MICROCHIP

ATAN0219

ATAK51005-V1 User's Guide

Introduction

This user's guide provides setup and usage instructions for the Car Access Reference System (CARS) featuring Remote Keyless Entry (RKE), Passive Entry/Passive Start (PEPS) and vehicle Immobilization (IMMO) functionality, based on the Microchip's GEN2 communication protocols. It offers a complete car access system for various car access products and its evaluation. The reference designs are both scalable and configurable through either the PC application or source code modifications, enabling adaptation of the basic hardware and software building blocks to meet the most recent requirements for specialized systems.

Features

- Full Car Access System Capability:
  - Vehicle IMMO
  - Multichannel RF RKE
  - LF PEPS
- Open System Software:
  - Open Immobilizer Protocol (AOIP) immobilizer stack using AES-128
  - RKE RF rolling code using AES-128
  - PEPS protocol with a high-precision 3D localization using AES-128
  - Scalable and configurable
  - PC Graphical User Interface (GUI) for system visualization and viewing data communication
- Body Computer Emulation using the SAMC21J18A XplainedPro (XPRO) Evaluation Board

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1. Quick References

1.1 Reference Documentation

For further details, refer to the following:

- *ATAN0088 Open Source Immobilizer Protocol Stack Application Note*
- *ATAN0073 Short Form Description of the Atmel PEPS System Application Note*
- *ATAN0014 RF System Architecture Considerations Application Note*
- *AVR411: Secure Rolling Code Algorithm for Wireless Link Application Note*
- *ATAN0218-ATAK51005-V1 Quick Start Guide*

1.2 Hardware Prerequisites

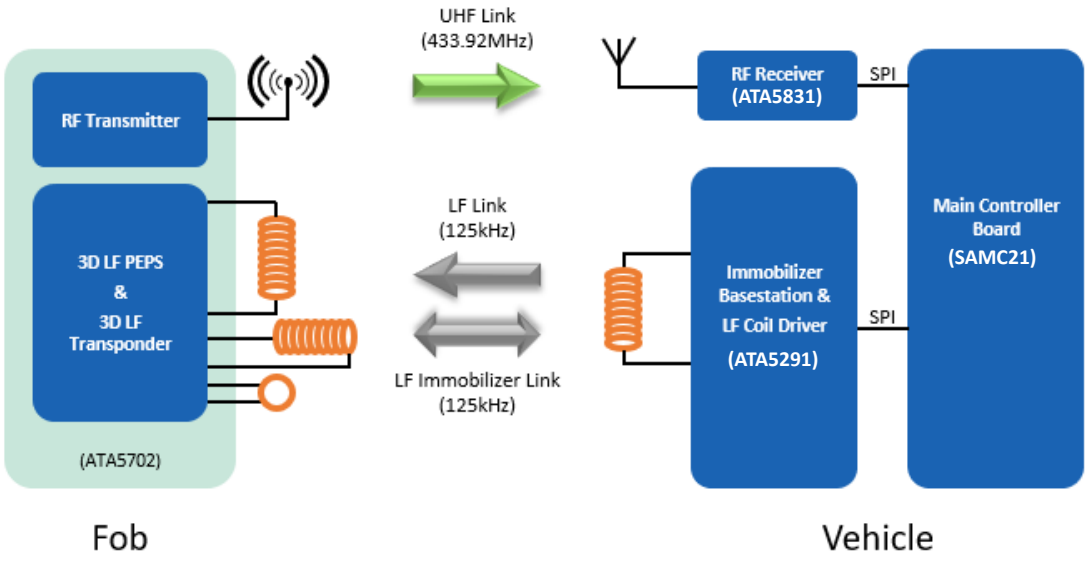
- Vehicle-side boards
  - One ATSAMC21-XPRO microcontroller board
  - One ATA5291-XPRO LF coil driver with built-in immobilizer base station board
  - One ATA5831-XPRO RF transceiver board
  - One ATAB-LFTX-V4.0 LF antenna module (can be configured as an inductive load needed for the immobilizer
- Fob and transponder
  - One ATAB5702A RF transmitter with 3D LF PEPS and 3D LF immobilizer transponder board
- Other accessories
  - One UHF SMA whip antenna (included with ATA5831-XPRO board)
  - One USB cable
  - One DC plug to banana plugs adapter cable (included with the ATA5291-XPRO board)

Note: The fob (ATAB5702A-V2.3B) requires a CR2032 lithium battery for operation, which is not provided.

2. Kit Overview

This section describes the different blocks supported by the CARS.

Figure 2-1. CARS System Block Diagram



2.1 Immobilizer Block

The immobilizer is considered the system foundation because it must always work, even if the fob battery is dead, and secures a vehicle against unauthorized engine starts. It consists of a base station, placed in the vehicle, that provides the LF (125 kHz) magnetic field enabling a wireless link with the transponder in the fob to be established. This LF immobilizer link is used to exchange the power supply and digital data between the vehicle and the passive transponder.

The implemented immobilizer system supports Microchip's AOIP, which consists of an open/unlicensed protocol stack based on AES-128 encryption. First, the `ReadUID` command is sent to the fob. The fob has to decode the `ReadUID` command and respond with its unique ID (UID) value. If the received UID value is correct (matches the stored UID), the start authentication command is issued and challenge data is sent to the fob based on the authentication type (unilateral or bilateral). The fob receives the challenge, performs the encryption and sends a ciphered response back. This response is received by the base station and verified to complete the authentication process.

Notes:

1. The fob is a receive-only device; therefore, the ciphered response back to the base station is accomplished by loading/unloading the magnetic field to encode the data.
2. For more details on the AOIP protocol, refer to the *ATAN0088 Open Source Immobilizer Protocol Stack Application Note*.

2.2 RKE Block

RKE functionality provides the means to lock or unlock and even start the vehicle from a long distance with a fob carried by the user. The system consists of an RF receiver in the vehicle and an RF transmitter in the fob. Unlike the immobilizer operation, the RKE operation requires a battery (CR2032 or equivalent) to be inserted in the fob.

The implemented RKE system supports Microchip messaging protocol (AVR411), which consists of a unidirectional UHF link that is secured based on an AES-128 rolling code algorithm. The message contains information that is used to verify the identity and authenticity of the user and the intended action (command code).

Note: RF and UHF are used interchangeably in this document. For more details on the RKE protocol, refer to the *AVR411: Secure Rolling Code Algorithm for Wireless Link Application Note*.

2.3 PEPS Block

The PEPS functionality provides the user with a means to lock/unlock and start a vehicle just by having the electronic fob with them, without the need to actively interact with it. It consists of an LF coil driver placed in the vehicle, which generates a strong magnetic field on multiple (optional) LF PEPS antennas.

The passive fob implemented in the PEPS system can wake up on this LF field and receive the incoming data via the unidirectional LF link. The fob also measures the strength of the magnetic field, which is used to determine the position of the fob relative to the vehicle (outside or inside). Then, it encrypts the received challenge data (using AES) and returns the correct cipher response, together with the positioning information, to the vehicle via the unidirectional UHF link.

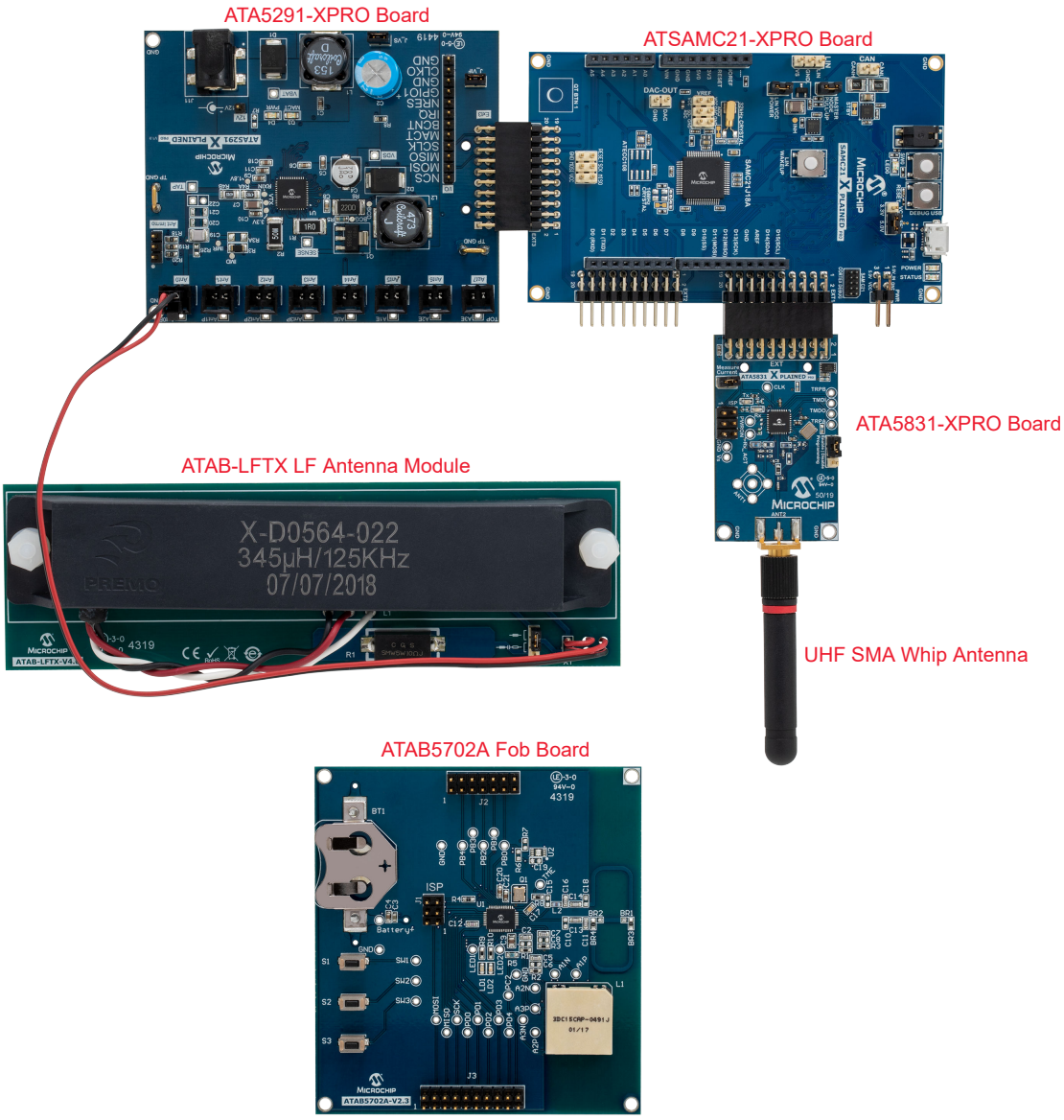
Note: For more details on the PEPS protocol, refer to the *ATAN0073 Short Form Description of the Atmel PEPS System Application Note*.

