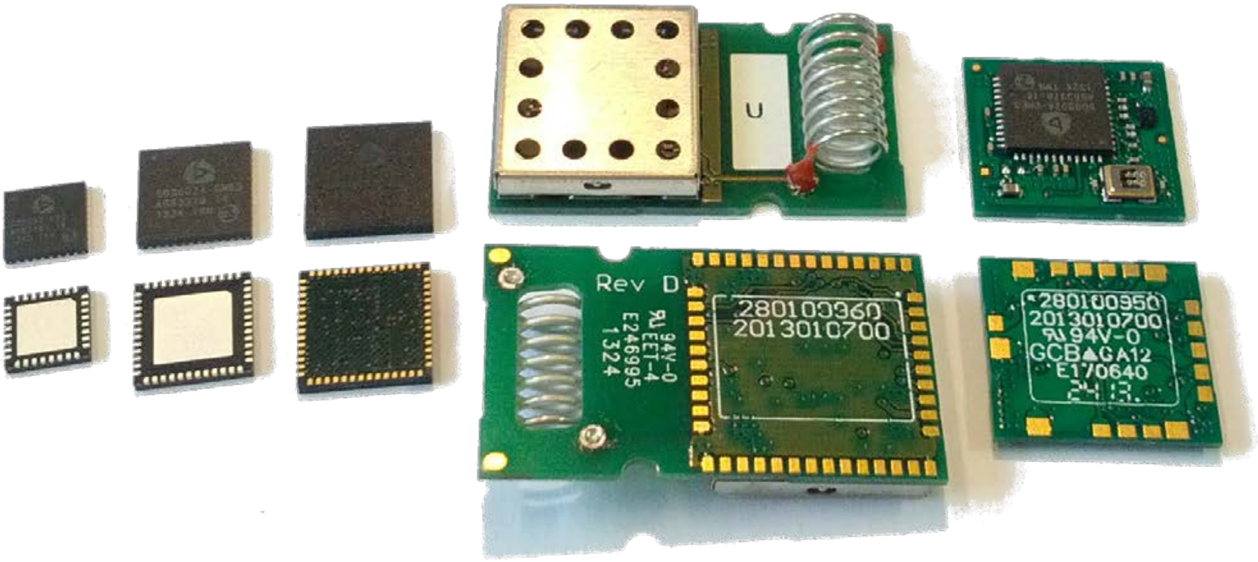
# INTEGRATION GUIDE FOR Z-WAVE® DEVICES




**The purpose of this document is to provide an implementation guide for integrating Z-Wave devices into product designs. It is intended for product design engineers who aim for a fast integration of 500 series Z-Wave devices.**

## 1 OVERVIEW

The 500 series Z-Wave device portfolio is shown in Table 1.1. The SD3503 serial interface SoC is designed for easy integration and provides OEM customers short time-to-market. It exposes the Z-Wave serial API via the USB or UART. The SD3502 is a general-purpose SoC with a built-in microcontroller and Z-Wave radio transceiver, making it ideal for single chip products. The ZM5101 SiP module combines the general-purpose SoC, crystal, supply decoupling components, and RF matching components into a single small-footprint module requiring only an external SAW filter for use. The ZM5304 serial interface module is a fully self-contained module that includes a Z-Wave modem, on-board NVM, and built-in antenna. The module is approved as a FCC modular transmitter. The ZM5202 general-purpose Z-Wave module combines the general-purpose SoC, crystal, supply decoupling components, RF matching components, and SAW filter into an I/O limited module.

**Table 1.1: Z-Wave device portfolio**

| Type | QFN32<br>SoC<br>5mm x 5mm | QFN48<br>SoC<br>7mm x 7mm | LGA56<br>SiP<br>8mm x 8mm | PCB48<br>SoM<br>15mm x 27mm | PCB18<br>SoM<br>13mm x 14mm |
|---|---|---|---|---|---|
| **Chip** | SD3503 | SD3502 | | | |
| **Module** | | | ZM5101 | ZM5304 | ZM5202 |

The applicable modules are clearly stated at the beginning of each of the following sections.

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# 3 PROGRAMMING AND DEBUGGING INTERFACE

| SD3503 | SD3502 | ZM5101 | ZM5304 | ZM5202 |
|---|---|---|---|---|
| Applicable | Applicable | Applicable | Applicable | Applicable |

A programming interface is **mandatory** if In-System Programming of a Z-Wave device is required, i.e., programming whilst soldered onto the product PCB. Depending on the available space, either a connector or test pads as shown in Figure 3.1 and Figure 3.2 can be chosen. A connector is useful for debugging during the development phase of the product, while test pads are suitable for a production environment.

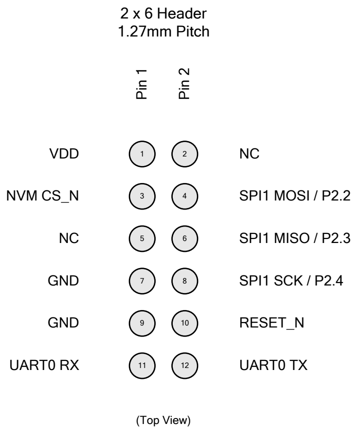



**Figure 3.1: Z-Wave SPI ISP interface (*SD3502, ZM5101, ZM5202*)**

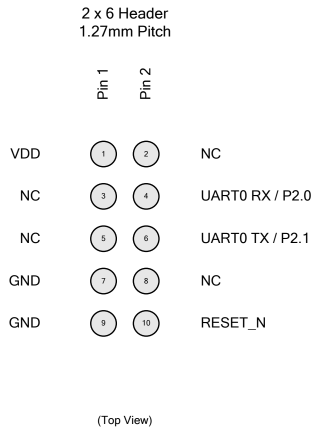



**Figure 3.2: Z-Wave UART ISP interface (*SD3503, ZM5304*)**

If a connector is used, the Harwin M50-3800542 male IDC connector, and Harwin M50-3000645 or M50-3000545 female board connector is recommended. The functionality of the pins from the programmer's perspective is shown in Table 3.1. Refer to [1] for programming instructions.

