APS002 APPLICATION NOTE

MINIMIZING POWER CONSUMPTION IN DW1000 BASED SYSTEMS

Version 1.0

This document is subject to change without notice

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1 Introduction

1.1 Overview

This application note is concerned with how to minimize power consumption in DW1000 based systems. It examines the contributory factors in the system that contribute to the overall power consumption of a DW1000-based node and discusses the optimisations that can be made to minimize the power consumption due to each of those factors so as to minimize the overall power consumption.

Designing low-power systems in general is not trivial and there is a significant body of literature on the subject. The intention of this note is not to give guidelines on general low-power product design; rather, its intention is to give guidelines related specifically to the use of the DW1000.

There are a number of other application notes available on www.decawave.com dealing with particular aspects of the subject of this application note and these are referenced during the course of this application note where relevant; www.decawave.com also contains details of Decawave's products as well as a range of additional support material.

1.2 Overview of the document

This document begins by presenting an overview of the key determinants of power consumption and goes on to discuss each of those determinants in detail.

The results of that discussion are presented as a set of "rules" that can be applied to your design to ensure power consumption is minimized.

The document is organised as outlined in Table 1.

Table 1: Document overview

Section	Title	Description
Section 2	What determines power consumption in DW1000 systems?	Gives an overview of the key factors that determine power consumption in a DW1000 node.
Section 3	Power supply architectures	Discusses how the choice of power supply architecture can influence overall power consumption
Section 4	Device states & related power consumption	Outlines the various different operational states in the DW1000 and the power consumption of each
Section 5	System Parameter choices	Discusses how the choice of operating parameters for the DW1000 influences the power consumption that can be achieved.
Section 6	Strategies for intermittent operation	Discusses how choices relating to intermittent operation can influence node power consumption.
Section 7	Protocol and System design choices	Deals with the impact of system design & the design of the communications or ranging protocol on node power consumption.
Section 8	Other considerations	Deals with other potential contributors to power consumption not already discussed
Section 9	Conclusion	Presents a summary of rules for achieving minimum power consumption.
Section 10	References	Lists the sources cited in this application note.
Section 11	Document history	Presents the revision history of this application note.
Section 12	Major changes	Lists the changes between revisions of this application note.

Section	Title	Description
Section 13	About Decawave	Presents basic information about Decawave including contact information

2 What determines power consumption in DW1000 systems?

2.1 Introduction

In any electronic system, power consumption is one system parameter in a complex tradeoff with other system parameters including performance and cost. Depending on your particular requirements, a tradeoff that is acceptable in another system may not be acceptable for your system.

The guidelines presented here assume that minimizing power consumption is the overriding goal – it may not be; for example some of the guidelines presented here are in direct contradiction to the guidelines presented in APS017 (maximizing range in DW100 based systems).

You need to decide which system parameters are more important in your particular application and apply more weight to the relevant guidelines.

2.2 Power supply architectures

The particular power supply architecture that you use in your design can impact power consumption. How your product is powered and how that power supply voltage is transformed into the voltages required for the DW1000 to operate correctly has a direct impact on the power consumption of the system.

Section 3 discusses this topic in more detail.

2.3 DW1000 Device States

The DW1000 can be in one of a number of “states” at any particular point in time. Each state has a different power consumption. By minimizing the time spent in high power consumption states and maximizing the time spent in low power consumption states the overall power consumption can be minimized.

Section 4 discusses this topic in more detail.

2.4 Choice of system parameters

The power consumption of the DW1000 is directly related to the choices you make in terms of system parameters such as operating channel, data rate, preamble length, number of data bytes & PRF. Each of these has a quantifiable effect on power consumption.

Section 5 discusses each of these in more detail.

2.5 Intermittent operation

The DW1000 provides for a number of low power states; the choice of which low power state to enter between intermittent operations has a significant impact on overall system power consumption.

Section Strategies for Intermittent Operation6 discusses this in more detail.

2.6 System Design and Protocol choice

The choice of system design and the design of the communications protocol between nodes to implement that system both have a fundamental impact on node power consumption.

Section Strategies for Intermittent Operation0 discusses this in more detail.

2.7 Other Considerations

2.7.1 Power consumption planning

It is important to consider all consumers of power in your system when developing your power budget and to analyse the power profiles of each of these consumers so that peak power requirements can be determined and system components (regulators / DC / DC converters) sized accordingly

2.7.2 Maximise system efficiency

The manner in which you implement your system, particularly from a software perspective, can have an impact on system power consumption and needs to be considered carefully.

Section 8 examines these considerations.

3 Power supply architecture

3.1 Introduction

This section deals with power supply architectures for DW1000-based designs.

3.2 DW1000 power connections

The first thing to understand is the number and type of power supply connections required by the DW1000 for correct operation.

The chip operates from a nominal 3.3 V supply. Some circuits in the chip are directly connected to the external 3.3 V supply. Other circuits are powered from a number of on-chip low-dropout regulators. The outputs of these LDO regulators are brought out to pins of the chip for decoupling purposes. Refer to Figure 1 for further details.

The majority of the supplies are used in the analog & RF section of the chip where it is important to maintain supply isolation between individual circuits to achieve the required performance.