3. Kit Setup

Perform the following steps to set up the ATAK51005-V1 kit:

1. On the ATSAMC21-XPRO microcontroller board, ensure that the VCC-SEL jumper is set to the 5.0V position.
2. Insert the ATA5291-XPRO LF coil driver/immobilizer board in the EXT3 connector on the ATSAMC21-XPRO board.
3. Connect the ATAB-LFTX LF antenna module to Ant0 on the ATA5291-XPRO board.
4. Ensure that the J1 jumper on the LF antenna module is set to the inductor only (▬) position.
   Note: For use of the antenna on the Ant1-7 connectors, ensure that the jumper on the LF antenna module is set to the LCR position.

Figure 3-1. ATAK51005-V1 Kit Setup



5. Insert the ATA5831-XPRO RF transceiver board in the EXT1 connector on the ATSAMC21-XPRO board.
6. Connect the UHF SMA whip antenna to the ATA5831-XPRO board at the ANT2 SMA connector.

7. Connect the 12V DC power supply to the power socket (J11) on the ATA5291-XPRO board using the DC plug adapter cable.

Note: Always ensure that the adapter cable and the USB cable are unplugged prior to inserting or removing any boards within the system.

4. CARS Kit PC Evaluation Utility

This section describes the programming and configuration settings for using the CARS kit PC evaluation utility.

Note: The latest version of the utility is available for download at www.microchip.com/developmenttools/ProductDetails/ATAK51005-V1.

4.1 Programming Kit Software

Program all the individual boards that comprise the kit prior to use. For more details, refer to 6. Programming Instructions.

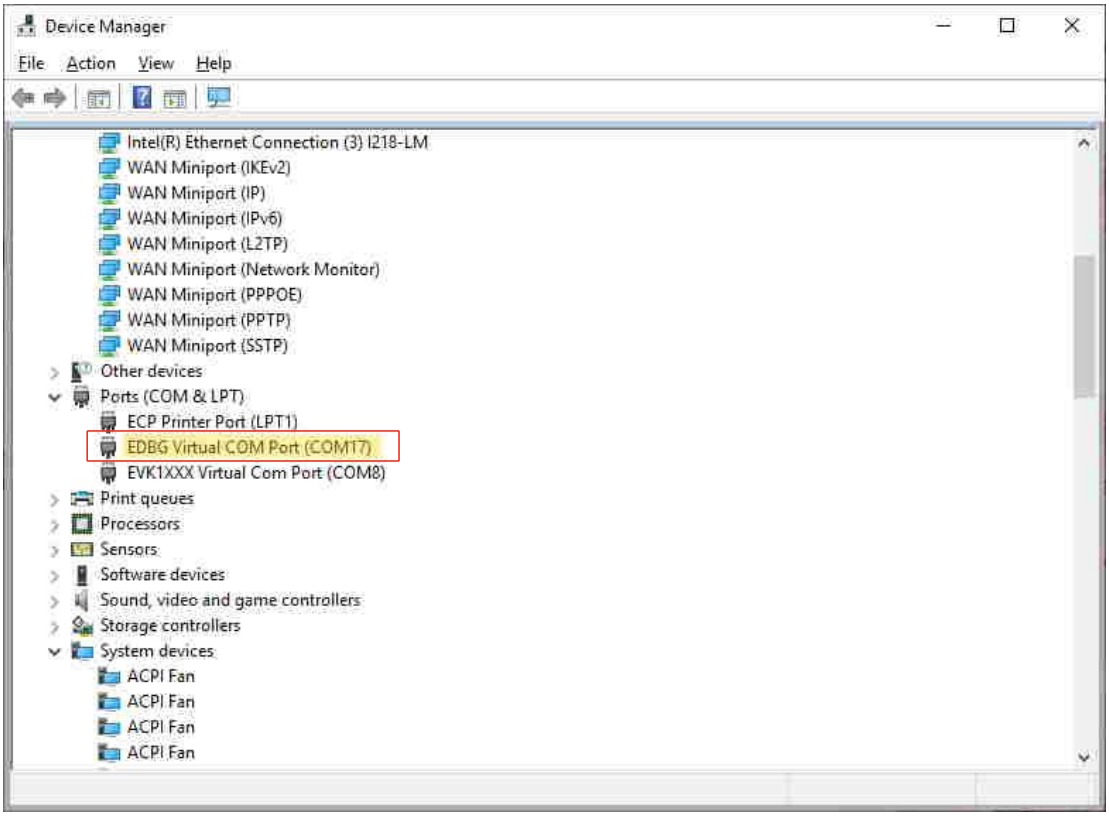
4.2 Determining the ATSAMC21-XPRO Virtual COM Port Number

The system software consists of a CARS kit PC evaluation utility, which runs on a host PC and communicates with the ATSAMC21-XPRO board via the virtual COM port. Install the USB driver (Windows 10 and later) to support the ATSAMC21-XPRO virtual COM port via a USB connection (see 7. XPRO USB Driver Installation).

Perform the following steps for determining the ATSAMC21-XPRO virtual COM port number:

1. Connect the micro-USB plug to the USB connector on the ATSAMC21-XPRO board.
2. Connect the other end of the USB cable to an open USB port on the PC. Open the Windows Device Manager on the PC.
3. Expand the “Ports (COM & LPT)” menu, then note the COM port assigned to the “EDBG Virtual COM Port”. In this example, COM17 is used while connecting the CARS kit evaluation utility program to the ATSAMC21-XPRO board.

Figure 4-1. Virtual COM Port Assignment



Note: Always ensure that the adapter cable and the USB cable are unplugged prior to inserting or removing any boards within the system.

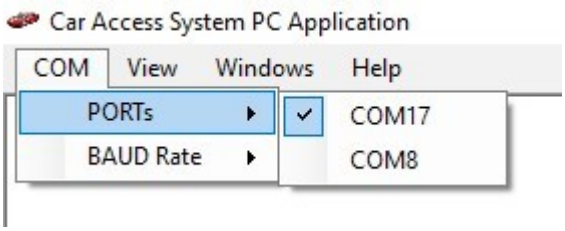
4.3 COM Port and Baud Rate Settings

Navigate to the folder containing the downloaded ATAK51005-V1 software files and open the `CARS_PC_Application.exe` file. Perform the following steps for the COM port and baud rate settings.

COM Port Settings

In the Car Access System PC Application window, navigate to *COM* > *PORTs* > *COM17*.

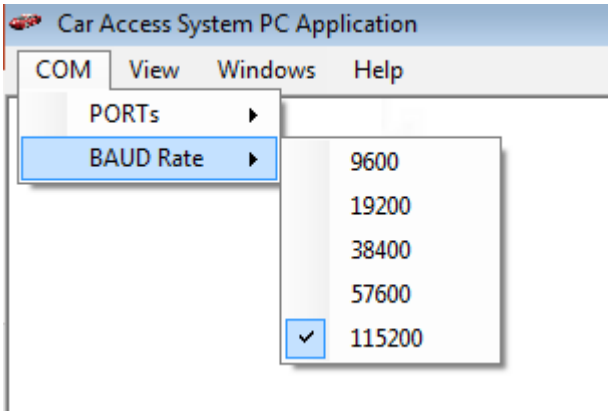
Figure 4-2. COM Port Selection



Baud Rate Settings

In the Car Access System PC Application window, navigate to *COM* > *BAUD Rate* > *115200*.

Figure 4-3. Baud Rate selection



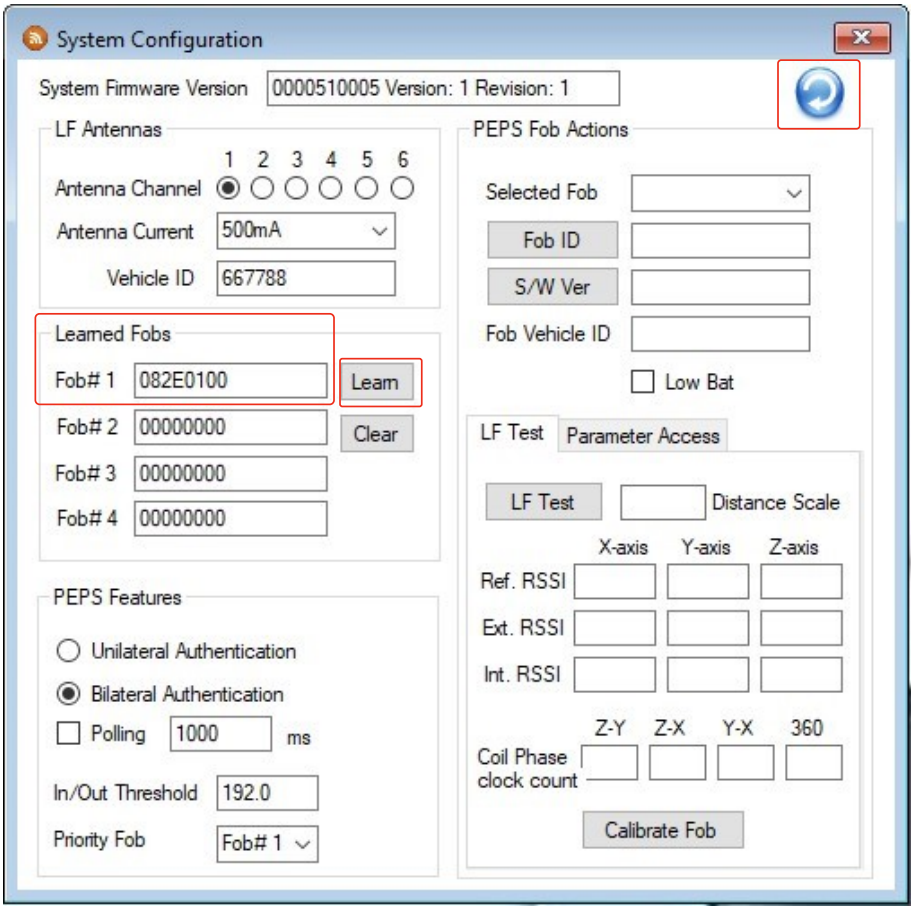
The CARS utility is now ready for use.

4.4 Initial Configuration of the CARS Kit PC Evaluation Utility

Perform the following steps for configuring the CARS kit:

1. In the Car Access System PC Application window, navigate to *View* > *System Configuration*.
2. Click on the refresh icon to update the system's firmware version and other variables. The system software version loads correctly if the connection is valid (COM port is open).