**Table 3.1: Z-Wave ISP pin functionality**

| Pin Name | Pin Location (SPI) | Pin Location (UART) | Type | Function |
|---|---|---|---|---|
| **GND** | 7, 8 | 7, 8 | S | Common ground between the programmer and Z-Wave device |
| **VDD** | 1 | 1 | S | +3.3V supply used to power the programmer |
| **NC** | 2, 5 | 2, 3, 5, 8 | - | Not connected |
| **RESET_N** | 10 | 10 | O | Driven low by the programmer to place the Z-Wave device in a reset state |
| **UART0 TX / P2.1** | 12 | 6 | I | Receive UART serial data from Z-Wave device |
| **UART0 RX / P2.0** | 11 | 4 | O | Transmit UART serial data to Z-Wave device |
| **SPI1 MISO / P2.3** | 6 | - | I | Receive SPI serial data from Z-Wave device |
| **SPI1 MOSI / P2.2** | 4 | - | O | Transmit SPI serial data to Z-Wave device |
| **SPI1 SCK / P2.4** | 8 | - | O | SPI clock provided by the programmer to Z-Wave device |
| **NVM CS_N** | 3 | - | O | Chip select of external NVM sharing SPI bus |

## 3.1 PROGRAMMING INTERFACE OVERVIEW

Below is a table showing which interfaces can be used to program the flash memory of the various Z-Wave products:

**Table 3.2: Available programming interfaces**

| | SD3502 | SD3503 | ZM5101 | ZM5202 | ZM5304 |
|---|---|---|---|---|---|
| SPI programming | X | | X | X | |
| UART programming | X | X | X | | X |
| USB programming | X | X | X | | X |

## 3.2 NON-VOLATILE REGISTERS

All Z-Wave devices contain a NVR flash page that is used to store critical calibration and configuration information, please refer to [5] for details. It is **mandatory** to preserve the NVR contents when programming.

# 4 CALIBRATION

It is **mandatory** to calibrate Z-Wave devices during production. Refer to [2] for calibration instructions.

## 4.1 TRANSMITTER

| SD3503 | SD3502 | ZM5101 | ZM5304 | ZM5202 |
|---|---|---|---|---|
| Applicable | Applicable | Applicable | NA | NA |

The radio transmitter must be calibrated to ensure optimum frequency separation during modulation.

## 4.2 CRYSTAL

| SD3503 | SD3502 | ZM5101 | ZM5304 | ZM5202 |
|---|---|---|---|---|
| Applicable | Applicable | NA | NA | NA |

The crystal frequency must be calibrated to ensure minimum error of the radio carrier frequency.

# 5 RF VERIFICATION TOOL

| SD3503 | SD3502 | ZM5101 | ZM5304 | ZM5202 |
|---|---|---|---|---|
| Applicable | Applicable | Applicable | Applicable | Applicable |

The Micro RF Link tool can be used to verify the RF performance of a device without the overhead of the Z-Wave protocol. The same RF PHY present in the Z-Wave protocol is used. The tool is suitable when investigating RF performance and performing RF regulatory tests. It requires that the chip can be programmed over ISP or APM and that UART0 is connected to a terminal over RS-232 if a user interface is required. For a comprehensive users-manual to the Micro RF Link tool, please refer to [3].

# 6 COMPONENT SPECIFICATIONS

## 6.1 EXTERNAL NVM

| SD3503 | SD3502 | ZM5101 | ZM5304 | ZM5202 |
|---|---|---|---|---|
| Applicable | Applicable | Applicable | NA | Applicable |

Some Z-Wave firmware APIs require external memory implemented on the product PCB for information storage (like routing table, HomeID, etc.). It is **important** that the correct memory size be chosen. Refer to [4] for details about the external NVM selection criteria.

As shown in Figure 6.1 the SPI interface is used to access an external serial EEPROM or flash, and a GPIO is used as the chip select. The GPIO chosen as the chip select can be specified in the NVR flash page. Refer to [5] for the NVR flash page contents.

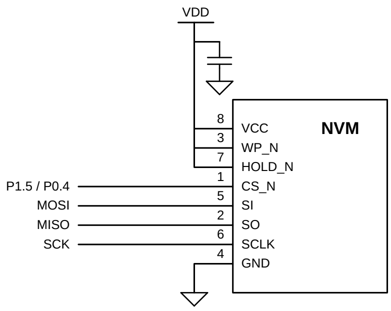



**Figure 6.1: Example external NVM**

Minimum specifications of an external EEPROM defined by the Z-Wave protocol are described below.

**Table 6.1: EEPROM specification**

| Parameter | Value |
|---|---|
| **Size** | 32kByte |
| **SPI Modes** | (CPOL=0,CPHA=0) & (CPOL=1,CPHA=1) |
| **Supply Voltage Range** | 2.3V to 3.6V |
| **Clock Speed** | 4MHz |
| **Page Write Size** | Max 256B |
| **Software Protection** | Yes |
| **Self-timed Write Cycle** | 5ms |
| **Endurance** | 1 Million Cycles |
| **Data Retention** | 100 Years |
| **Temperature** | -40°C to +85°C |

**Table 6.2: EEPROM instruction set**

| Command | Opcode | Description |
|---|---|---|
| **WREN** | 0x06 | Enable Write Operations |
| **WRDI** | 0x04 | Disable Write Operations |
| **RDSR** | 0x05 | Read Status Register |
| **WRSR** | 0x01 | Write Status Register |
| **READ** | 0x03 | Read Data from Memory |
| **WRITE** | 0x02 | Write Data to Memory |

**Table 6.3: EEPROM status registers**

| Bit | Name | Description |
|---|---|---|
| **7** | WPEN | Write Protect Enable |
| **6, 5, 4** | X | Undefined |
| **3** | BP1 | Block Protection Bit 1 |
| **2** | BP0 | Block Protection Bit 0 |
| **1** | WEN | Write Enable Latch |
| **0** | N_RDY | Ready |

Minimum specifications of an external flash defined by the Z-Wave protocol are described below. It is important to select a flash memory with a small page erase size in order to fulfill the endurance required within the lifetime of Z-Wave products.

