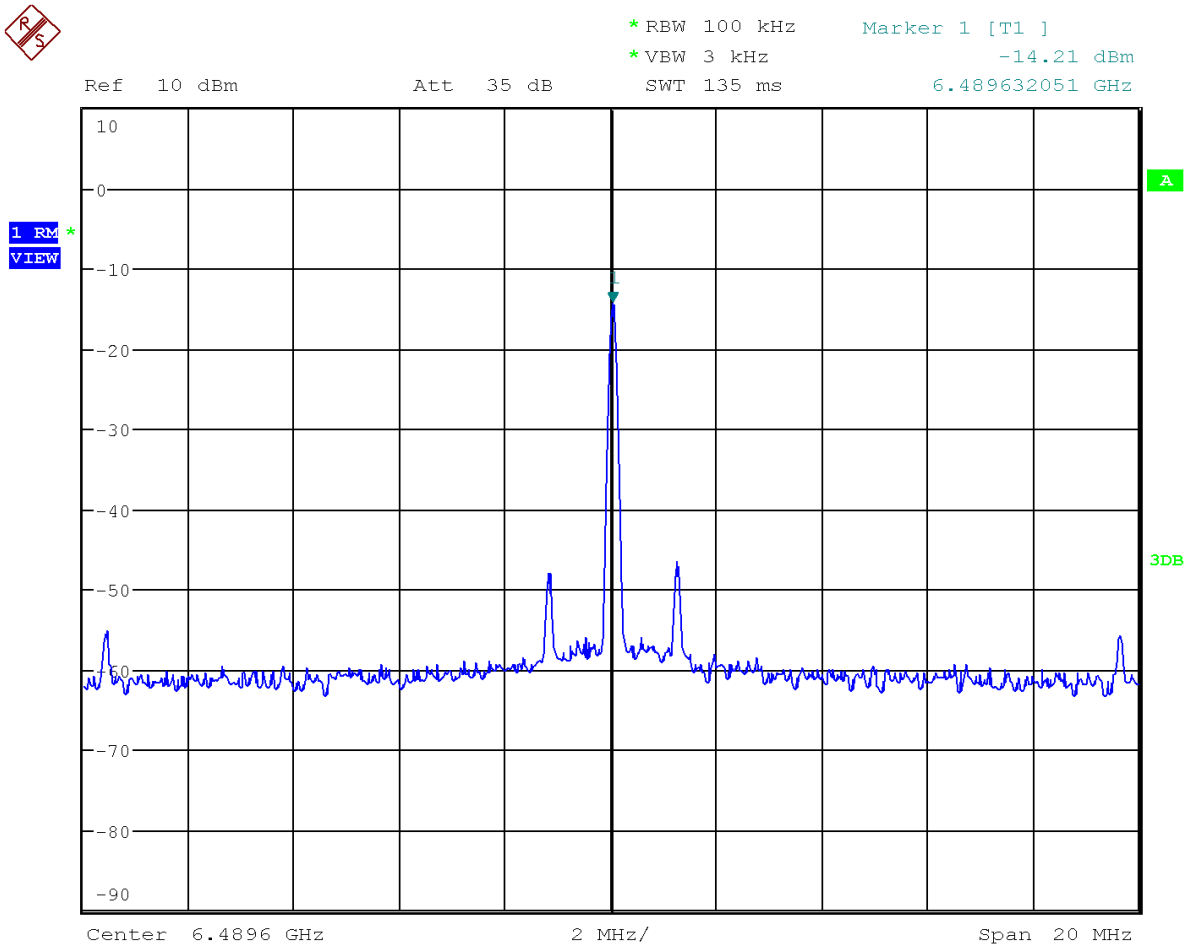


**Figure 6: Continuous wave output**

### 6.3.8 Example 4b: continuous frame mode

This example application activates continuous frame mode for 2 minutes with a predefined configuration. On a correctly configured spectrum analyser (use configuration values on the picture below), the output should look like this:

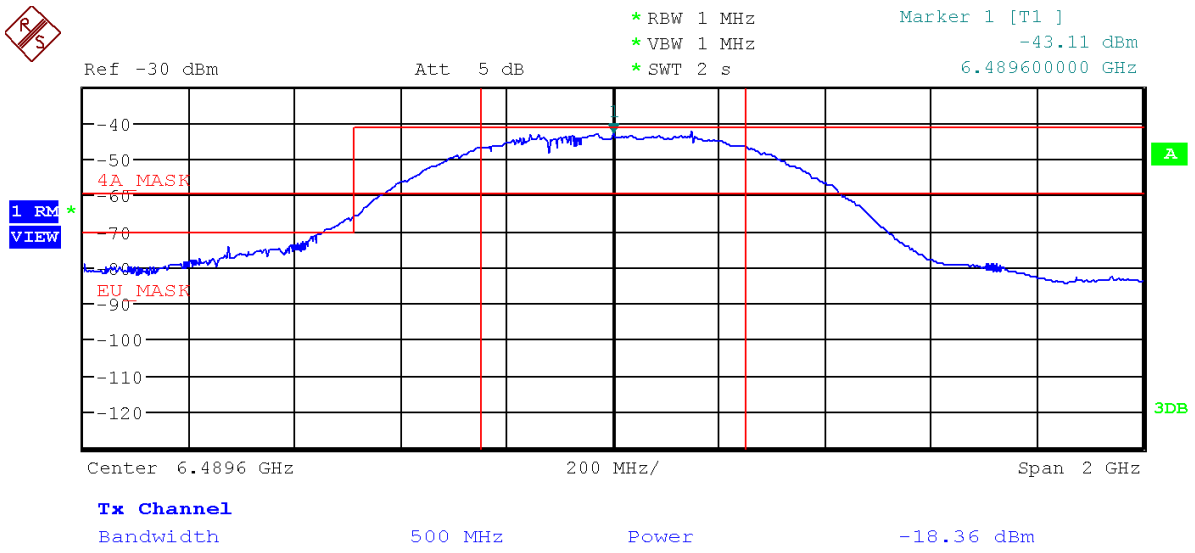


**Figure 7: Continuous frame output**

### 6.3.9 Example 5a: double-sided two-way ranging (DS TWR) initiator

This is a simple code example which acts as the initiator in a DS TWR distance measurement exchange. This application sends a "poll" frame (recording the TX time-stamp of the poll), and then waits for a "response" message expected from the "DS TWR responder" example code (companion to this application – see section 6.3.10). When the response is received its RX time-stamp is recorded and we send a "final" message to complete the exchange. The final message contains all the time-stamps recorded by this application, including the calculated/predicted TX time-stamp for the final message itself. The companion "DS TWR responder" example application works out the time-of-flight over-the-air and, thus, the estimated distance between the two devices.

### 6.3.10 Example 5b: double-sided two-way ranging responder

This is a simple code example which acts as the responder in a DS TWR distance measurement exchange. This application waits for a "poll" message (recording the RX time-stamp of the poll) expected from the "DS TWR initiator" example code (companion to this application), and then sends a "response" message recording its TX time-stamp, after which it waits for a "final" message from the initiator to complete the exchange. The final message contains the remote initiator's time-stamps of poll TX, response RX and final TX. With this data and the local time-stamps, (of poll RX, response TX and final RX), this example application works out a value for the time-of-flight over-the-air and, thus, the estimated distance between the two devices, which it writes to the LCD.

### 6.3.11 Example 6a: single-sided two-way ranging (SS TWR) initiator

This is a simple code example which acts as the initiator in a SS TWR distance measurement exchange. This application sends a "poll" frame (recording the TX time-stamp of the poll), after which it waits for a "response" message from the "SS TWR responder" example code (companion to this application) to complete the exchange. The response message contains the remote responder's time-stamps of poll RX, and response TX. With this data and the local time-stamps, (of poll TX and

response RX), this example application works out a value for the time-of-flight over-the-air and, thus, the estimated distance between the two devices, which it writes to the LCD.