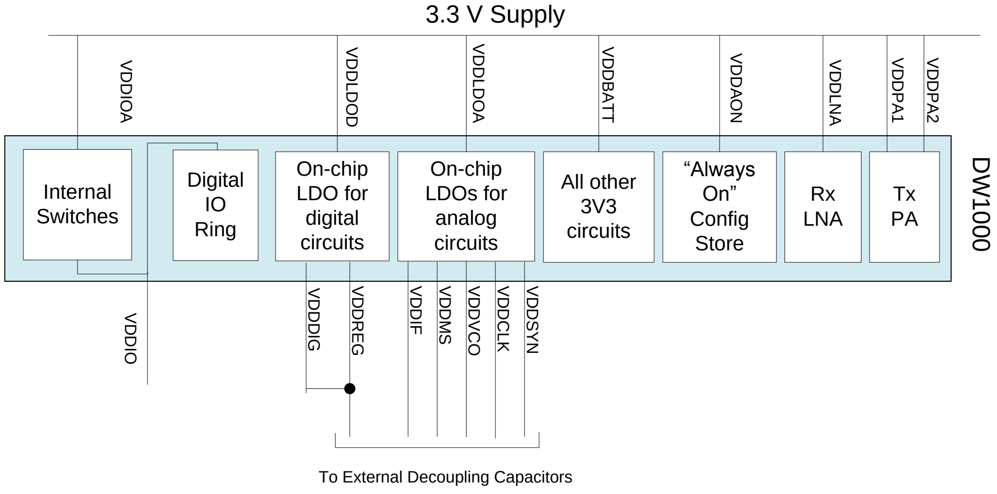


Figure 1: Power Supply Connections

Refer to Appendix 1 for the pin numbers of power / ground connections to the DW1000. Note that the bottom of the chip is a large ground pad that must be soldered to the application PCB for correct operation.

You should refer to the DW1000 data sheet [1] for details of the correct connection of the various power and ground pins and particular considerations around the powering up and down of the DW1000 to ensure correct operation.

3.3 Sources of primary supply

Decawave application note APH005 [4] deals with the choice of primary supply for your DW1000 design.

RULE 3.3: To optimize power consumption choose the most appropriate power source for your application.

3.4 Use a DC/DC converter for the primary 3V3 supply

The DW1000 is sufficiently robust to power supply noise to allow the use of a DC / DC converter for the primary 3V3 supply provided the manufacturer's circuit and layout recommendations are followed and decoupling, as per 3.6.1 below, is used.

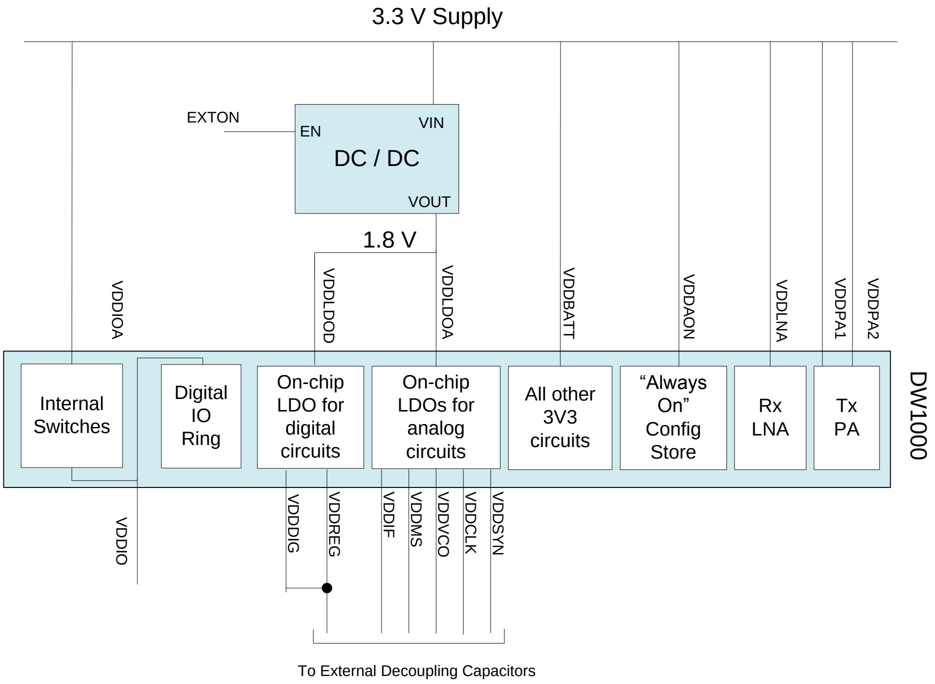
This can provide power savings over a linear regulator depending on the primary supply voltage. Indeed, a DC / DC converter may be the only choice depending on the range of the primary supply voltage (for example in battery applications, as the battery discharges, it may be necessary to boost the battery voltage using a boost converter to keep it within the acceptable voltage range of the DW1000).

RULE 3.4: To minimize power consumption use a high efficiency external DC/DC converter for the primary 3V3 supply.

3.5 Use an external DC/DC converter for VDDLDOD and VDDLDOA

VDDLDOD and VDDLDOA are the inputs to the on-chip low-drop out regulators. The outputs of these regulators are either 1.2 V or 1.4 V. If these regulators are supplied from a 3.3 V supply then they must drop from that 3.3 V supply down to their respective output voltages. This represents a considerable waste of power, as heat, in these on-chip regulators.

To avoid this, the VDDLDOD and VDDLDOA pins may be supplied from a much lower voltage; typically 1.8 V sourced from an external DC / DC converter. This has a significant impact on overall power consumption and is highly recommended as a means of reducing overall system power consumption although there is an additional cost to be considered.



RULE 3.5: To minimize power consumption always use a high efficiency external DC/DC converter to supply VDDLDOD and VDDLDOA and not 3.3 V.

A list of recommended DC / DC converters is given in the DW1000 data sheet [1]. You should follow the manufacturer's recommendations in terms of decoupling and layout for your chosen DC / DC converter to achieve best performance. The DC / DC converter can be enabled using the EXTON pin of the DW1000 so that the converter is only enabled when the DW1000 is operating.

3.6 Other factors

3.6.1 Decoupling

The DW1000 requires relatively high peak currents for very short durations of time. It is very important that your power supply design be capable of effectively supplying these peak currents so that the supply voltage does not “droop” and go out of spec.