**Table 6.4: Flash specification**

| Parameter | Value |
|---|---|
| **Size** | 128kByte (1Mbit), for 6.71+ controllers and newer 256kByte (2Mbit) |
| **SPI Modes** | (CPOL=0,CPHA=0) & (CPOL=1,CPHA=1) |
| **Supply Voltage Range** | 2.3V to 3.6V |
| **Clock Speed** | 4MHz |
| **Page Write Size** | 256B |
| **Page Erase Size** | 256B |
| **Software Protection** | Yes |
| **Page Read** | 85µs |
| **Page Write Cycle** | 25ms |
| **Endurance** | 100k Cycles |
| **Data Retention** | >20 Years |
| **Temperature** | -40°C to +85°C |

**Table 6.5: Flash instruction set**

| Command | Opcode Adesto | Opcode Micron | Description |
|---|---|---|---|
| **WREN** | 0x06 | 0x06 | Write Enable |
| **WRDI** | 0x04 | 0x04 | Write Disable |
| **RDID** | 0x9F | 0x9F | Read Identification |
| **RDSR** | 0xD7 | 0x05 | Read Status Register |
| **WRSR** | 0x01 | 0x01 | Write Status Register |
| **READ** | 0x03 | 0x03 | Read Data Bytes |
| **FAST_READ** | 0x0B | 0x0B | Read Data Bytes at Higher Speed |
| **PW** | 0x58 | 0x0A | Page Write (256B) |
| **PP** | 0x02 | 0x02 | Page Program |
| **PE** | 0xDB | 0xDB | Page Erase (256B) |
| **DP** | 0xB9 | 0xB9 | Deep Power-down |
| **UDP** | 0x79H | - | Ultra-deep Power-down |
| **RDP** | 0xAB | 0xAB | Release from Deep Power-down |

**Table 6.6: Flash status register**

| Bit | Name | Description |
|---|---|---|
| **7** | SRWD | Status Register Write Disable |
| **6, 5, 4** | X | Undefined |
| **3** | BP1 | Block Protect 1 |
| **2** | BP0 | Block Protect 0 |
| **1** | WEL | Write Enable Latch |
| **0** | WIP | Write In Progress |

### 6.1.1 RECOMMENDED COMPONENTS

**Table 6.7: External NVM components**

| Type | Manufacturer | Component Number | Size | Supported by SDKs | EOL Issued |
|---|---|---|---|---|---|
| **EEPROM** | ON Semiconductor | CAT25256 | 32kB | All | - |
| **EEPROM** | Atmel Corporation | AT25256B | 32kB | All | - |
| **Flash (note 3)** | Adesto Technologies | AT25PE20 | 256kB | 6.51.07+, 6.61+, 6.71+ & 6.81+ | - |
| **Flash (note 1)** | Micron Technology | M25PE10 | 128kB | All | Yes |
| **Flash (note 1)** | Micron Technology | M25PE20 | 256kB | All | Yes |
| **Flash (note 1)** | Micron Technology | M25PE40 | 512kB | All | Yes |
| **Flash (note 1)** | Micron Technology | M25PE80 | 1MB | 6.51.07+, 6.61+, 6.71+ & 6.81+ | Yes |
| **Flash (note 2 & 3)** | Adesto Technologies | AT45DB021E | 256kB | 6.51.07+, 6.61+, 6.71+ & 6.81+ | - |
| **Flash (note 2 & 3)** | Adesto Technologies | AT45DB041E | 512kB | 6.51.07+, 6.61+, 6.71+ & 6.81+ | - |
| **Flash (note 2 & 3)** | Adesto Technologies | AT45DB081E | 1MB | 6.51.07+, 6.61+, 6.71+ & 6.81+ | - |
| **Flash (note 2 & 3)** | Adesto Technologies | AT45DB161E | 2MB | 6.51.07+, 6.61+, 6.71+ & 6.81+ | - |
| **Flash (note 2 & 3)** | Adesto Technologies | AT45DB321E | 4MB | 6.51.07+, 6.61+, 6.71+ & 6.81+ | - |
| **Flash (note 2 & 3)** | Adesto Technologies | AT45DB641E | 8MB | 6.51.07+, 6.61+, 6.71+ & 6.81+ | - |

Note 1: Not recommended in new designs.
Note 2: Not pin compatible (with EEPROM and Micron) requiring a new printed circuit board layout compared to ZDB5101.
Note 3: Flash software driver initialize to 256 bytes page size.

The NVR flash page must be initialize with configuration information about the external NVM component used, please refer to [5] for details.

## 6.2 SAW FILTER

| SD3503 | SD3502 | ZM5101 | ZM5304 | ZM5202 |
|---|---|---|---|---|
| Applicable | Applicable | Applicable | NA | NA |

It is **mandatory** that a SAW filter be used in Z-Wave device designs. A SAW filter attenuates unwanted radio emissions and improves the receiver blocking performance. Three regions are defined to cover the global Z-Wave frequency range. The SAW filter specifications described in

Table 6.8,

Table 6.9, and

Table 6.10 is recommended for new designs, while legacy designs could still use the 400 series SAW filter specifications.

**Table 6.8: Region E**

| | Frequency Range | Unit | Minimum | Typical | Maximum |
|---|---|---|---|---|---|
| **Operating temperature** | - | °C | -30 | - | +85 |
| **Insertion loss** | 865.0 to 870.1MHz | dB | - | - | 3.5 |
| **Amplitude ripple** | 865.0 to 870.1MHz | dB | - | - | 2.0 |
| **Relative attenuation** | 0.1 to 800.0MHz | dB | 40 | - | - |
| | 805 to 830MHz | dB | 35 | - | - |
| | 835 to 855MHz | dB | - | - | - |
| | 860 to 862MHz | dB | - | - | - |
| | 890 to 1000MHz | dB | 40 | - | - |
| | 1005 to 2000MHz | dB | 30 | - | - |
| | 2005 to 3000MHz | dB | 30 | - | - |
| | 3005 to 4000MHz | dB | 30 | - | - |
| | 4005 to 6000MHz | dB | - | - | - |
| **In / out impedance** | - | Ω | - | 50 | - |

**Table 6.9: Region U**

| | Frequency Range | Unit | Minimum | Typical | Maximum |
|---|---|---|---|---|---|
| **Operating temperature** | - | °C | -30 | - | +85 |
| **Insertion loss** | 908.2 to 916.3MHz | dB | - | - | 2.5 |
| **Amplitude ripple** | 908.2 to 916.3MHz | dB | - | - | 1.5 |
| **Relative attenuation** | 720 to 800MHz | dB | 45 | - | - |
| | 805 to 840MHz | dB | - | - | - |
| | 845 to 870MHz | dB | 40 | - | - |
| | 870 to 895MHz | dB | - | - | - |
| | 940 to 1000MHz | dB | 9 | - | - |
| | 1005 to 2000MHz | dB | 9 | - | - |
| | 2005 to 3000MHz | dB | 17 | - | - |
| | 3005 to 4000MHz | dB | - | - | - |
| | 4005 to 6000MHz | dB | - | - | - |
| **In / out impedance** | - | Ω | - | 50 | - |