Figure 4-4. System Configuration Window



3. Place the ATAB5702A fob board in close proximity (<10 cm) to the LF antenna module, as shown in the following figure.

Figure 4-5. Fob Placement

4. Click the **Learn** button in the System Configuration window.
5. The fob UID in the “Learned Fobs” section indicates the successful completion of the learn procedure.
6. If the learn procedure is unsuccessful, repeat step 4 a couple of times. If it still fails, try moving the ATAB5702A fob board position slightly on the LF antenna module and repeat step 4.

Notes:

- The learn procedure is required for the system to function properly, during which, the fob and the base station exchange the UID and secret keys. The fob UID value is stored in the ATSAMC21-XPRO non-volatile memory upon completion of this procedure.
- Do not click the **Clear** button in the System Configuration window as doing so erases all stored UID values. Without the stored values, the system car access functions, PEPS authentication and RKE messaging do not operate.

5. System Operation

The system includes the following features:

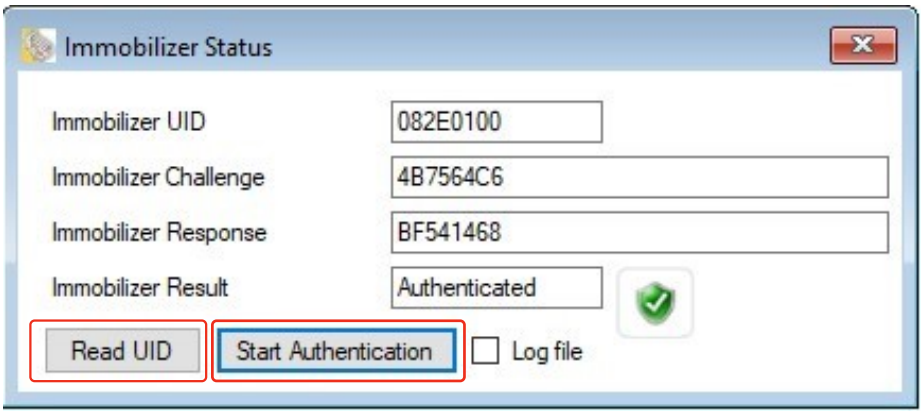
- Immobilizer functionality:
  - Supports AOIP
  - Support for AES-128 encryption
  - Passive fob authentication supporting unidirectional authentication (UA)
  - Support for base station to transponder key learn sequence used during the learning procedure
  - Support for several utility immobilizer commands (such as communication or transponder data management)
- RKE functionality:
  - Support for unidirectional AES-based rolling code protocol
  - Use of multiple channel UHF messaging provides robustness against the effects of multipath or in-band interference
- PEPS wake-up functions:
  - Selectable LF driver coil
  - Selectable LF driver current (I_{COIL} = 50 mA to 1000 mA)
  - LF driver polling support
  - Configurable preamble and header settings for LF wake-up via source code updates
  - Unidirectional UHF data return channel included

5.1 Immobilizer Operation

The immobilizer functionality is tested using the base station hardware (ATSAMC21-XPRO/ATA5291-XPRO/LF antenna module) and the ATAB5702A fob board. The CARS PC application displays the UID, challenge, response and result of the authentication in the Immobilizer Status window each time the authentication command is executed. Perform the following steps to test the immobilizer using the CARS PC application running on the host PC:

1. If not done so already, follow the procedure detailed in 4. CARS Kit PC Evaluation Utility.
2. Navigate to *View* > *Immobilizer*. The Immobilizer Status window shows the following data fields:

Figure 5-1. Immobilizer Status Window



- "Immobilizer UID" – Displays the unique ID value received from the fob
- "Immobilizer Challenge" – Displays the most current challenge data sent to the fob
- "Immobilizer Response" – Displays the most current response data received from the fob
- "Immobilizer Result" – Displays the authentication status
- "Log file" – Selecting this check box creates a new record line in a comma-separated variable (CSV) document for each received message when it is selected.

3. Place the fob near the LF antenna module within a short distance (<10 cm).
4. Click the **Read UID** button to execute the `ReadUID` command. The `ReadUID` command is sent to the fob and the fob responds by sending its UID.
   Note: This command works even for fobs not learned by the system.
5. Click the **Start Authentication** button to execute fob authentication. The green shield icon () indicates the immobilizer status upon successful execution of the start authentication command.
   Note: The Immobilizer Challenge and the Immobilizer Response values are different each time a new authentication sequence is executed because the Immobilizer Challenge is a random number. The UID value is fixed every time.
6. To test passive operation, remove the battery from the fob and repeat steps 3 through 5.

5.2 Remote Keyless Entry Operation

The RKE functionality is tested using the base station hardware (ATSAMC21-XPRO/ATA5831-XPRO) and the ATAB5702A fob board. The RKE functionality can be observed using the RKE Message Status window. On the fob, all three buttons provide RKE command messages. Each button also has two types of press actions – short press and long press, with each type handled differently. The following table shows how these are currently configured.

Table 5-1. Fob Push Buttons Functionality

Button Action	S1	S2	S3
Short press	Lock	Unlock driver door	Open trunk
Long press	Remote start	Unlock all doors	Close trunk

Except for a long press of S1, all of the other buttons transmit the RKE command messages using FSK modulation at 9.6 kbps. To carry out a long-range remote start function, a long press of S1 changes to ASK modulation at 1 kbps. The remote start function command reduces the transmitted data rate. The decrease in data rate enhances the RF sensitivity of the RF transceiver board, which increases the range. The transmitting and receiving devices are seamlessly changed, demonstrating their power and flexibility.

For high-quality performance, even in the presence of noise, each button press sends three RKE messages sequentially on three different UHF channels, referred to as Time and Frequency Domain Redundancy. Thus, it increases the probability of successful reception of at least one of the messages.

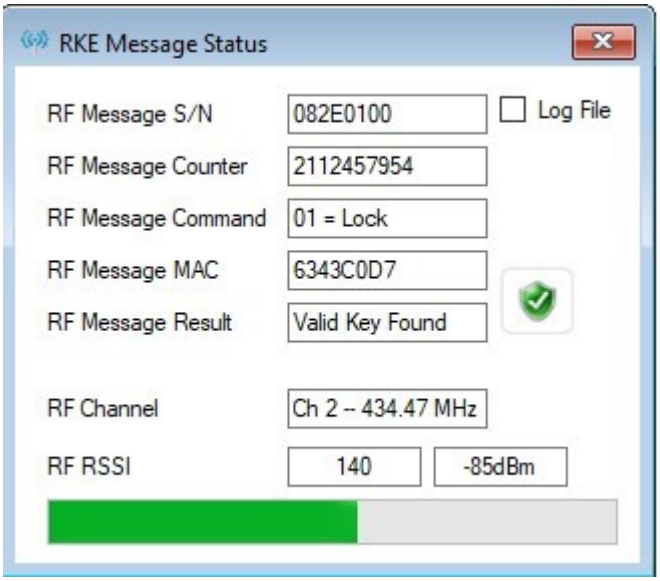
Note: For more details on the RF protocol, refer to the *AVR411: Secure Rolling Code Algorithm for Wireless Link Application Note*. For more details on time and frequency domain redundancy, refer to the *ATAN0014 RF System Architecture Considerations Application Note*.

5.2.1 RKE Operation

Once one or more fobs are paired with the system, the RKE can be tested using the CARS PC application running on the host PC as follows:

1. If not done so already, follow the procedure detailed in 4. CARS Kit PC Evaluation Utility.
2. Navigate to *View* > *RKE Messaging*. The RKE Message Status window shows the following data fields:

Figure 5-2. RKE Message Status Window



- "RF Message S/N" – Displays the UID returned by the fob. The same UID value for a given fob displays in the learned fobs section of the System Configuration window.
- "Log file" – Selecting this check box creates a new record line in a CSV document for each received message when it is selected.
- "RF Message Counter" – Displays the rolling code message counter value sent to the vehicle. This value is incremented for every key push. All RKE commands increment the counter value. The counter is checked against a window of valid counts on the vehicle side to prevent recording and replaying of past RKE messages from being accepted as valid, which is commonly referred to as Replay Attack.
- "RF Message Command" – Displays the most recent RKE command received from the fob.
- "RF Message MAC" – Displays the received 4-byte (32-bit) Message Authentication Code (MAC).
- "RF Message Result" – Displays the result of the comparison between the expected MAC (computed using AES-128) and the received MAC.
- "RF Channel" – Displays the RF channel that received the message.
- "RF RSSI" – The signal strength measured at the RF transceiver board displays in three formats. There is a decimal representation read directly from the RF transceiver device followed by a calculated dBm value. Finally, there is a bar graph that provides visual representation.

3. Press any of the RKE buttons, as discussed in the 5.2 Remote Keyless Entry Operation, to send the RKE message.

5.3 PEPS Operation

The PEPS functionality is tested using the base station hardware (ATSAMC21-XPRO/ATA5831-XPRO/ATA5291-XPRO/LF antenna module) and the ATAB5702A fob board. The PEPS operation is commanded by the CARS PC application to send LF wake-up messages to the fob, which, then, responds with information via the RF channel.

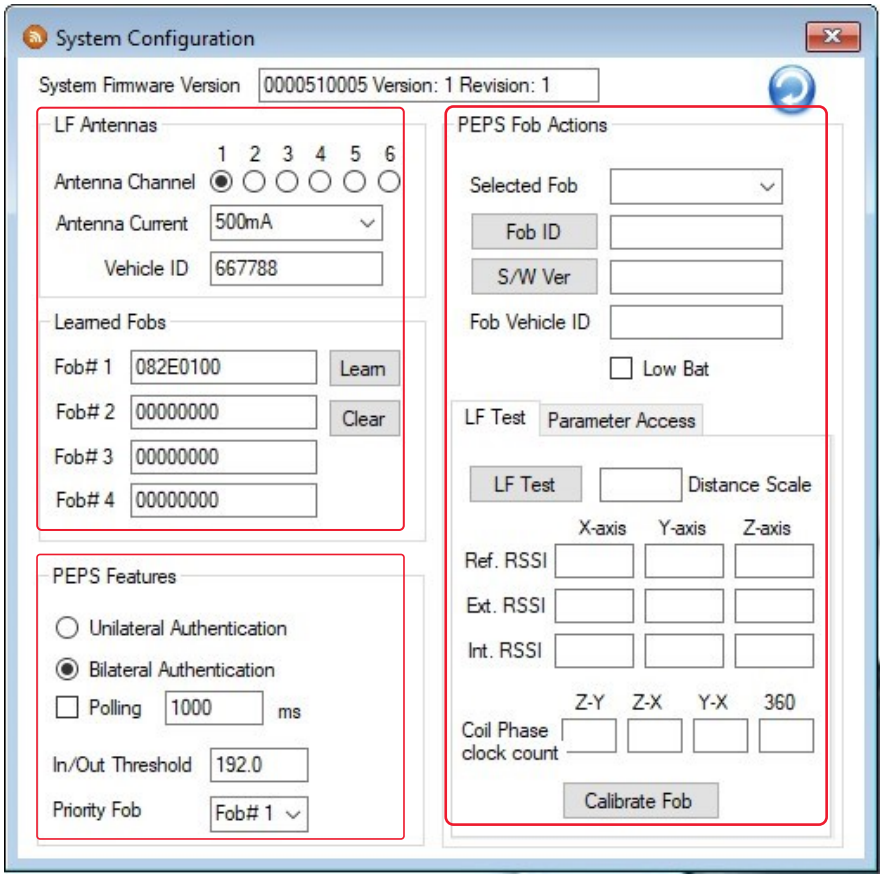
5.3.1 System Configuration Window Overview

The System Configuration window has the following functions:

- Displays specific software information
- Reports the status of the learned fobs
- Selects the PEPS authentication method
- Selects a PEPS fob to perform testing
- To set the calibration values and provide an interface to read/write user data in each selected fob

In the Car Access System PC Application window, navigate to *View > System Configuration* to open the System Configuration window, as shown in the following figure.