The receiver of the DW1000 is very sensitive, typically in the -98 to -101 dBm region. While it is not overly sensitive to power supply noise, care should be taken with the design of the power supply so that noise on the supply rails is minimised. Decoupling should be used on all supplies as shown in the DW1000 datasheet [1]. Refer to APH001 - Hardware Design Guide [3] for an in-depth treatment of this topic.

RULE 3.6.1: Keep power supplies quiet through the correct use of decoupling

4 DW1000 device states and related power consumption

4.1 Introduction

The DW1000 has a number of internal device states. It can reside in only one of these states at any one time and each one has a different power consumption.

4.2 Device states

In order of increasing power consumption these are as shown in Table 2.

Table 2: DW1000 Device states

Name	Description	Typical Idd range
OFF	The chip is powered down and draws no current	0 mA
DEEPSLEEP	This is the lowest power state apart from the OFF state. In this state SPI communication is not possible. This state requires an external pin to be driven (can be SPICSn held low or WAKEUP held high) for a minimum of 500 µs to indicate a wake up condition. Once the device has detected the wake up condition, the EXTON pin will be asserted and internal reference oscillator (38.4 MHz) is enabled.	50 - 100 nA
SLEEP	In this state the DW1000 will wake up after a programmed sleep count. The low power oscillator is running and the internal sleep counter is active. The sleep counter allows for periods from approximately 300 ms to 450 hours before the DW1000 wakes up.	1 µA
INIT	This is the lowest power state that allows external micro-controller access. In this state the DW1000 host interface clock is running off the 38.4 MHz reference clock. In this mode the SPICLK frequency can be no greater than 3 MHz.	4 mA
IDLE	In this state the internal clock generator is running and ready for use. The analog receiver and transmitter are powered down. Full speed SPI accesses may be used in this state.	12 mA (Ext DC / DC) 18 mA (No Ext DC / DC)
TX	The DW1000 is actively transmitting a packet	Configuration Dependent
RX	The DW1000 is actively looking for preamble or receiving a packet	Configuration Dependent

There are various constraints over the permitted transitions between these states and the length of time transitions may take. For example in the DEEPSLEEP and SLEEP states the on-chip crystal oscillator is disabled so it can take in the region of 3 – 4 ms before the device is capable of transmitting / receiving a frame when exiting from these states. These restrictions are explained in detail in the DW1000 Data sheet [1] and DW1000 User Manual [2].

4.3 General guidance

To minimize power consumption the device should remain in high power consuming states for the minimum amount of time necessary and then return to the lowest possible power consuming state as quickly as possible.

This concept has implications for the choice of system parameters discussed in Section 5, intermittent operation as discussed in Section 6 and protocol / system design choices as discussed in Section 6.3.

RULE 4.3: To minimize power consumption spend as little time as possible in high power states and as much time as possible in low power or off states.

5 System parameter choices

5.1 Introduction

This section discusses the impact of system operating parameter choices on power consumption. The DW1000 is highly configurable. For each chosen configuration the power consumption of the device will be different so it is very important to understand the influence these configuration parameters have on device performance.

System parameter choices include: -

- Choice of operating channel
- Choice of data rate
- Choice of preamble length
- Choice of PRF

The respective impact of each of these on overall power consumption is discussed below.

5.2 Channel Parameters

5.2.1 Frequency

In general, higher frequency channels consume more power than lower frequency channels. If an option exists (and there may not be one depending on regulatory and other constraints) choose the lowest channel available.

RULE 5.2: To minimize power consumption use the lowest available channel frequency that meets the other requirements of your system.

5.3 Frame Parameters

5.3.1 Parameters concerned with frame duration

5.3.1.1 Data rate selection

Payload duration depends on the chosen data rate and the number of bytes being transferred.

Data rate also impacts receiver sensitivity. As can be seen in the receiver sensitivity characteristics section of the DW1000 datasheet [1], the sensitivity improves as you go from the highest supported data rate (6.8 Mbps) to the lowest (110 kbps). Using the lowest data rate will therefore maximise link margin and range.

However, the disadvantage of a lower data rate is that frames take a longer time to be transmitted & received and so there is a power consumption penalty.

RULE 5.3: To minimize power consumption use the highest data rate possible that meets the other requirements of your system.

5.3.1.2 Number of data bytes

You should minimize the number of bytes being transferred so as to keep payload duration as short as possible for a given data rate.

RULE 5.4: To minimize power consumption use the lowest number of data bytes possible that meets the other requirements of your system.

5.3.1.3 Preamble selection

The choices of preamble code and preamble length affect the ability of the receiver to detect the incoming signal in the noise and accurately determine the first path. The minimum length preamble receivable by the DW1000 is 64 symbols. The maximum supported by the DW1000 is 4096. Generally speaking the preamble needs to be long enough for the receiver to detect the signal and lock its carrier and timing recovery loops. Having a preamble that is longer than necessary takes up air time and unnecessarily increases system power consumption for no appreciable increase in performance.

Recommended preamble sequence lengths for different data rates are given in the operational design choices section of the DW1000 user manual [2].