**Table 6.10: Region H**

| | Frequency Range | Unit | Minimum | Typical | Maximum |
|---|---|---|---|---|---|
| **Operating temperature** | - | ˚C | -30 | - | +85 |
| **Insertion loss** | 919.5 to 926.5MHz | dB | - | - | 3.2 |
| **Amplitude ripple** | 919.5 to 926.5MHz | dB | - | - | 1.0 |
| **Relative attenuation** | 40 to 870MHz | dB | 40 | - | - |
| | 875 to 885MHz | dB | 35 | - | - |
| | 890 to 905MHz | dB | 20 | - | - |
| | 945 to 955MHz | dB | 20 | - | - |
| | 960 to 1000MHz | dB | 20 | - | - |
| | 1005 to 1500MHz | dB | 40 | - | - |
| | 1505 to 3000MHz | dB | 20 | - | - |
| | 3005 to 4000MHz | dB | - | - | - |
| | 4005 to 6000MHz | dB | - | - | - |
| **In / out impedance** | - | Ω | - | 50 | - |

### 6.2.1 MANDATORY COMPONENTS

**Table 6.11: SAW filters**

| Region | Distributor | Component Number | Note |
|---|---|---|---|
| **E** | ACTE A/S, www.acte.dk, salessupport@acte.dk | SF4000-868-07-SX | Preferred |
| | ACTE A/S, www.acte.dk, salessupport@acte.dk | SF1141-868-02-SX | Alternative |
| **U** | ACTE A/S, www.acte.dk, salessupport@acte.dk | SF4000-914-06-SX | Preferred |
| | ACTE A/S, www.acte.dk, salessupport@acte.dk | SF1141-911-01-SX | Alternative |
| **H** | ACTE A/S, www.acte.dk, salessupport@acte.dk | SF1256-923-02 | |

### 6.2.2 OPTIONAL COMPONENTS

**Table 6.12: SAW filters**

| Region | Distributor | Component Number | Note |
|---|---|---|---|
| **E** | ACTE A/S, www.acte.dk, salessupport@acte.dk | SF4000-869-14-SX | Improved LTE rejection |

## 6.3 CRYSTAL

| SD3503 | SD3502 | ZM5101 | ZM5304 | ZM5202 |
|---|---|---|---|---|
| Applicable | Applicable | NA | NA | NA |

The crystal is part of the oscillator that generates the reference frequency for the digital system clock and RF carrier. It is a critical component of a Z-Wave device. Further, it is **mandatory** to calibrate the crystal, refer to section 4.

External load capacitors must be mounted to ensure proper oscillation of the parallel resonant crystal as shown in Figure 6.2.

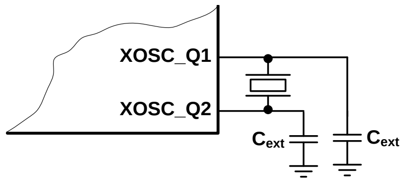



**Figure 6.2: External load capacitors for crystal**

The value of each external load capacitor can be calculated using the following formula:

$$C_{ext} = 2(C_{load} - C_{stray})$$

Where $C_{ext}$ is a single external load capacitor, $C_{load}$ is the crystal load capacitance specified in the datasheet, and $C_{stray}$ is the stray capacitance in the oscillator circuit, which is typically around 2pF.

### 6.3.1 MANDATORY COMPONENTS

**Table 6.13: Crystals**

| Distributor | Component Number | EOL issued |
|---|---|---|
| ACTE A/S, www.acte.dk, salessupport@acte.dk | QD1251-01-SX | Yes |
| ACTE A/S, www.acte.dk, salessupport@acte.dk | QD2750-07-SX | |

The value of $C_{ext}$ should be approximately 20 pF, but varies according to the stray capacitance of the PCB.

# 7 SUPPLY FILTER

A good power supply filter is strongly recommended as part of the schematic. A symmetric π filter with a ferrite can be used. The ferrite suppresses high frequency noise, while the capacitors decouple the power supply by acting as a source for fast transients currents.

## 7.1 WITH ANALOG POWER DOMAIN

| SD3503 | SD3502 | ZM5101 | ZM5304 | ZM5202 |
|---|---|---|---|---|
| Applicable | Applicable | Applicable | NA | NA |

For Z-Wave devices that have an analog supply, the filter shown in Figure 7.1 is **strongly recommended**.

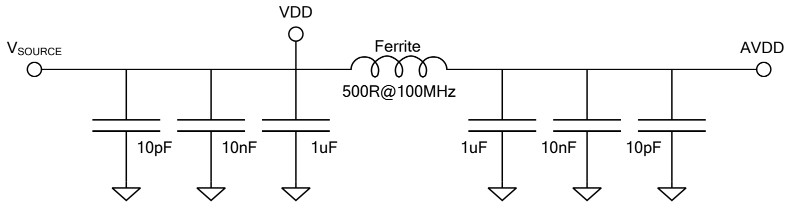



**Figure 7.1: Filter with analog supply**

## 7.2 WITHOUT ANALOG POWER DOMAIN

| SD3503 | SD3502 | ZM5101 | ZM5304 | ZM5202 |
|---|---|---|---|---|
| NA | NA | NA | Applicable | Applicable |

For Z-Wave devices with only the digital supply, the filter shown in Figure 7.2 is **strongly recommended**.

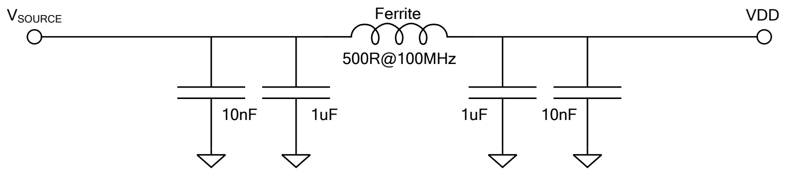



Figure 7.2: Filter without analog supply

# 8 MATCHING CIRCUIT

| SD3503 | SD3502 | ZM5101 | ZM5304 | ZM5202 |
|---|---|---|---|---|
| Applicable | Applicable | NA | NA | NA |

The PA of the transmitter should be matched for maximum power transfer and the LNA of the receiver must be matched for lowest noise. The components C1, L1, and L2 form the matching circuit of the PA, while the components L2 and L3 form the matching circuit of the LNA. The matching circuit is show in Figure 8.1.