Figure 5-3. System Configuration Window



The System Configuration window contains the following sections and associated data fields:

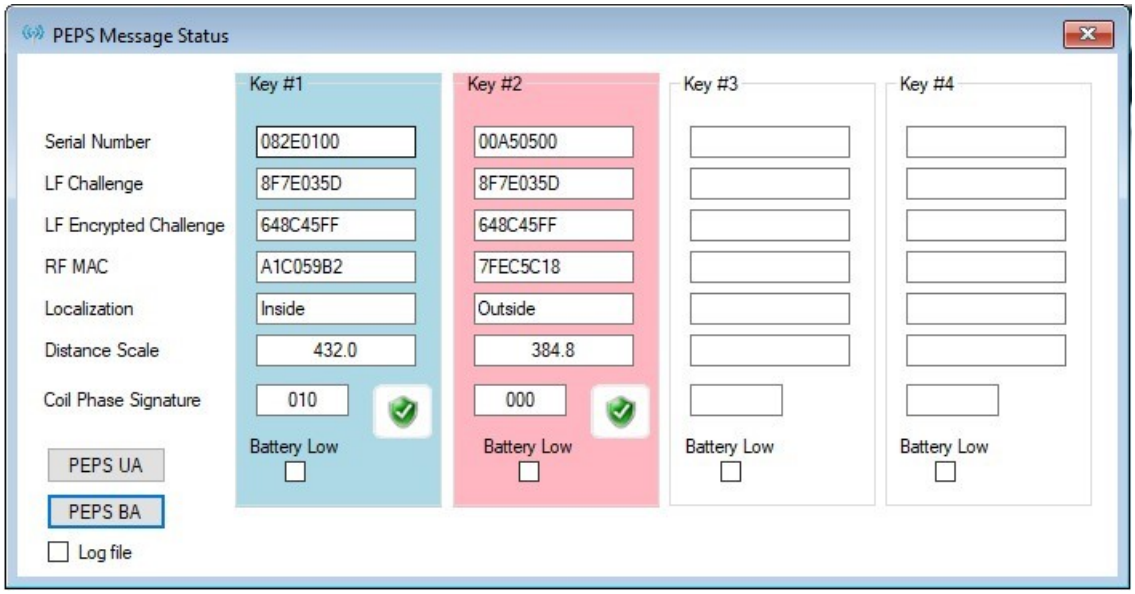
- "LF Antennas" – This section includes controls used to select the antenna channel and the current and associated vehicle ID.
  - "Antenna Channel" – Selecting any of these radio buttons assigns which antenna channel is used to send the LF message from the vehicle. The LF antenna module must be connected to the corresponding port on the ATA5291-XPRO board for this to function properly. Note that the Ant connector number on the ATA5291-XPRO board starts at Ant0 while the antenna channel displayed on the CARS PC application starts with Antenna Channel 1. As a result, Antenna Channel 1 on the PC application corresponds with Ant0 on the board. This offset count continues for all six antenna channels.
    Note: When antenna channel 1 is used, ensure that the J1 jumper on the LF antenna module is set to the inductor only (▬) position. When channels 2 through 6 are used, ensure the J1 jumper on the LF antenna module is set to the LCR option.
  - "Antenna Current" – This drop-down list determines the amount of current flowing in the LF antenna during the LF message. This is directly related to the field strength at a given distance from the antenna. Therefore, any change to this value has a direct impact on the performance of the localization during PEPS.
  - "Vehicle ID" – Sets the wake-up value transmitted with the LF message. Only fobs that are looking for this value wake up and respond. The vehicle ID is set in the fob during the learn procedure and is user-definable.
- "Learned Fobs" – This section lists up to four individual fob IDs paired with the system and saved in memory.
  - "Learn" – This button performs the initial pairing of any new fobs to the system using the immobilizer LF field provided by the LF antenna module. For details on the learn procedure, see 4.4 Initial Configuration of the CARS Kit PC Evaluation Utility .
  - "Clear" – This button erases all the saved fob secret keys and configuration data from the system memory.
    Note: The system does not have full functionality until a fob is paired.

- "PEPS Features" – This section includes configuration settings that affect PEPS messaging functions, including the type of authentication during polling, as well as, a polling interval.
  - "Unilateral and Bilateral Authentication" – Selecting either of these radio buttons has an effect on the type of communication used during polling only.
  - "Polling"– Range checking and the determination of a desired threshold performance can easily be done with polling. Selecting this check box starts the polling cycle, which repeats at a rate set in milliseconds. **Note:** 500 ms is the minimum allowable value.
  - "In/Out Threshold" – Used to determine if a fob is inside or outside of the vehicle by comparing the distance scale result against the in/out threshold value. The boundary value is user-definable and can be specified by entering a new value (1-599) in this field.
  - "Priority Fob" – This drop-down list allows users to specify which fob is given priority when responding to a PEPS command following the common slot of the anti-collision process.
- "PEPS Fob Actions" – This section allows for selection and communication with an individual fob even with other PEPS fobs present.
  - "Selected Fob" – This drop-down list allows direct access to an individual fob. Selecting "Broadcast" allows communication with any fob, even unlearned ones. This facilitates accessing a fob ID even if the vehicle ID for that specific fob is unknown.
  - "Fob ID" – This button provides a way to access the current fob ID, the vehicle ID and the battery status.
  - "S/W Ver" – This button requests the current fob software version.
  - "Low Bat" – This check box is selected by the software if the battery voltage in the current fob is below the low battery threshold (approximately 2.6V).
  - "Fob Vehicle ID" – Displays the vehicle ID stored within the current fob.
  - "LF Test" – This tab displays all the details relating to a test LF field measurement. Details such as the external, internal RSSI values and coil phase clock counts display here. The distance scale value is determined by the combined result of all post-RSSI processing. In a standard PEPS message, the distance scale and the coil phase values are sent.
  - "Parameter Access" – This tab displays general user memory sections of the fob EEPROM that can be accessed via the PEPS system link. These are configured into 32 blocks of memory with each block having 16 bytes of data available. The data can be displayed in HEX or ASCII format. To access the memory, the fob must first be put into a password-protected diagnostic mode by clicking the "Enter Diag" button. Then, for several seconds, the fob responds to read or write commands.
  - "Calibrate Fob" – This button initiates a calibration cycle, which provides reference values as each fob LF antenna coil axis has slightly different gains due to the antenna coil, capacitor and IC tolerances. This is typically done at the end-of-line testing by the manufacturer and is necessary to achieve consistent results. It only needs to be performed once for each fob.

5.3.2 PEPS Message Status Window Overview

The PEPS Message Status window displays the challenge or response information along with localization details for each fob that is learned to the system. In the Car Access System PC Application window, navigate to *View* > *PEPS Messaging* to open the PEPS Message Status window, as shown in the following figure.

Figure 5-4. PEPS Message Status Window



The PEPS Message Status window shows the following data fields:

- "Serial Number" – Displays the received fob ID. This must correspond to the value in the Learned Fobs section of the System Configuration window.
- "LF Challenge" – Displays the 4-byte LF challenge data that was sent to the fob. This challenge data is sent during bilateral and unilateral authentication.
- "LF Encrypted Challenge" – Displays the 4-byte LF encrypted data sent to the fob during bilateral authentication only.
- "RF MAC" – Displays the received RF MAC (message authentication code) value from the fob.
- "Localization" – Displays the current localization status of the current fob (for example, inside or outside the vehicle). This is determined by comparing the distance scale value against the In/Out Threshold value displayed in the System Configuration window.
  Note: The fob section is highlighted in blue if the fob is found "inside" and pink if the fob is found "outside." This allows for an easy determination from a distance while the range of the system is being tested.
- "Distance Scale" – Indicates the RSSI scale value received.
- "Coil Phase Signature" – Displays a three-digit binary code, where:

Table 5-2. Coil Phase Signature Calculation

Bit Position	Calculation Using Coil Phase Clock Count Values	Bit Value (if 90° < Calculated Result < 270°)	Bit Value (Otherwise)
1	$\frac{Z-Y\ value}{360\ value}\ x\ 360$	1	0
2	$\frac{Z-X\ value}{360\ value}\ x\ 360$	1	0
3	$\frac{Y-X\ value}{360\ value}\ x\ 360$	1	0

Note: The Z-Y, Z-X, Y-X and 360 coil phase clock count values are found in the "PEPS Fob Actions" section of the System Configuration window.