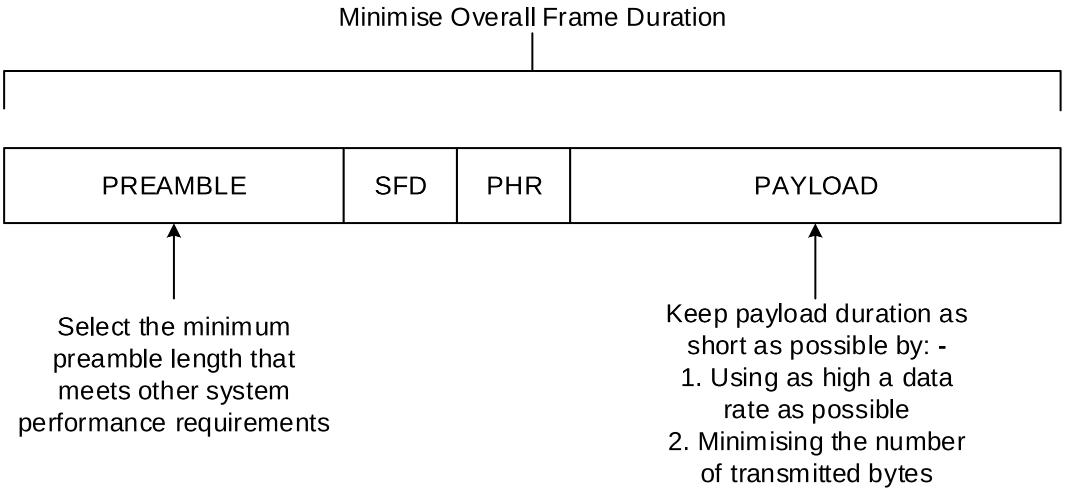
RULE 5.4: Use the shortest preamble length possible that meets the other requirements of your system.

5.3.2 PRF selection

There is a marginal difference in power consumption between the 16 MHz PRF and 64 MHz PRF with 16 MHz PRF having slightly lower power consumption.

RULE 5.5: Use 16 MHz PRF for lowest power consumption

5.3.3 Summary



6 Strategies for Intermittent Operation

6.1 Introduction

This section deals with strategies that can be employed to minimize power consumption when the DW1000 based node is not required to be in permanent operation (i.e. permanently transmitting & receiving). This includes most “tag” implementations in Real Time Location Systems (RTLS) where the node communicates briefly and is not required to communicate again for some time.

6.2 Minimising power between operations

6.2.1 Introduction

The DW1000 has four low current states each drawing different current. These are the first four rows of Table 2 above.

Your choice of low power state depends to a great extent on your use case.

6.2.2 Powering down the DW1000

Obviously when completely powered down (i.e. power removed from all power supply pins) the DW1000 draws no current. However there are disadvantages to doing this particularly around powering the DW100 back up and the time at which this operation can occur in relation to the voltages present on the power supply lines. Refer to [1] for more information on this topic.

External components are required to implement a complete power-off of the DW1000 and care needs to be taken over the state of signals connected to the DW1000 when it is powered off to avoid any spurious powering via DW1000 I/O pins.

6.2.3 Using DEEPSLEEP

In this mode, the DW1000 draws current in the 50 to 100 nA region.

6.2.4 Using SLEEP

In this mode, the DW1000 draws approximately 1 µA. An on-chip low power oscillator (not the main 38.4 MHz oscillator) is running which drives an on-chip programmable counter. When this counter times out the DW1000 wakes up. By choosing the appropriate counter value, sleep periods of 300 ms to 450 hours can be configured. This mode can be used to wakeup other external circuitry.

6.2.5 Using INIT

In this mode, the DW1000 draws approximately 4 mA. The 38.4 MHz on-chip oscillator is running but the on-chip PLLs are not enabled. In this mode, the DW1000 can be returned to an operational state much more quickly than any of the three states mentioned above.

Consider using this state when you know the DW1000 will be required for a subsequent operation in less than 3 to 5 ms (the time it takes the crystal oscillator to power up).

6.2.6 Summary

These various options can be summarised as follows: -

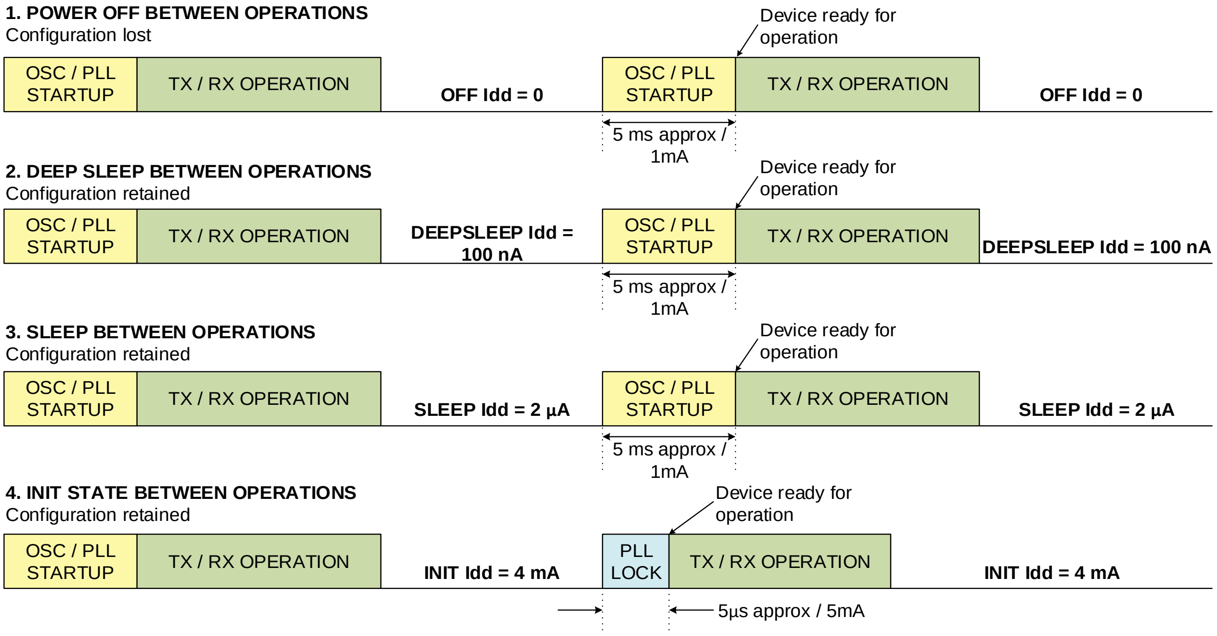


Figure 2: Power state options between operations

Rule 6.3: Use the INIT state for lowest power consumption between operations when the time between those operations is less than the start-up time of the crystal oscillator.