The components that are selected should conform to the minimum specification described in Table 8.1.

Table 8.1: Matching components

| Parameter | Value |
|---|---|
| **Temperature** | -30 to +85°C |
| **Tolerance** | ±3% for inductors<br>±0.1pF for capacitors |
| **Self-resonance** | >> 1GHz |

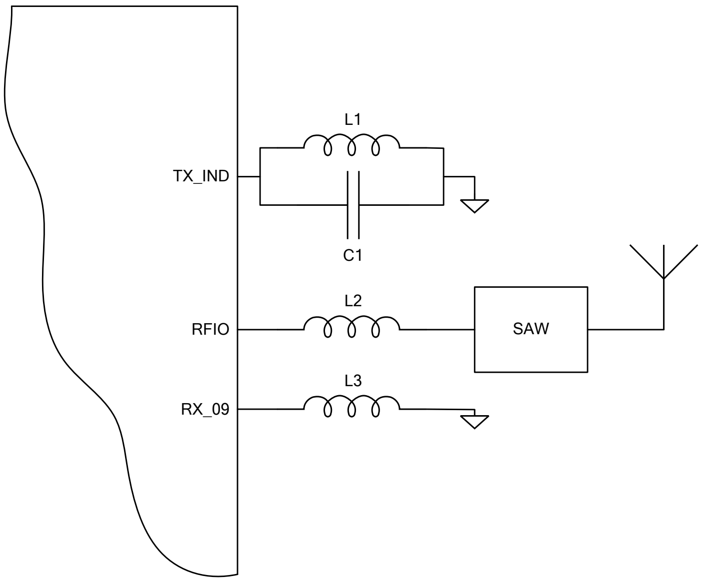



**Figure 8.1: Matching circuit**

## 8.1 MATCHING PROCEDURE

Finding appropriate values for the components should be considered an iterative task.

**Table 8.2: Recommended initial values**

| Designator | Value |
|---|---|
| **C1** | 5.6 pF |
| **L1** | 5.6 nH |
| **L2** | 12 nH |
| **L3** | 27 nH |

1. Select initial values for L1, and C1 to resonate at the Z-Wave carrier frequency, $f_{carrier}$.

$$f_{carrier} = \frac{1}{2\pi\sqrt{L1 \cdot C1}}$$

2. Select an initial value for L2. In general, reducing the value of L2 increases the transmit power and harmonics, while increasing it reduces the transmit power and harmonics.
3. Fine tune C1 and L1 to obtain maximum transmit power. Several iterations of step 2 and 3 would be required to arrive at an optimum solution. The *txsweep* command of the Micro RF Link tool can be used to verify the desired frequency range.
4. Select an initial value of L3 and fine-tune it to obtain the best sensitivity and lowest LO leakage. In some cases, L2 may require a retuning. If the value of L2 is changed, then the transmit power should be rechecked. The *rx r <framecount>* command of the Micro RF Link tool can be used to measure the FER.
5. Finally verify that the output power and harmonics of the transmitter, and sensitivity and LO leakage of the receiver, is as specified in the datasheet of the Z-Wave device.

## 8.2 MEASUREMENT SETUP

The output power should be measured with a spectrum analyzer as shown in Figure 8.2 and sensitivity as shown in Figure 8.3. In both cases, place the fixed attenuator as close as possible to the transmitter.

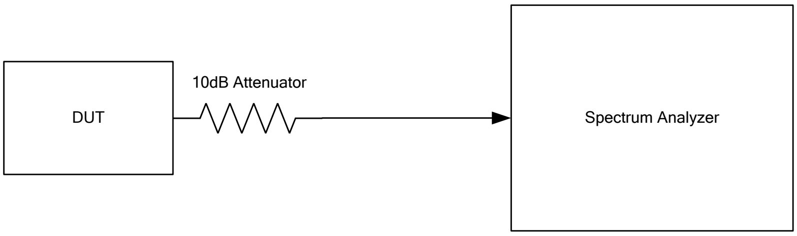



**Figure 8.2: Measuring transmitter output power**

When measuring the sensitivity, first measure and record the output power of the Z-Wave frame generator using the spectrum analyzer. A Z-Wave module programmed with the Micro RF Link tool can be used as the Z-Wave frame generator. Then a fixed attenuator can be used along with a variable attenuator to adjust the input power of the DUT. For example, by setting the output power of the Z-Wave generator to -20dBm, a fixed 50dB attenuator and a variable 50dB attenuator can be used to measure the sensitivity with a 1dB resolution. Place the fixed attenuator close to the Z-Wave generator and conduct the measurements is radio silent environment.

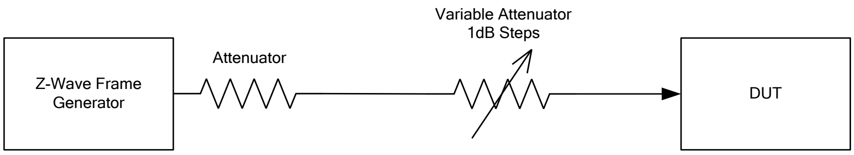



**Figure 8.3: Measuring receiver sensitivity**

# 9 PCB IMPLEMENTATION

| SD3503 | SD3502 | ZM5101 | ZM5304 | ZM5202 |
|---|---|---|---|---|
| Applicable | Applicable | Applicable except section 9.6 | Applicable except section 9.5 and 9.6 | Applicable except section 9.6 |

A good PCB implementation is required to obtain the best performance from a Z-Wave device. The following subsections describe items that should be considered when designing the PCB layout.

## 9.1 PLACEMENT

In general, it is **mandatory** that all decoupling and matching components should be placed as close as possible to the Z-Wave device, and on the same layer to reduce trace parasitics. It is also recommended that the SAW filter placed as close as possible to inductor L2 on the same layer.

It is **strongly recommended** that the Z-Wave device be placed at close to a corner of the PCB, away from any high frequency switching circuits.