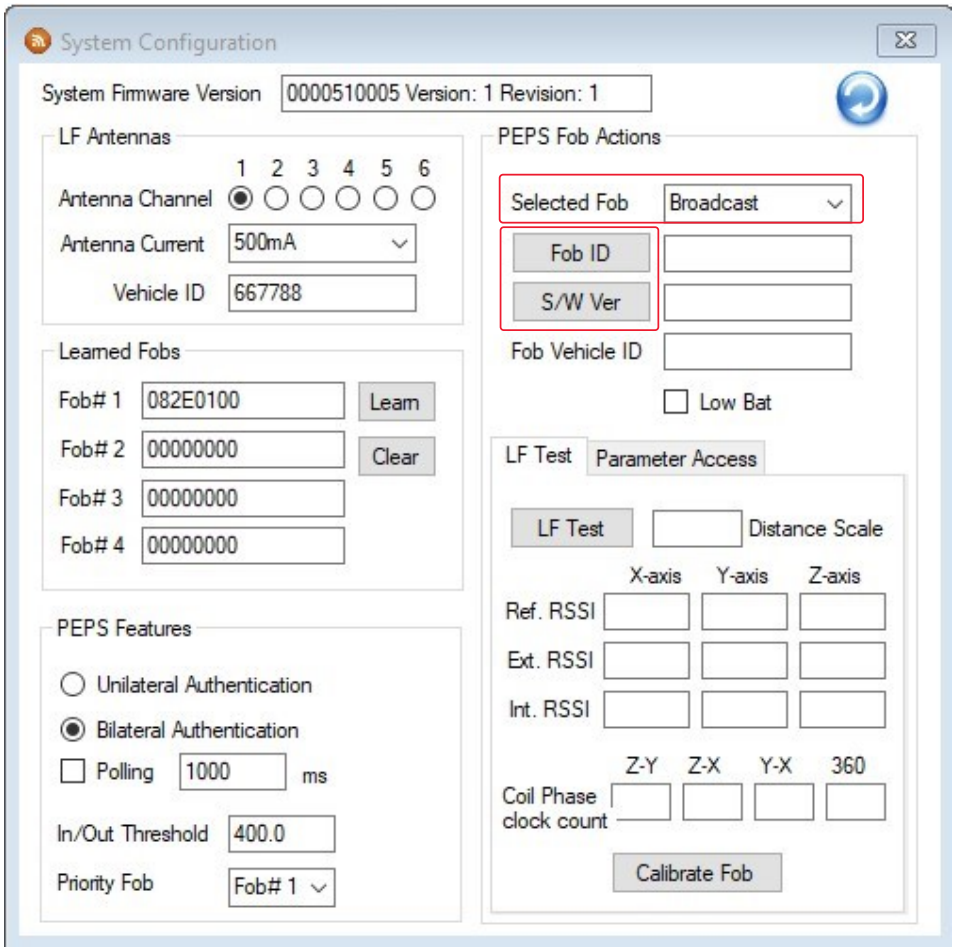
- "Battery Low" – This check box is selected by the software if the fob returns a low voltage warning indicating the battery voltage is below 2.6V (approximately).
- "Log file" – Selecting this check box creates a new record line in a CSV document for each received message when it is selected.

5.3.3 Identifying FOBS within LF Range

Identify the available fobs by sending out a broadcast, which returns the Fob# in the selected fob field. Perform the following steps to identify the available fobs within the LF range:

1. If not done already, follow the procedure detailed in 4. CARS Kit PC Evaluation Utility.
2. In the System Configuration window, choose *Broadcast* from the Selected Fob drop-down list.
3. Click the **Fob ID** button to send the broadcast request, as shown in the following figure. The available fobs respond with their fob IDs and their Fob# assignments. The “Fob Vehicle ID” field displays the returned vehicle ID.
4. Click the **S/W Ver** button to send the software version request to the fob. The “S/W Ver” field displays the returned software version number.

Figure 5-5. Identifying FOBS in Range Test Window



Notes:

- To use the broadcast function, it is recommended that only one fob be within range, and it must have a battery inserted in the battery socket.
- Fobs that are not paired with the current system or that have a different vehicle ID, can also be identified as within range. If the located fob is paired with the system, the selected fob index changes to the location in the system where the fob is believed to be stored. It is recommended that the fob ID be verified by checking it against the list of learned fobs.

5.3.4 Fob Calibration Overview

In a PEPS system, the learned fobs receive the LF signal and measure the magnetic field strength as an RSSI value. This value is reported to the vehicle and determines the fob’s position with respect to the transmitting LF antenna. To ensure RSSI accuracy, the fobs must be calibrated, including normalization and compensation, along all the three LF

antenna coil axes (X, Y and Z-axis).Typically, this calibration is performed during the final test using high precision equipment at the fob's manufacturing facility. However, with the help of the CARS PC application, the end-of-line calibration sequence is approximated by clicking the **Calibrate Fob** button in the System Configuration window.

The normalization procedure is used to establish a relationship between a known magnetic flux density and a measured RSSI value. Ideally, an Helmholtz coil is used to perform this task but, considering the constraints of the kit, this is not feasible. Instead, the RSSI value for each fob's LF antenna coil axis (X, Y and Z) is measured at a fixed distance (50 cm) from the transmitting LF antenna. Arbitrarily using the x-axis as the reference, the difference in measurements of the other two axes are stored in the EEPROM as the Normalization Constants. On the other hand, the compensation procedure accounts for any non-ideal influences; for example, magnetic flux disturbances due to adjacent ferrous bodies, temperature, aging effects and so on. The compensation procedure is based on the following:

- "Ref. RSSI" – Denotes the internal RSSI values measured with reference conditions (end-of-line) [1]
- "Int. RSSI" – Denotes the current internal RSSI measured with no external LF signal present [2]
- "Ext. RSSI" – Denotes the current external RSSI measured with external LF signal present [3]

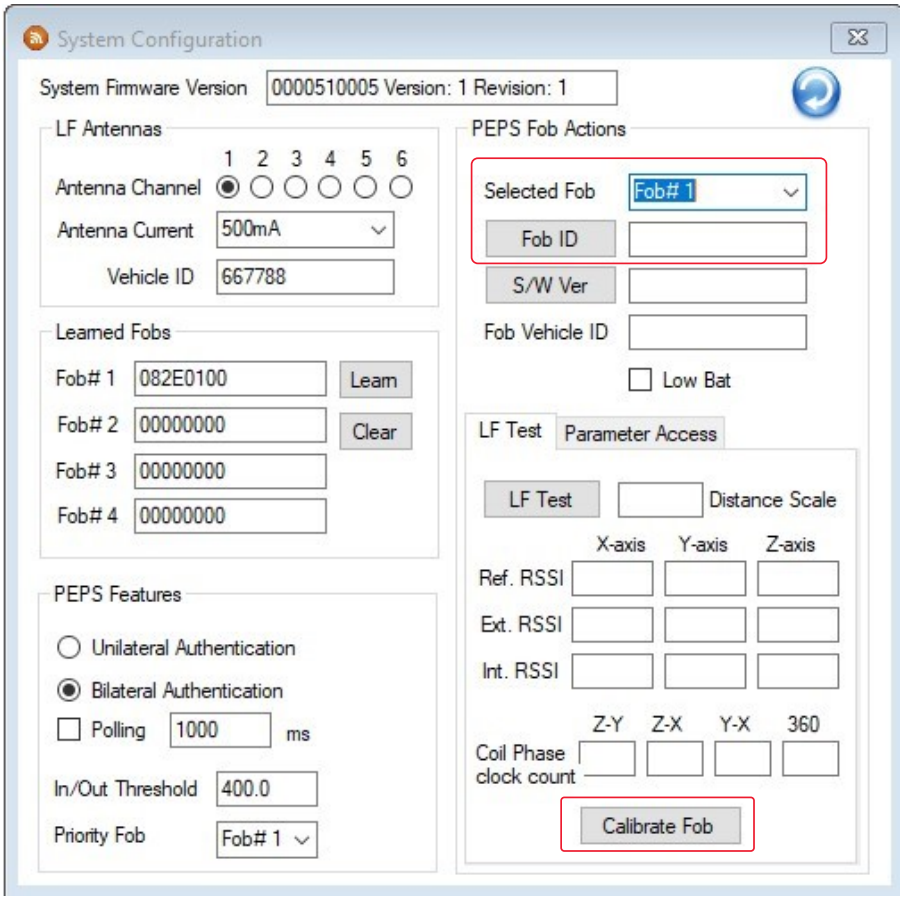
The actual RSSI amplitude is, then, calculated by adding the error term [1] – [2] to the values measured at [3]. The normalization and compensation procedures ensure that a constant RSSI is reported, regardless of the fob orientation, and ensures accuracy over a large set of influences.

5.3.5 Fob Calibration Process

Perform the following calibration steps for each fob separately:

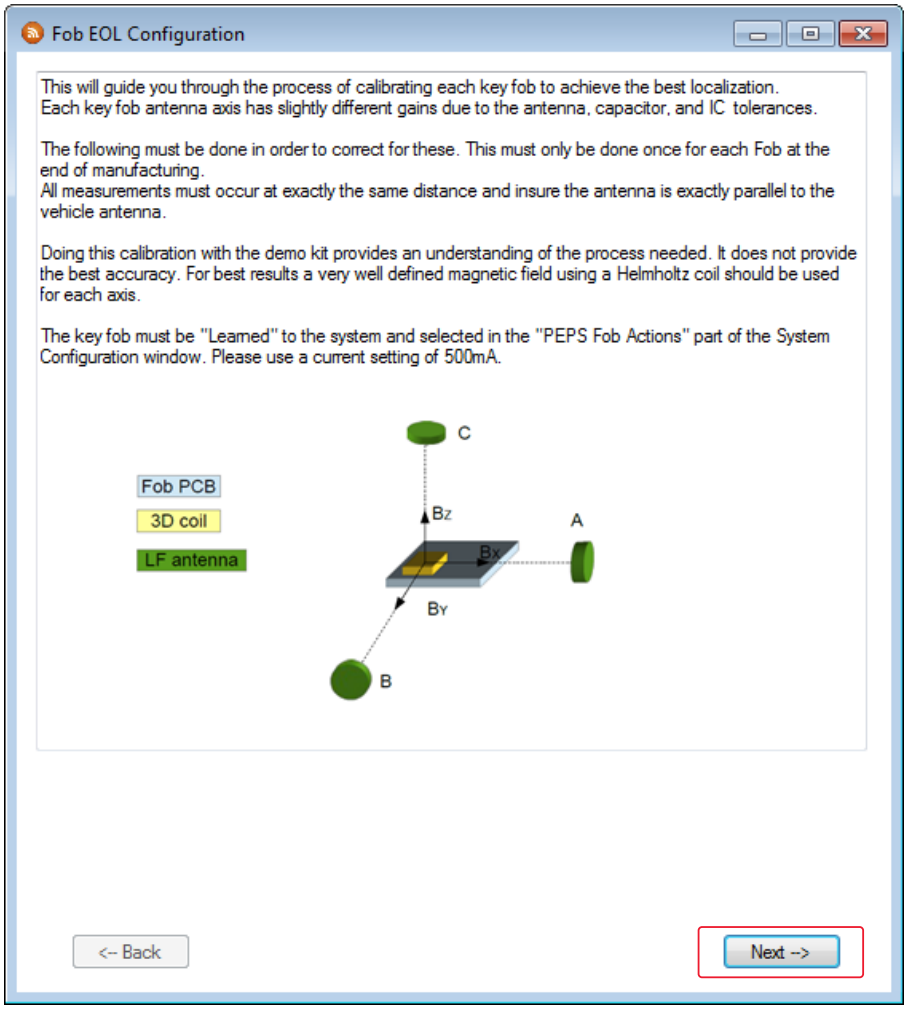
1. If not done already, follow the procedure detailed in 4. CARS Kit PC Evaluation Utility.
2. In the System Configuration window, choose the fob to be calibrated in the "Selected Fob" drop-down list, as shown in the following figure.
3. Click the **Fob ID** button followed by the **Calibrate Fob** button.