Rule 6.4: Choose between the other three low power states (OFF, DEEPSLEEP, SLEEP, depending on your use case) bearing in mind that in the OFF case, the DW1000 register configuration is not retained and will need to be reprogrammed on power-up which requires more time than the other two cases.

6.3 Using additional features of the DW1000 to reduce power consumption in receive mode

The DW1000 contains a number of receiver operating modes specifically intended for low power operation in receive mode. These are denoted “Low Power Listening mode” and “Low power Sniff mode” and “Sniff mode” respectively. In each of these modes the IC alternates between receiving mode and some form of lower power mode automatically.

The detailed description and operation of these modes is beyond the scope of this note. You should refer to the DW1000 User Guide [2] for more detailed information.

Rule 6.5: Considering using one of the built in low power listening modes supported by the DW1000 to reduce average receiver power consumption if appropriate for your use case.

7 Protocol & System Design Choices

7.1 Introduction

This section deals with system design choices, the choice of operating protocol between DW1000 nodes in a system and the impact these can have on node power consumption. APS001 [5] covers this topic in some detail so only a summary is reported here.

7.2 Stay out of receive mode as much as possible

Receive mode in the DW1000 consumes more power than transmit mode. Protocols should be designed so that DW1000 nodes are not left in receive mode for long periods of time “listening” for communications from other nodes. See APS001 [5].

RULE 7.2: Use protocols in which the DW1000 is not required to remain in receive mode for long periods of time.

7.3 Choose your lowest power state carefully & get back there as quickly as possible

If no other action is taken, on completion of a transmit or receive operation, the DW1000 will return to the IDLE state and remain there for the next command. This is a relatively high power state compared to INIT / SLEEP / DEEPSLEEP / OFF and it is not recommended to leave the DW1000 in this state unless you know the following operation is due to happen in a very short time.

Once a transmit or receive operation is complete you should return the device to the lowest power state permitted by your application as quickly as possible.

The DW1000 has facilities to allow software configure the IC to automatically transition to the SLEEP or DEEPSLEEP state on completion of an operation; e.g. the IC can be configured to transition into the DEEPSLEEP state once the transmission of the current frame is complete. If you intend using this feature the appropriate bits should be set to ensure the device makes this transition automatically. Refer to [2] for details of these various options.

If you are powering down the DW1000 between operations then this should be done as soon as possible after the completion of the preceding operation.

Remember that it takes some 3 – 5 ms to return to the IDLE state from DEEPSLEEP or SLEEP because the crystal oscillator must restart. It may make sense to remain in IDLE mode during the transition between Tx and Rx in a TWR exchange if you know the turnaround time of the other node in the exchange and so can remain in IDLE until it is necessary to enable the receiver. See APS001 [5] for more information.

Rule 7.3: Provided it makes sense to do so, return to SLEEP / DEEPSLEEP / OFF as quickly as possible after the previous operation is complete.

7.4 Minimize transferred data

Transmitting and receiving data uses power. A significant part of any given frame’s duration is the fixed overhead (preamble, PHR) but the data payload duration can also be significant depending on the number of bytes transmitted. Minimizing the number of transmitted bytes does the following: -

- Allows the DW1000 to return to a lower power state sooner than for a large payload
- Minimizes on-air time thereby allowing more transmissions from other nodes

You should design your systems protocol to transfer the required information in the minimum number of bytes.

You should also consider schemes where data transfer is carried out by some other mechanism and the DW1000 is used to timestamp receive signals only.

RULE 7.4: Keep the number of data bytes in any exchange as low as possible to minimize message length

7.5 Consider carefully the choice between TDOA and TWR schemes

In a Time Difference of Arrival (TDOA) based location scheme, a mobile node broadcasts a single blink that is received by a number of time synchronised anchors. In a Two Way Ranging (TWR) location scheme the mobile node must range in turn to a number of fixed anchors. The TDOA scheme is, by definition, more power efficient from the point of view of the mobile node.

In a TDOA scheme the anchor nodes must be synchronised (either physically via hardware or logically in a location engine). In a TWR scheme this synchronisation is not necessary and therefore TWR schemes are generally simpler to implement.

You should consider carefully the technical challenges of implementing a TDOA scheme vs. the power consumption disadvantages of a TWR scheme.

Rule 7.5: Carefully consider your choice of location scheme (TDOA vs TWR) and weigh up the power benefits of a TDOA scheme vs the technical challenge of its implementation.

7.6 In an individual ranging exchange keep turnaround times between transmit and receive as short as possible

In a two way ranging exchange, the goal is to complete the exchange as quickly as possible and return to a low power state once it is finished. The exchange involves a number of transmissions and receptions as detailed in APS013 [7].

In order to keep the duration of this exchange to a minimum and return both nodes to their lowest power state you should keep turnaround times between the various parts of the exchange as short as possible.