### 6.3.12 Example 6b: single-sided two-way ranging responder

This is a simple code example which acts as the responder in a SS TWR distance measurement exchange. This application waits for a "poll" message (recording the RX time-stamp of the poll) expected from the "SS TWR initiator" example code (companion to this application), and then sends a "response" message to complete the exchange. The response message contains all the time-stamps recorded by this application, including the calculated/predicted TX time-stamp for the response message itself. The companion "SS TWR initiator" example application works out the time-of-flight over-the-air and, thus, the estimated distance between the two devices.

# 7 APPENDIX 2 – BIBLIOGRAPHY:


| | |
|---|---|
| [1] | Decawave DW1000 Data Sheet |
| [2] | Decawave DW1000 User Manual |
| [3] | IEEE 802.15.4-2011 or "IEEE Std 802.15.4™-2011" (Revision of IEEE Std 802.15.4-2006).<br>IEEE Standard for Local and metropolitan area networks— Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs). IEEE Computer Society Sponsored by the LAN/MAN Standards Committee.<br>Available from http://standards.ieee.org/ |


**Table 19: Bibliography**

# 8 DOCUMENT HISTORY

**Table 20: Document History**

| Revision | Date | Description |
|---|---|---|
| 1.0 | 1st November 2013 | Initial release for production device. |
| 1.5 | 4th November 2014 | Scheduled update |
| 1.7 | 1st July, 2015 | Scheduled update |
| 2.0 | 4th December, 2015 | Added new simple example project descriptions |

# 9 MAJOR CHANGES

## 9.1 Release 1.5

| Page | Change Description |
|---|---|
| All | Update of version number to 1.5 |
| All | Various typographical changes |
| 9 | Updated the API to match driver version 2.12.0 |

## 9.2 Release 1.7

| Page | Change Description |
|---|---|
| All | Update of version number to 1.7 |
| All | Various typographical changes |
| 3 | New Disclaimer as new source includes ST's library files |
| 9 | Updated the API to match driver version 2.16.0 |
| New APIs | New API functions: dwt_OTPrevision, dwt_setGPIOvalue, dwt_setGPIOdirection, dwt_setGPIOforEXTTRX, |
| Table 17 | New OTP map |

## 9.3 Release 2.0

| Page | Change Description |
|---|---|
| All | Update of version number to 2.0 |
| All | Various typographical changes |
| 9 | Updated the API to match driver version 3.0.0 |
| API removal | Removal of the following APIs: dwt_getldotune, dwt_getotptxpower, dwt_readantennadelay |
| 17 | Updated dwt_initialise parameters |
| 18 | Updated dwt_configure parameters |
| 40 | Updated dwt_configuresleep parameters |
| 41 to 44 | Fixed wake-up time value occurrences from 200 to 500 microseconds |
| 54 | Renamed dwt_readdignostics to dwt_readdiagnostics |
| 59 | Added new dwt_otp read API |

| Page | Change Description |
|---|---|
| 68 | Added missing function dwt_checkoverrun |
| 71 | Added new deca_sleep API |
| Appendix 1 | Added new simple example project descriptions |

# 10 ABOUT DECAWAVE

Decawave is a pioneering fabless semiconductor company whose flagship product, the DW1000, is a complete, single chip CMOS Ultra-Wideband IC based on the IEEE 802.15.4 standard UWB PHY. This device is the first in a family of parts.

The resulting silicon has a wide range of standards-based applications for both Real Time Location Systems (RTLS) and Ultra Low Power Wireless Transceivers in areas as diverse as manufacturing, healthcare, lighting, security, transport, and inventory and supply-chain management.

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