Figure 5-6. FOB Calibration



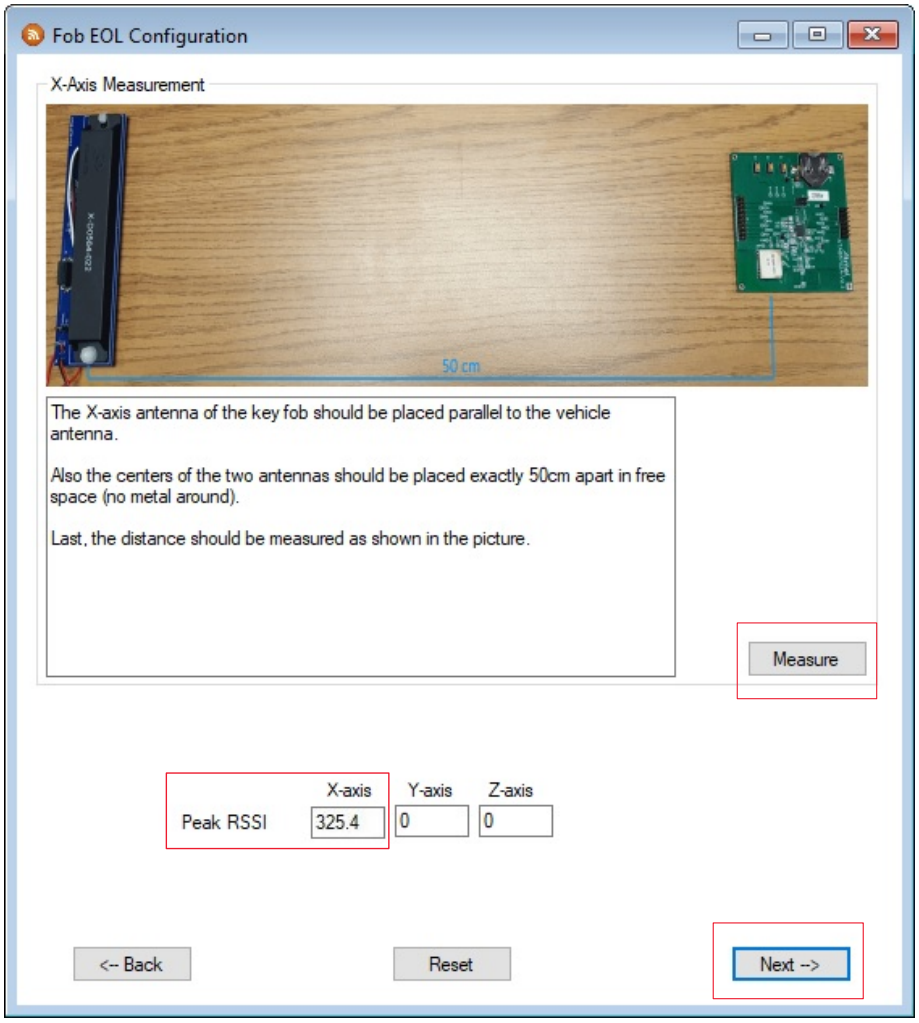
4. Click the **Next** button within the Fob EOL Configuration window.

Figure 5-7. FOB EOL Configuration Window



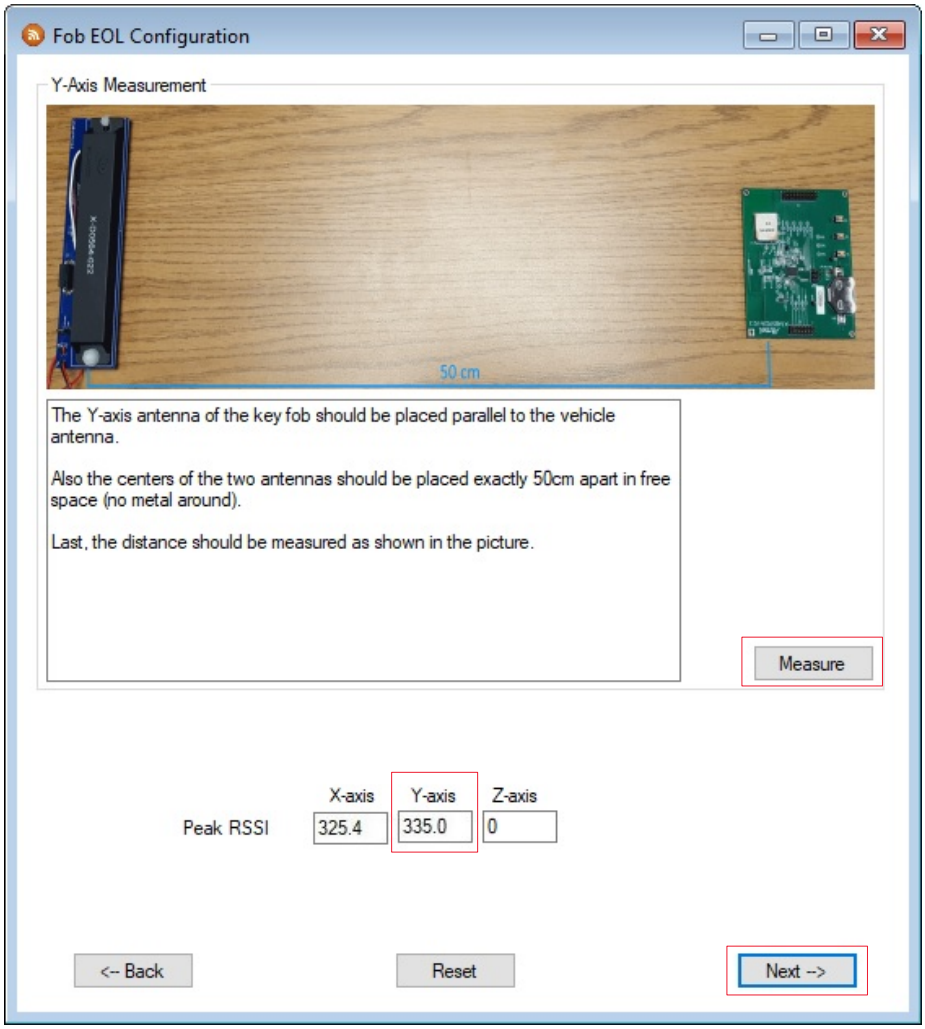
5. Position the LF antenna module and the fob (as shown in the following figure) to align the X-axis of the fob with the LF antenna module axis, then click the **Measure** button. This measures the current X-axis RSSI signal amplitude and updates the result to the “Peak RSSI” field for the X-axis. Click the **Measure** button several times to ensure the peak value is stable.
6. Click the **Next** button.

Figure 5-8. X-Axis Peak RSSI



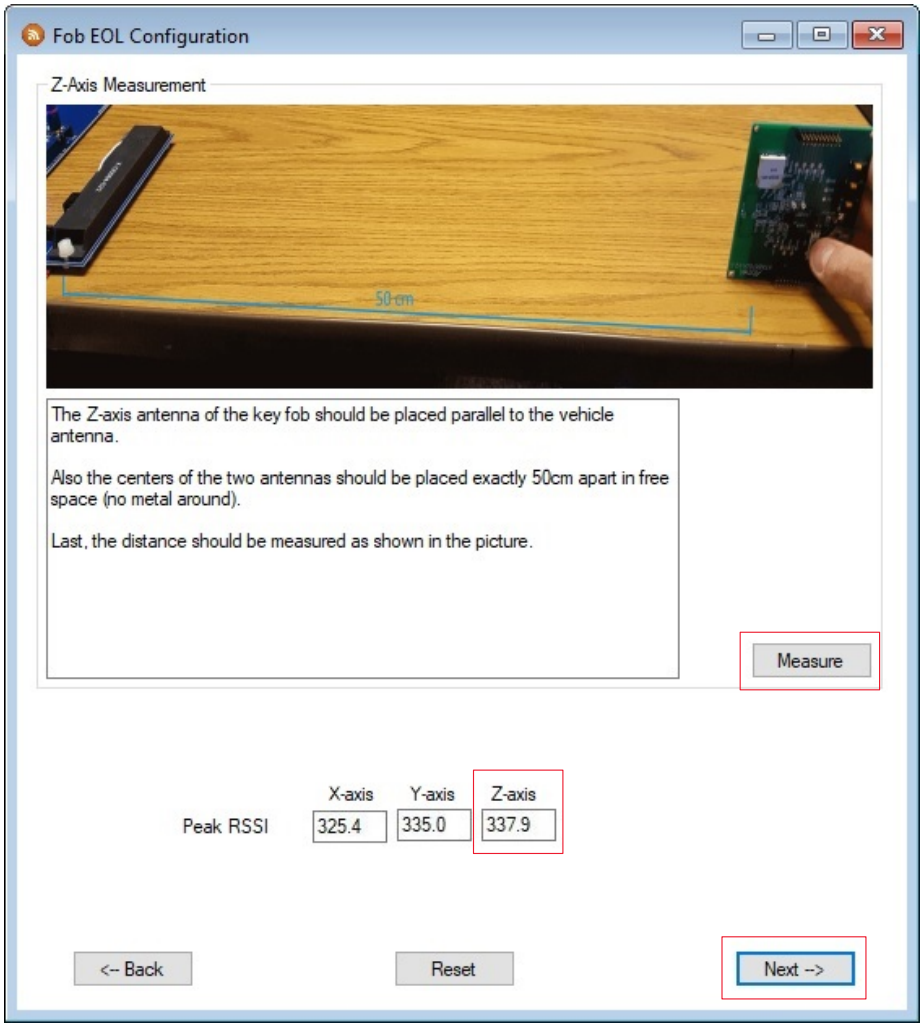
7. Position the fob (as shown in the following figure) to align the Y-axis, then click the **Measure** button. This measures the current Y-axis RSSI signal amplitude and updates the result to the “Peak RSSI” field for the Y-axis. Click the **Measure** button several times to ensure the peak value is stable.
8. Click the **Next** button.