TAG POLLS ANCHOR AND DOES TWO-WAY RANGING SEQUENCE

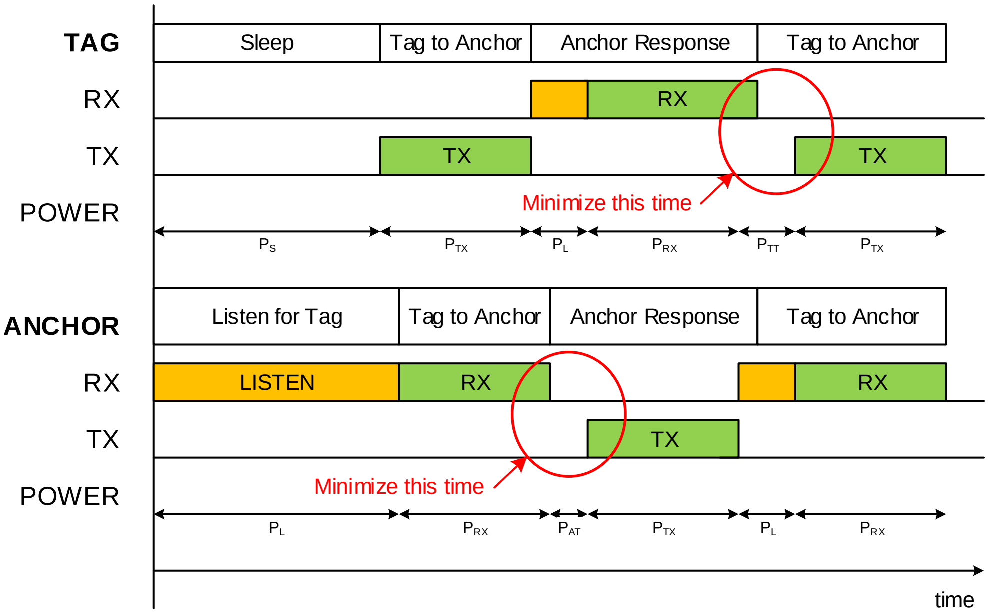


Figure 3: Minimizing turnaround time at each node in a TWR exchange

RULE 7.6: Keep the turnaround time between receive and transmit modes in a two-way ranging application as low as possible by ensuring tag and anchor code is efficiently written.

7.7 Keep the overall exchange with multiple anchors in a TWR scheme as short as possible

In a TWR location scheme, a mobile node must range with a number of fixed nodes in order to derive a location. As well as minimising the duration of the exchanges with each of the anchors, you should minimise the time between the completion of one exchange and the start of the next as short as possible. See Figure 4 below.

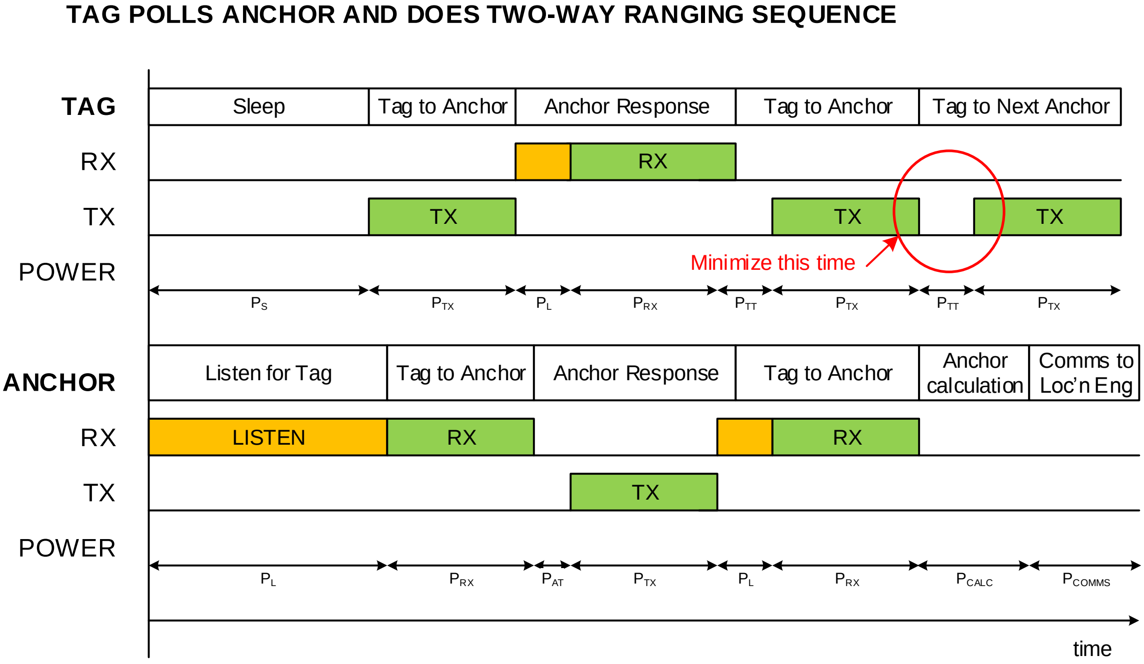


Figure 4: Minimize the changeover time between anchors in a TWR scheme

RULE 7.7.1: In a two way ranging scheme, keep the time between the completion of the ranging exchange by the tag with one anchor and the start of the exchange with the next as short as possible by ensuring the tag code is efficiently written.

OR

Rule 7.7.2: In a two way ranging scheme, use the interleaved two way ranging method to minimize the number of messages required and therefore the overall system power consumption. Refer to APS013 [7] for a detailed discussion of this scheme.

7.8 Dynamically adjust your location rate

In the vast majority of real time location systems location update rates are context dependent.

If the tag contains motion detection hardware (IMU, accelerometer) or the system has a back-channel for communications to the tag then the update rate can be dynamically updated depending on the motion of the tag.

If a tag is stationary since its last location update then subsequent updates provide no new information other than the fact that the tag has not moved so the interval between these updates can be increased. It is not advisable that stationary tags should stop sending updates entirely because the system will then not know whether the tag has failed or is simply not moving.

Similarly, if a tag is moving rapidly then its location will most likely need to be updated at a faster rate than if it is moving slowly. See Figure 5.

Since each transmission in a TDOA system or each ranging exchange in a TWR scheme consumes power it makes sense to adopt a dynamic rate adjustment technique to save power and extend battery life. In general:

- Stationary tags should use a lower update rate than moving tags.
- Faster moving tags should use a higher update rate than slower moving tags.