## 9.2 STACK-UP

If designing a product with the SD3502 or SD3503, it is recommended to use a 4-layer stack-up PCB as shown in Figure 9.1. The thickness of the PCB stack-up can be chosen to optimize cost. It is **strongly recommended** that a solid copper plane be used as the ground plane layer L2.

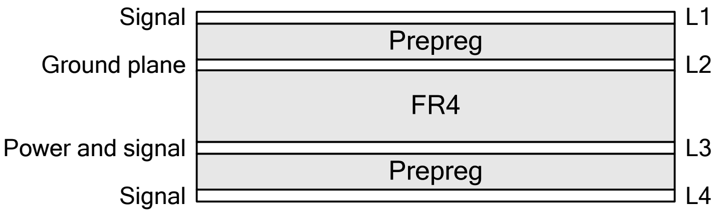



Figure 9.1: 4-layer stack-up

## 9.3 POWER ROUTING

It is **strongly recommended** that a star topology be adopted when routing power traces as shown in Figure 9.2. The supply filter is mounted at the root of the star, and smaller decoupling capacitors at the end of each branch.

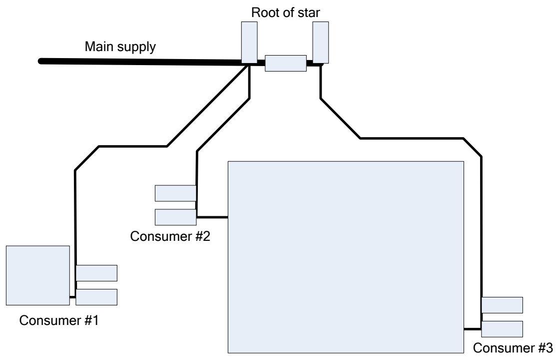



Figure 9.2: Star topology power routing

## 9.4 DECOUPLING

Power should be driven through decoupling capacitors to prevent parasitic inductances as shown in Figure 9.4. At least two grounding vias is recommended for each component as shown in Figure 9.3.

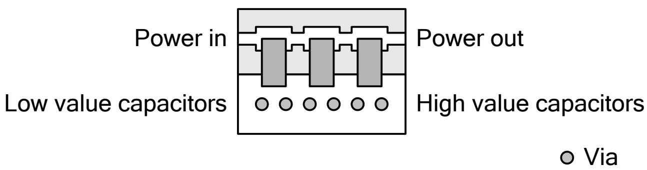



Figure 9.3: Grounded components

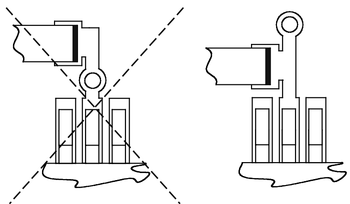


Figure 9.4: Pin decoupling

## 9.5 RF TRACE

It is **mandatory** that all high frequency RF traces, such as the trace to the antenna, be designed as transmission lines with a 50Ω characteristic impedance. A coplanar waveguide similar to Figure 9.5 is recommended for a transmission line on signal layer L1.

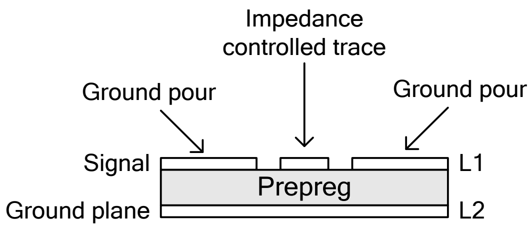



Figure 9.5: Coplanar waveguide

A via fence is recommended on both sides of a coplanar waveguide, as shown Figure 9.6, to short any return currents induced on the top layer to ground.

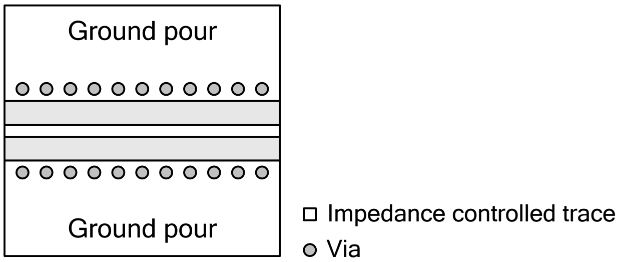



Figure 9.6: Via fence

A free tool, such as Saturn PCB Design Toolkit (http://www.saturnpcb.com/pcb_toolkit.htm), can be used to calculate the dimensions of the traces conveniently.

## 9.6 IC GROUNDING

QFN chips should be provided with a ground paddle with stitched-vias to minimize parasitic inductance and to provide a good thermal heat sink as shown in Figure 9.7.

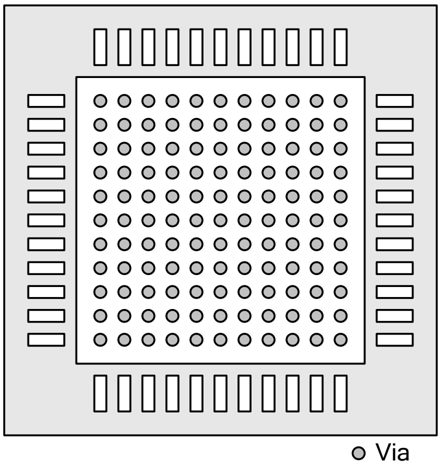



**Figure 9.7: IC ground paddle**

# 10 ANTENNA DESIGN

| SD3503 | SD3502 | ZM5101 | ZM5304 | ZM5202 |
|---|---|---|---|---|
| Applicable | Applicable | Applicable | NA | Applicable |

Since antenna design is very product dependent, it is **mandatory** to perform the antenna matching. Each product requires an individual design for best power transfer to the antenna and radiation characteristics. Refer to [6] for more information.

# 11 ESD

| SD3503 | SD3502 | ZM5101 | ZM5304 | ZM5202 |
|---|---|---|---|---|
| Applicable | Applicable | Applicable | Applicable | Applicable |

Since ESD can destroy the Z-Wave product, great care must be taken during manufacturing and assembly of final goods to avoid ESD.

By design, all pins of SD3502, SD3503 and ZM5101 are ESD protected up to a level of **2kV HBM**.

For the ZM5202 and ZM5304 modules, this level of ESD protection cannot be guaranteed, since the SAW filter of the modules has a much lower ESD level. This means, that the ESD level for the RFIO pin of ZM5202 and the antenna of ZM5304 is set by the ESD level of the SAW filters, whereas all other connections on the two modules are set by the ESD levels of the SD3502/SD3503 chips.