Figure 5-9. Y-Axis Peak RSSI



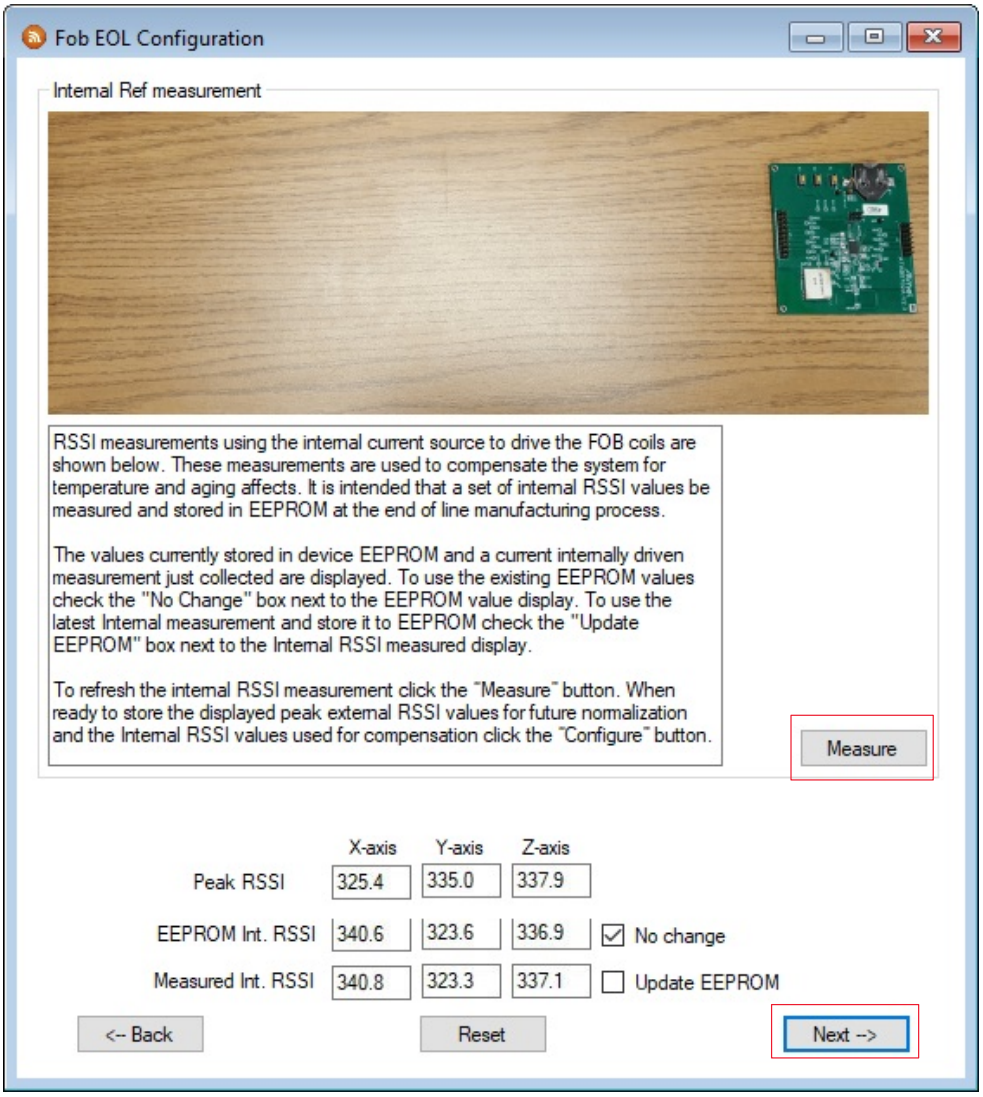
9. Position the fob (as shown in the following figure) to align the Z-axis, then click the **Measure** button. This measures the current Z-axis RSSI signal amplitude and updates the result to the “Peak RSSI” field for the Z-axis. Click the **Measure** button several times to ensure the peak value is stable.
10. Click the **Next** button.

Figure 5-10. Z-Axis Peak RSSI



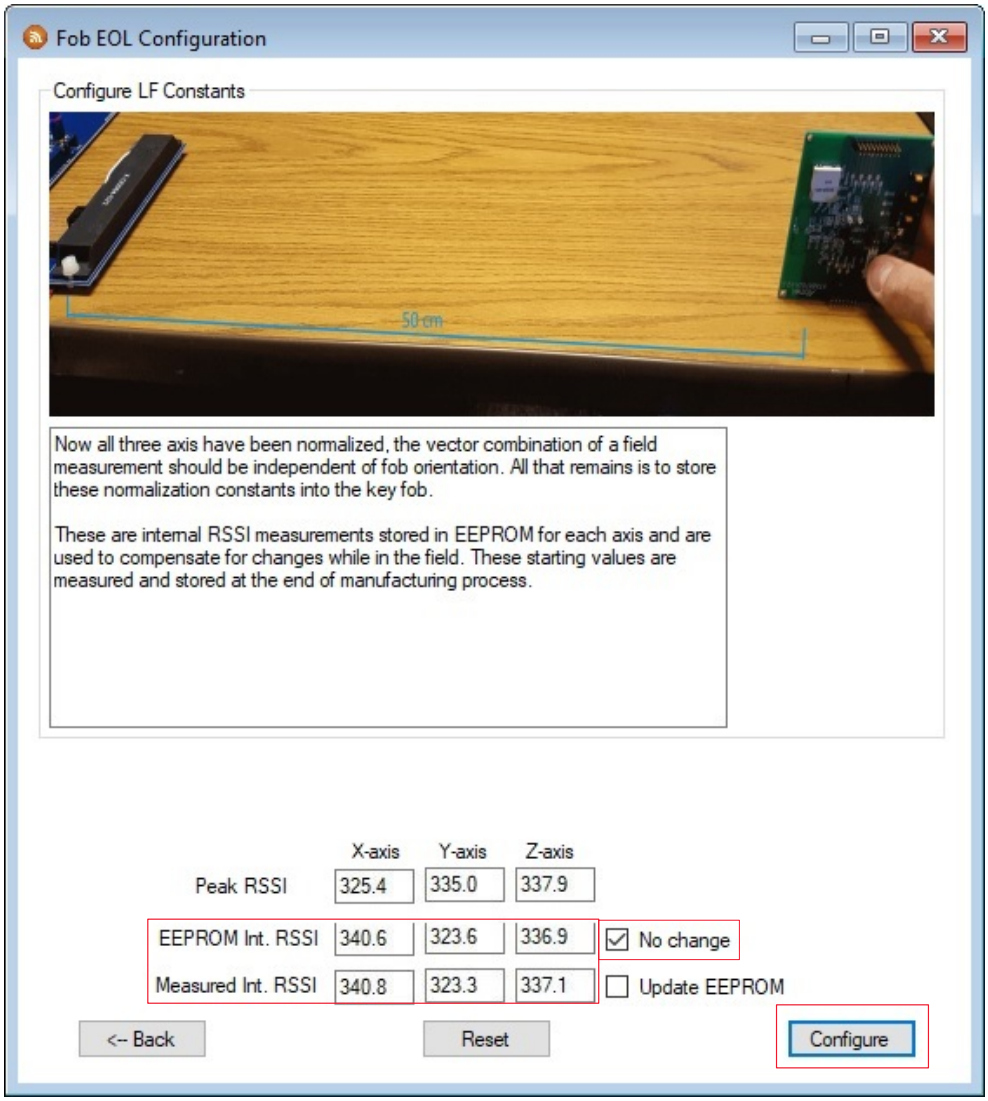
11. Click the **Measure** button (as shown in the following figure) to have the fob perform an internal RSSI measurement and display the results in the “Measured Int. RSSI” field. This measurement is performed by an internal current source, which drives each of the fob’s 3-axis LF antenna coil circuits.
12. Click the **Next** button.

Figure 5-11. Internal RSSI Measurement



13. Click the **Configure** button to store the compensation constants into the fob EEPROM (indicated by a blinking LED on the ATAB5702A fob board). Before closing the Fob EOL Configuration window, wait until the LEDs stop blinking.
    Note: If there is only a slight difference in the Int. RSSI values, select the “No change” check box.

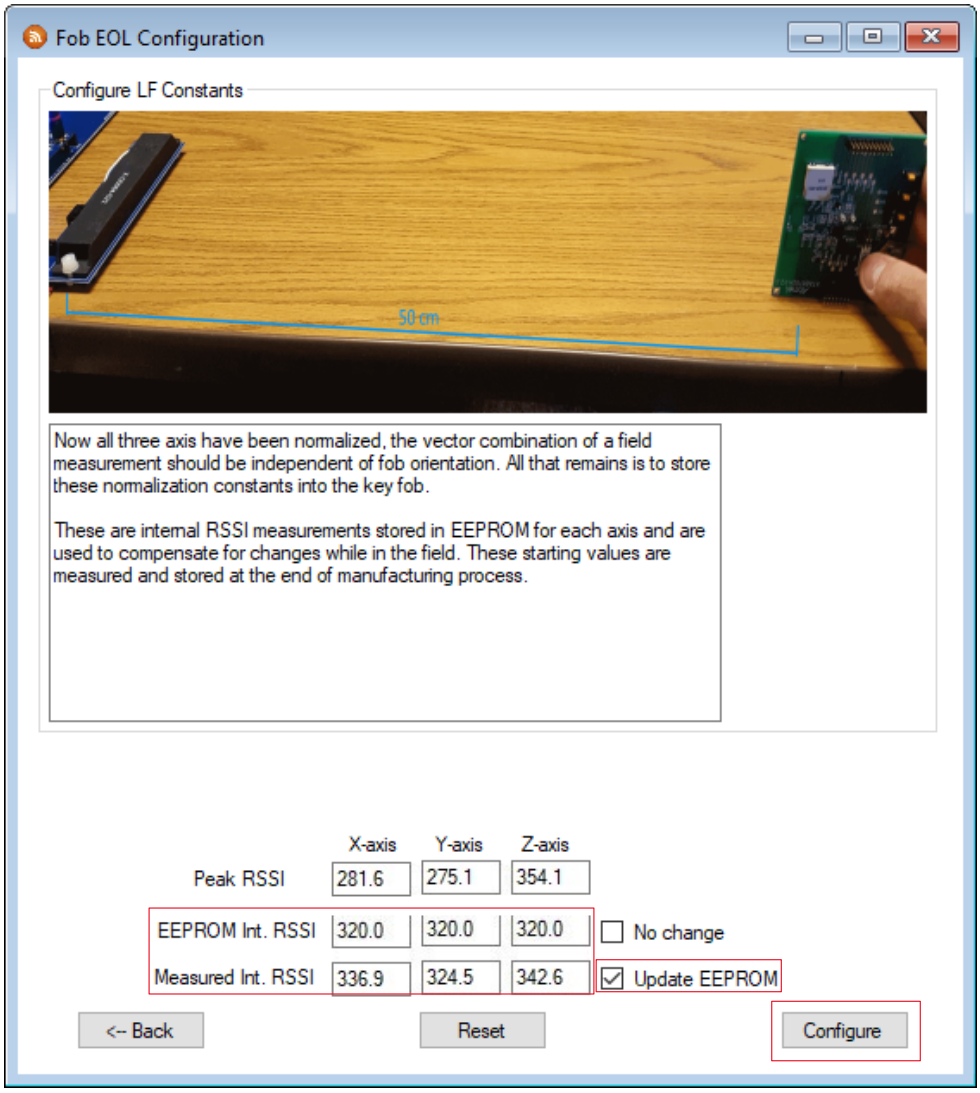
Figure 5-12. Slight Difference in Internal RSSI