You should consider incorporating the necessary hardware / software in your tag design to provide information on the motion of the tag to allow the tag location rate to be dynamically adjusted.

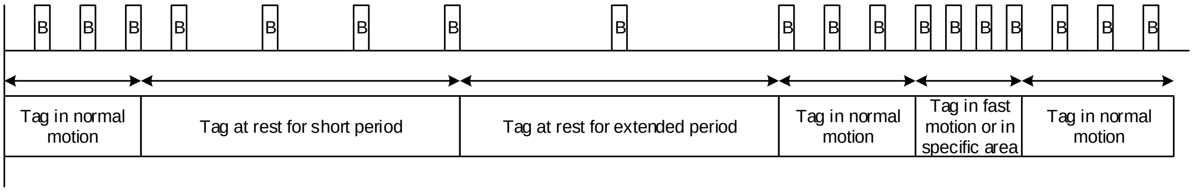
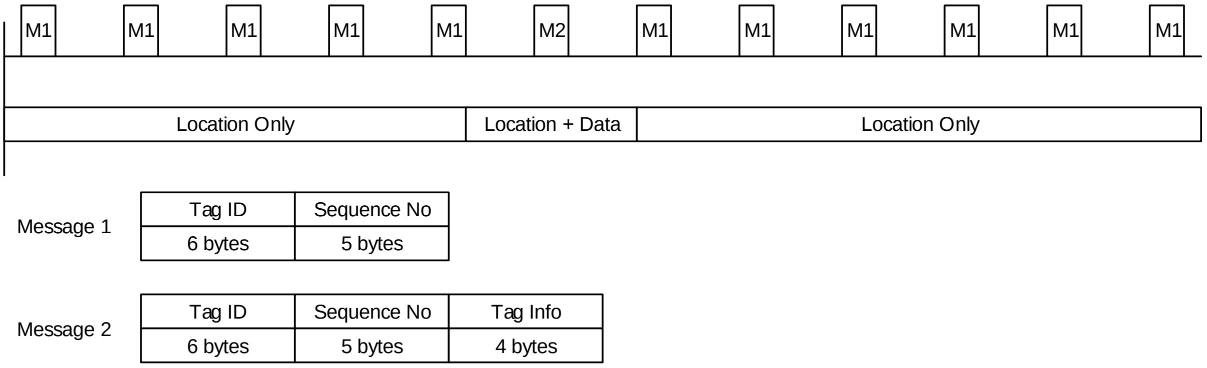


Figure 5: Dynamic location rate adjustment - example

RULE 7.8: Modify location update rates depending on whether the tag is moving and how fast it is moving.

7.9 Dynamically adjust your message content

It may not be necessary to report all tag related information (battery voltage, temperature, button status etc. etc.) each time the tag's location is determined. You should transfer only the information that is absolutely required for the intended operation so as to minimize payload length for the reasons given previously. See Figure 6 below.



Message 1

Tag ID	Sequence No
6 bytes	5 bytes

Message 2

Tag ID	Sequence No	Tag Info
6 bytes	5 bytes	4 bytes

Figure 6: Dynamic message content adjustment - example

RULE 7.9: Dynamically modify message content so as to keep payload durations as short as possible.

7.10 Use another technology to decide when to activate the DW1000

One way to consider the DW1000 is as a distance measurement sensor in a system based around sensor fusion. In these kinds of schemes the DW1000 is not the primary communications method between two nodes; some other communications scheme exists (e.g. LF, UHF, 2.4 GHz narrow band or some other scheme).

It is possible to use this other communications scheme to determine exactly when to enable the DW1000s in both nodes to perform a ranging measurement so as to minimize the power consumption of the DW1000 subsystem in each node.

RULE 7.10: Consider using another communications scheme to control when the DW1000s in two nodes are activated so as to minimise power consumption.

8 Other considerations

8.1 *Introduction*

This section considers other aspects of power consumption minimisation.

8.2 *Power consumption planning*

Planning the power consumption profile of your system is very important so that you understand all the contributors to power consumption as well as the power profiles of each of these consumers so that peak power requirements can be determined and system components (regulators / DC / DC converters) sized accordingly

By doing this you can take action to minimise the consumption of each contributor so that the actual consumption of your system is as you intend it to be.

Decawave provides a power calculator tool, available from your local Decawave representative, to help you calculate the power consumption of the DW1000 subsystem in your design. This tool can greatly simplify the calculation of power consumption and the sizing of batteries for mobile tag applications.

Rule 8.2: Use Decawave’s power calculator tool, this application note and the other application notes referred to in this note to help you in the design of your system to achieve optimum power consumption.

8.3 *Maximize power efficiency from a software perspective*

In general for minimum power consumption your system should perform whatever operation is required as power-efficiently and quickly as possible and then go into a low power or off state until it is required to perform the next operation.

You should carefully review the manner in which your software is designed to ensure it is performing the required operations in a power-efficient manner. Standard low-power software coding techniques should be used; for example interrupts should be used in preference to polling. This topic is well covered in the literature and is beyond the scope of this note; suffice to say that these techniques should be applied to achieve lowest power consumption.

Rule 8.3: Use low-power software design techniques to ensure your system software achieves the lowest possible power consumption.

9 Conclusion

9.1 Introduction

This note presents an overview of the issues to be considered when trying to minimise the power consumption of your DW1000 based node.

9.2 Power supply architectures

Rule Number	Rule
3.3	To optimize power consumption choose the most appropriate power source for your application
3.4	To minimize power consumption use a high efficiency external DC/DC converter for the primary 3.3 V supply
3.5	To minimize power consumption always use a high efficiency external DC/DC converter to supply VDDLDOD and VDDLDOA and not 3.3 V
3.6.1	Keep power supplies quiet through the correct use of decoupling

9.3 Device states

Rule Number	Rule
4.3	To minimize power consumption spend as little time as possible in high power states and as much time as possible in low power states or the “off” state.