The ESD level of a SAW filter is typically **<< 2kV HBM**.

# 12 SDK SPECIFIC REQUIREMENTS

Some SDK versions impose additional requirements that must be addressed during production. This section describes those requirements. Only the SDKs mentioned here have additional requirements.

## 12.1 SDK 6.7X

It is **mandatory** to set the Readback protection lock bit of the flash [1] in the SoC on SDK 6.71+ devices to protect IP and security of the Z-Wave network.

NVR layout v0.2 or newer is **mandatory** for SDK 6.71+ devices. Two new fields, PUK and PRK are added and are a requirement for the S2 solution. It is **mandatory** to populate these fields according to the algorithm given in reference [5].

## 13 ABBREVIATIONS

| Abbreviation | Description |
|---|---|
| 2FSK | 2-key Frequency Shift Keying |
| 2GFSK | 2-key Gaussian Frequency Shift Keying |
| ACM | Abstract Control Model |
| ACMA | Australian Communications and Media Authority |
| ADC | Analog-to-Digital Converter |
| AES | Advanced Encryption Standard |
| API | Application Programming Interface |
| APM | Auto Programming Mode |
| AV | Audio Video |
| BOD | Brown-Out Detector |
| CBC | Cipher-Block Chaining |
| CDC | Communications Device Class |
| CE | Conformité Européenne |
| COM | Communication |
| CPU | Central Processing Unit |
| CRC | Cyclic Redundancy Check |
| D | Differential |
| D- | Differential Minus |
| D+ | Differential Plus |
| DAC | Digital-to-Analog Converter |
| DC | Direct Current |
| DMA | Direct Memory Access |
| DUT | Device Under Test |
| ECB | Electronic CodeBook |
| EMS | Electronic Manufacturing Services |
| EOL | End Of Life |
| ESD | Electro Static Discharge |
| ESR | Equivalent Series Resistance |
| FCC | Federal Communications Commission |
| FET | Field Effect Transistor |
| FER | Frame Error Rate |
| FLiRS | Frequently Listening Routing Slave |
| FR4 | Flame Retardant 4 |
| FSK | Frequency Shift Keying |
| GFSK | Gaussian Frequency Shift Keying |
| GP | General Purpose |
| GPIO | General Purpose Input Output |
| HBM | Human Body Model |
| I | Input |
| I/O | Input / Output |
| IC | Integrated Circuit |
| IDC | Insulation-Displacement Connector |
| IF | Intermediate Frequency |
| IGBT | Insulated-Gate Bipolar Transistor |
| INT | Interrupt |
| IPC | Interconnecting and Packaging Circuits |
| IR | Infrared |
| IRAM | Indirectly addressable Random Access Memory |
| ISM | Industrial, Scientific, and Medical |
| ISP | In-System Programming |
| ITU | International Telecommunications Union |
| JEDEC | Joint Electron Device Engineering Council |
| LED | Light-Emitting Diode |

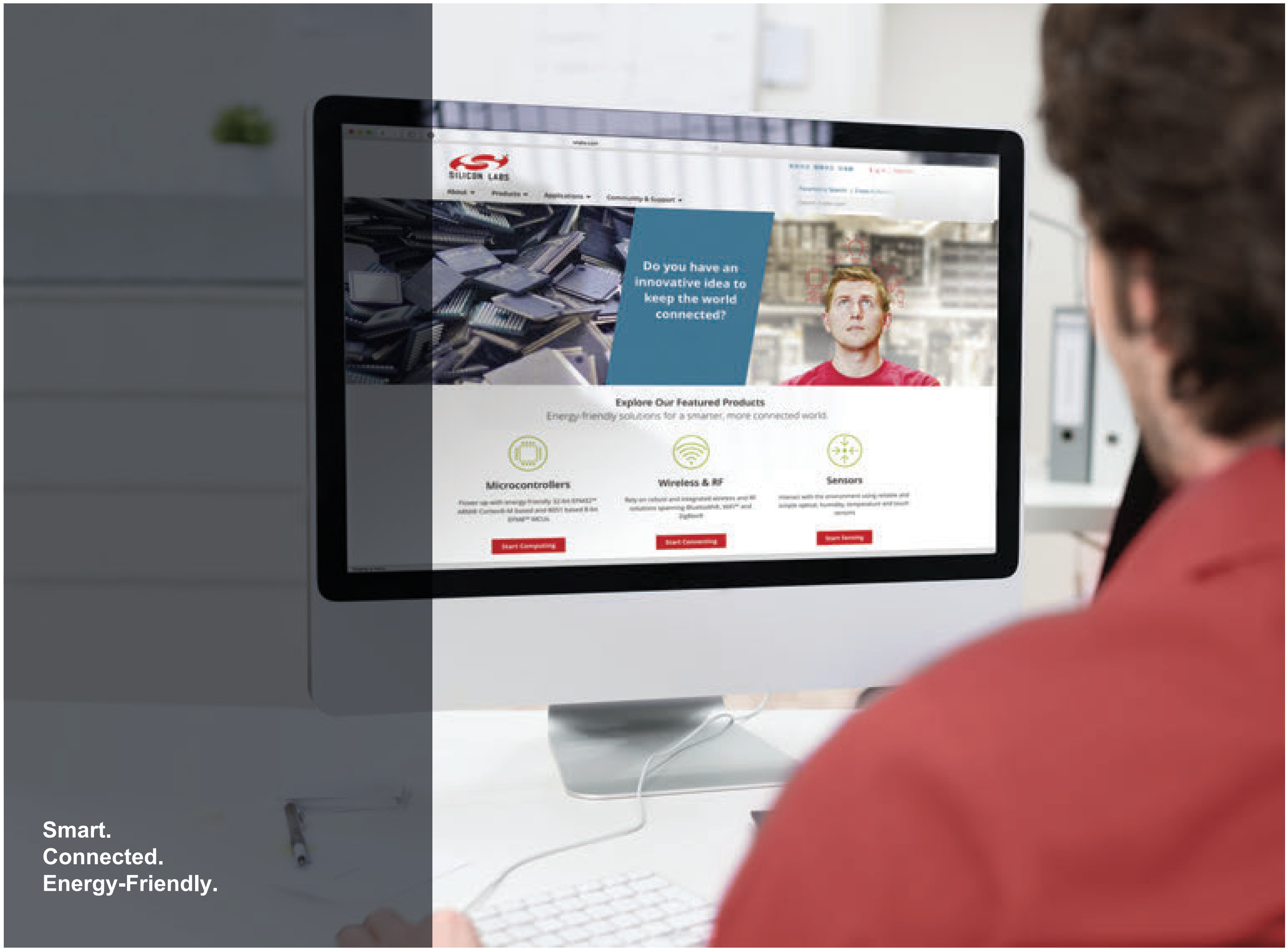
| Abbreviation | Description |
|---|---|
| LNA | Low-Noise Amplifier |
| LO | Local Oscillator |
| lsb | Least Significant Bit |
| LSB | Least Significant Byte |
| MCU | Micro-Controller Unit |
| MIC | Ministry of Internal affairs and Communications, Japan |
| MISO | Master In, Slave Out |
| MOSI | Master Out, Slave In |
| msb | Most Significant Bit |
| MSB | Most Significant Byte |
| NA | Not Applicable |
| NMI | Non-Maskable Interrupt |
| NRZ | Non-Return-to-Zero |
| NVM | Non-Volatile Memory |
| NVR | Non-Volatile Registers |
| O | Output |
| OEM | Original Equipment Manufacturer |
| OFB | Output FeedBack |
| OTP | One-Time Programmable |
| PA | Power Amplifier |
| Pb | Lead |
| PCB | Printed Circuit Board |
| PHY | L1 Physical Layer |
| POR | Power-On Reset |
| PWM | Pulse Width Modulator |
| QFN | Quad-Flat No-leads |
| RAM | Random Access Memory |
| RF | Radio Frequency |
| RoHS | Restriction of Hazardous Substances |
| ROM | Read Only Memory |
| RS-232 | Recommended Standard 232 |
| RX | Receive |
| S | Supply |
| SAW | Surface Acoustic Wave |
| SCK | Serial Clock |
| SFR | Special Function Register |
| SiP | System-in-Package |
| SPI | Serial Peripheral Interface |
| SRAM | Static Random Access Memory |
| T0 | Timer 0 |
| T1 | Timer 1 |
| TX | Transmit |
| UART | Universal Asynchronous Receiver Transmitter |
| USB | Universal Serial Bus |
| WUT | Wake-Up Timer |
| XRAM | External Random Access Memory |
| XTAL | Crystal |
| ZEROX | Zero Crossing |