9.4 System parameter choices

Rule Number	Rule
5.2	To minimize power consumption use the lowest available channel frequency that meets the other requirements of your system
5.3	To minimize power consumption use the highest data rate possible that meets the other requirements of your system
5.4	To minimize power consumption use the lowest number of data bytes possible that meets the other requirements of your system
5.5	Use the shortest preamble length possible that meets the other requirements of your system.
5.6	Use 16 MHz PRF for lowest power consumption

9.5 Strategies for intermittent operation

Rule Number	Rule
6.3	Use the INIT state for lowest power consumption between operations when the time between those operations is less than the start-up time of the crystal oscillator.
6.4	Choose between the other three low power states (OFF, DEEPSLEEP, SLEEP) depending on your use case bearing in mind that in the OFF case, the DW1000 register configuration is not retained and will need to be reprogrammed on power-up which requires more time than the other two cases.
6.5	Considering using one of the built in low power listening modes supported by the

Rule Number	Rule
	DW1000 to reduce average receiver power consumption if appropriate for your use case.

9.6 Protocol & System Design choices

Rule Number	Rule
7.2	Use protocols in which the DW1000 is not required to remain in receive mode for long periods of time
7.3	Provided it makes sense to do so, return to SLEEP / DEEPSLEEP / OFF as quickly as possible after the previous operation is complete
7.4	Keep the number of data bytes in any exchange as low as possible to minimize message length
7.5	Carefully consider your choice of location scheme (TDOA vs TWR) and weigh up the power benefits of a TDOA scheme vs the technical challenge of its implementation.
7.6	Keep the turnaround time between receive and transmit modes in a two-way ranging application as low as possible by ensuring tag and anchor code is efficiently written
7.7.1	In a two way ranging scheme, keep the time between the completion of the ranging exchange by the tag with one anchor and the start of the exchange with the next as short as possible by ensuring the tag code is efficiently written.
7.7.2	In a two way ranging scheme, use the interleaved two way ranging method to minimize the number of messages required and therefore the overall system power consumption.
7.8	Dynamically modify location update rates depending on whether the tag is moving and how fast it is moving
7.9	Dynamically modify message content to keep payload durations as short as possible.
7.10	Consider using another communications scheme to control when the DW1000 in a node is activated.

9.7 Other

Rule Number	Rule
8.2	Use Decawave's power calculator tool, this application note and the other application notes referred to in this note to help you in the design of your system to achieve optimum power consumption.
8.3	Use low-power software design techniques to ensure your system software achieves the lowest possible power consumption.

10 References

10.1 Listing

Reference is made to the following documents in the course of this Application Note: -

Table 3: Table of References

Ref	Author	Version	Title
[1]	Decawave	Current	DW1000 Datasheet
[2]	Decawave	Current	DW1000 User Manual
[3]	Decawave	Current	APH001 – Hardware Design Guide
[4]	Decawave	Current	APH005 – DW1000 Power Source Selection Guide – Selecting the power source for your DW1000 based product
[5]	Decawave	Current	APS001 – DW1000 Power Consumption – System related aspects of Power Consumption and how to optimize them when using the DW1000
[6]	Decawave	Current	APS003 – Introduction to RTLS
[7]	Decawave	Current	APS013 - DW1000 and two way ranging - The implementation of two-way ranging with the DW1000
[8]	Decawave	Current	APS017 – Maximizing range in DW1000 based systems

11 Document History

Table 4: Document History

Revision	Date	Description
1.0	30/09/16	Initial release.

12 Major Changes

Revision 1.0

Page	Change Description
All	Initial release.

13 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 802.15.4-2011 UWB standard. This device is the first in a family of parts that will operate at data rates of 110 kbps, 850 kbps and 6.8 Mbps.

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, inventory & supply chain management.

Further Information

For further information on this or any other Decawave product contact a sales representative as follows: -

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14 Appendix 1: DW1000 power supply connections

SIGNAL NAME	PIN	I/O (default)	DESCRIPTION
Digital Power Supplies			
VDDLDOD	26	P	External supply for digital circuits.
VDDIOA	28	P	External supply for digital IO ring.
VSSIO	32 43	G	Negative I/O ring supply. Must be connected to ground.
Digital Decoupling			
VDDREG	20	PD	Output of on-chip regulator. Connect to VDDDIG on PCB.
VDDDIG	44	PD	Output of on-chip regulator. Connect to VDDREG on PCB.
VDDIO	31 42	PD	Digital IO Ring Decoupling.
Analog Power Supplies			
VDDAON	25	P	External supply for the Always-On (AON) portion of the chip.
VDDPA1	18	P	External supply to the transmitter power amplifier.
VDDPA2	19	P	External supply to the transmitter power amplifier.
VDDLNA	15	P	External supply to the receiver LNA.
VDDLDOA	48	P	External supply to analog circuits.
VDDBATT	47	P	External supply to all other on-chip circuits. If a TCXO is being used with the DW1000 this pin should be supplied by the regulated supply used to power the TCXO.
Analog Supply Decoupling			
VDDCLK	9	PD	Output of on-chip regulator to off-chip decoupling capacitor.
VDDIF	7	PD	Output of on-chip regulator to off-chip decoupling capacitor.
VDDMS	6	PD	Output of on-chip regulator to off-chip decoupling capacitor.
VDDSYN	10	PD	Output of on-chip regulator to off-chip decoupling capacitor.
VDDVCO	11	PD	Output of on-chip regulator to off-chip decoupling capacitor.
Ground Paddle			
GND	49	G	Ground Paddle on underside of package. Must be soldered to the PCB ground plane for thermal and RF performance.

ABBREVIATION	EXPLANATION
G	Ground
P	Power Supply
PD	Power Decoupling