# 14 REVISION HISTORY

| Date | Version | Affected | Revision |
|---|---|---|---|
| 2017/03/28 | 14 | § 6.1 | Added Adesto Tech. 2-megabit AT25PE20-SSHN-T DataFlash. Added Adesto Tech. opcodes. |
| | | § 12.1 | SDK 6.7x specific instructions added. Readback protection and keypair in NVR. Algorithm for keypair generation. |
| | | § 4.1 | Changed ZM5202 and ZM5304 TX CAL to NA, as they are calibrated from factory. |
| 2017/03/15 | 13 | Table 6.7 | Micron issued EOL for M25PE40 and M25PE80 |
| 2016/11/23 | 12 | §6.1 | Removed EEPROM STMicroelectronics M95256 (32KB). Reference to NVR configuration of the external NVM used. |
| 2016/05/10 | 11 | §6.2 | SAW filter alternatives added, Region E and U specifications changed accordingly. Added SAW with LTE improved rejection |
| 2016/04/13 | 10 | Tabel 6.12 | Crystals: QD1251-01-SX EOL, added QD2750-07-SX Added EOL in section 12 Abbreviations |
| 2016/02/24 | 9 | Table 6.7 | Updated external NVM components list |
| 2015/10/09 | 8 | Table 6.7 | Changed EEPROM spec. to 32kB |
| | | §6.2 | SAW filters recommendation changed |
| | | §6.3 | Recommendations for crystals removed |
| 2014/06/18 | 7 | §6 | EEPROM Page Write Size = Max 256B |
| 2014/05/14 | 6A | §5 | Reference to users-manual, removed table 5.1 and figure 5.1 |
| | | §3.1 | Added section 3.1, overview of programming interfaces |
| | | §9.2 | SD3502 and SD3503 added to the sentence of 4-layer PCB |
| | | §11 | Added section about ESD |
| | | §15 | Changed document reference number to Micro RF Link |
| | | All | Added detailed contact information to Acte A/S |
| 2013/11/04 | 5A | Figure 3.1, Figure 3.2, | Updated the Z-Wave programming connector layout |
| | | Table 3.1, | Updated the pin numbers |
| | | §3, | Updated the recommended connector type |
| | | Table 6.13 | Updated the frequency tolerance of crystal |
| 2013/10/17 | 4A | Figure 9.2, | Updated the routing diagram |
| | | Figure 9.4, | Added pin decoupling diagram |
| | | §13, | Repeating table heading on subsequent pages |
| | | §15 | Fixed the reference document name |
| 2013/10/14 | 3C | §6.1 | Added reference to SRN for external NVM selection |
| 2013/10/14 | 3B | §All | Removed preliminary watermark |
| 2013/10/14 | 3A | Table 6.7 | Increase recommended external NVM sizes |
| 2013/10/01 | 2D | §3, | Removed the GPIO from the UART |
| | | §6.1 | Clarified the NVM specification |
| 2013/10/01 | 2C | §3, | Added the UART ISP connector layout |
| | | §4, | Changed calibration to mandatory |
| | | §6.2 | Changed SAW filter to strongly recommended |
| 2013/09/30 | 2B | §9.1, | Clarified the placement layer, and clarified the device placement |
| | | §9.6, | Clarified the statement about stitched-vias |
| | | §10 | Clarified the requirement of antenna matching |
| 2013/09/20 | 2A | §All | Initial draft |

## 15 REFERENCES


[1] Silicon Labs, “500 Series Z-Wave Chip Programming Mode”, INS11681.
[2] Silicon Labs, “500 Series Calibration User Guide”, INS12524.
[3] Silicon Labs, “Micro RF Link”, INS12880.
[4] Silicon Labs, “Z-Wave 500 Series SDK v6.51.00”, SRN12428.
[5] Silicon Labs, “500 Series Z-Wave Chip NVR Flash Page Contents”, SDS12467.
[6] Silicon Labs, “Antennas for Short Range Devices”, APL10045.

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