Notes:

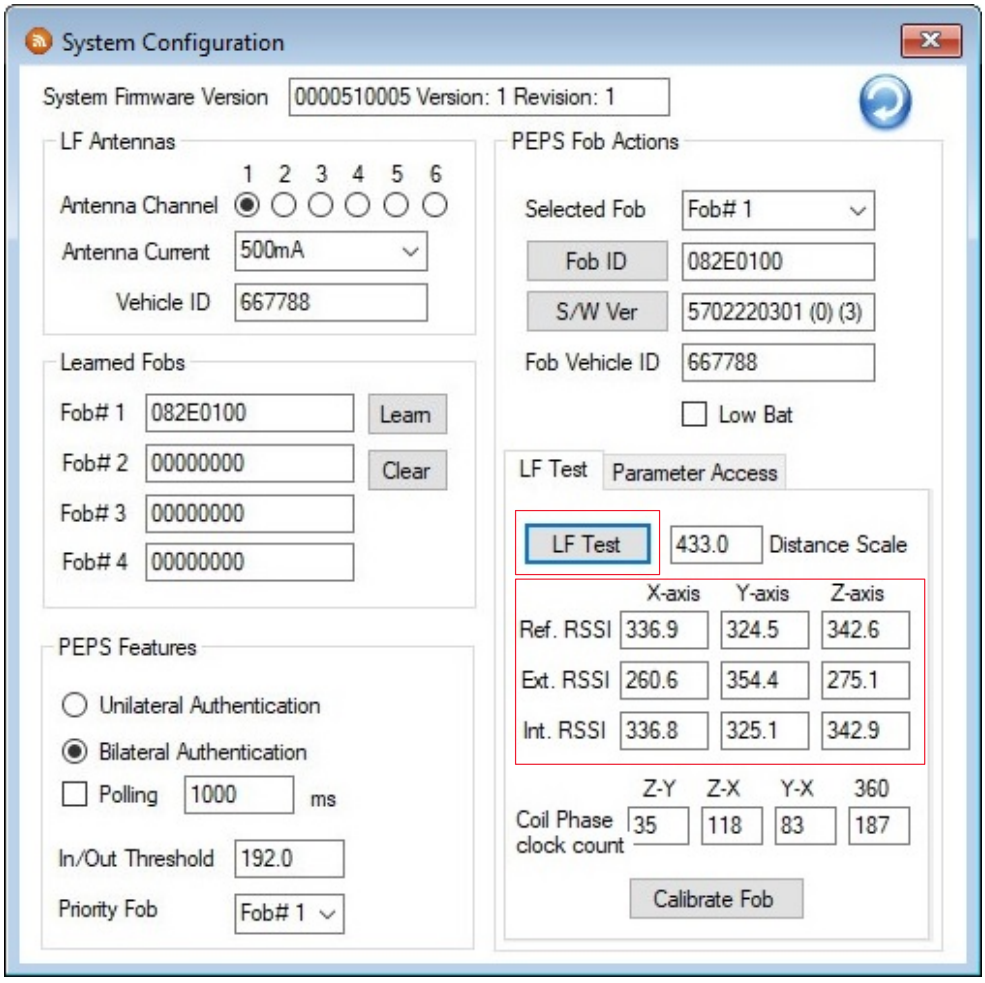
- If there is a significant difference between the "Measured Int. RSSI" and the "EEPROM Int. RSSI" fields, select the “Update EEPROM” check box. This can occur when the fob's components age over time or if a change in the circuit has occurred (for example, evaluating a different 3D coil).
- Selecting the “Update EEPROM” check box updates the RSSI values currently stored in the EEPROM with the newly measured values.

Figure 5-13. Significant Difference in Internal RSSI Values



14. Click the **LF Test** button in the System Configuration window to check if the calibration values are stored in the EEPROM, and to display the RSSI values in the respective fields within the “PEPS Fob Actions” section. The “Ref. RSSI” values under the “PEPS Fob Actions” section must match the “Measured Int. RSSI” values from the Fob EOL Configuration window. Repeat the fob calibration if these values do not match.

Figure 5-14. RSSI Values

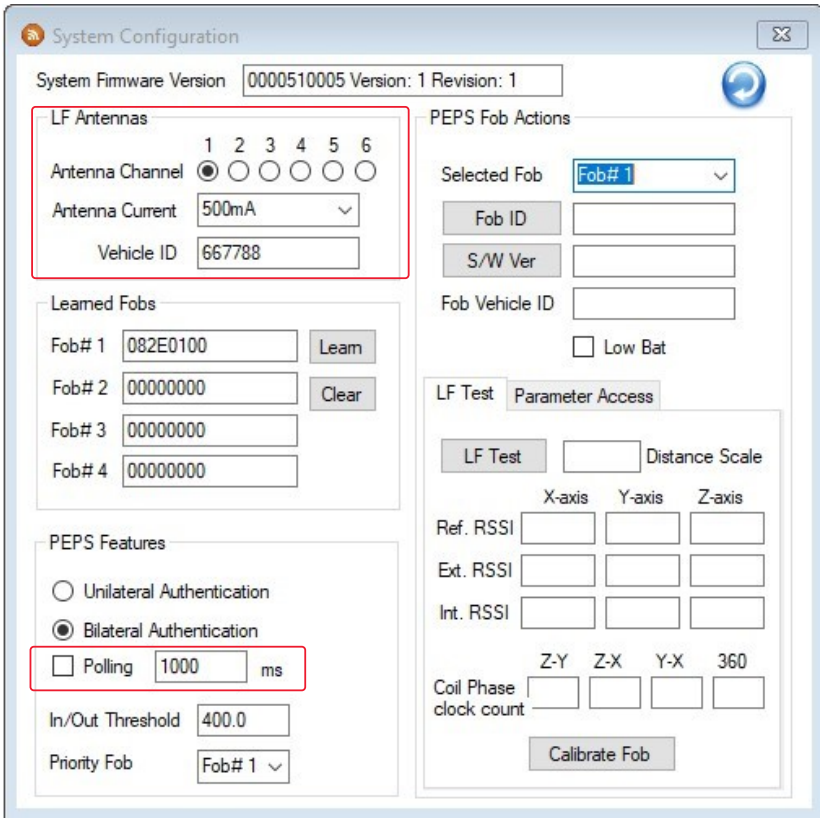


5.3.6 PEPS Wake-up Functionality

The PEPS wake-up functionality can be tested using the CARS PC application running on the host PC as follows:

1. If not done already, follow the procedure detailed in 4. CARS Kit PC Evaluation Utility.
2. If not done already, follow the calibration procedure detailed in 5.3.5 Fob Calibration Process .
3. Select the desired LF antenna channel to send the LF message, as shown in the following figure.
   Note: When Antenna Channel 1 is used, ensure that the J1 jumper on the LF antenna module is set to the inductor only ( ) position. When Antenna Channels 2 through 6 are used, ensure the J1 jumper on the LF antenna module is set to the LCR option. Note that the Ant connector number on the ATA5291 XPRO board starts at Ant0 while the antenna channel displayed on the CARS PC application starts with Antenna Channel 1. As a result, Antenna Channel 1 on the PC application corresponds with Ant0 on the board. This offset count continues for all six antenna channels.

Figure 5-15. LF Antennas and Polling



4. Select the desired LF Antenna Current.
5. Enter the polling interval value in milliseconds (for example, *1000*, meaning the LF wake-up signal is transmitted every one second).
   Note: 500 ms is the minimum allowable interval.
6. Select the “Polling” check box to enable polling and ensure that the LEDs on the fob blink each time the new wake-up signal is received.
7. Type in a new Vehicle ID (for example, *887766*), click on any other field within the window and ensure that the LEDs on the fob no longer blink. This demonstrates that the fob only wakes up for the vehicle it was paired to.
8. Type in the original Vehicle ID: *667788.*
9. Deselect the “Polling” check box to disable polling.

5.3.7 PEPS Communication

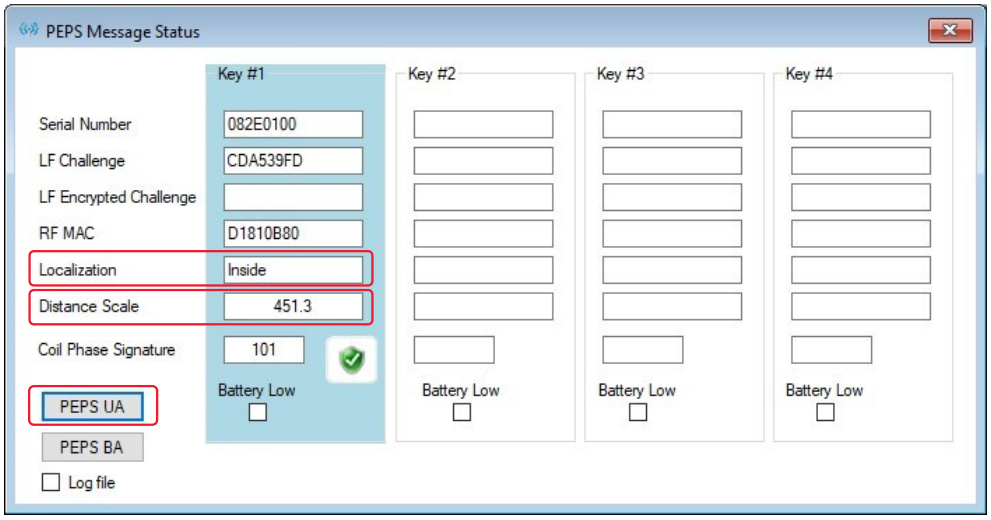
The PEPS communication functionality can be tested using the CARS PC application running on the host PC as follows:

1. If not done already, follow the procedure detailed in 4. CARS Kit PC Evaluation Utility.
2. If not done already, follow the calibration procedure detailed in 5.3.5 Fob Calibration Process .
3. Position the fob at the desired distance from the LF antenna module that will be used for the fob’s in/out threshold.
4. Navigate to *View* > *PEPS Messaging* to open the PEPS Message Status window, as shown in Figure 5-4.
5. Click the **PEPS UA** button and, after the authentication sequence completes, note the value of the number in the “Distance Scale” field of the PEPS Message Status window. Enter this value in the “In/Out Threshold” field of the System Configuration window (see Figure 5-15).
6. Move the fob closer to the LF antenna module.
7. Click the **PEPS UA** button within the PEPS Message Status window to execute the unilateral authentication sequence.

Note: The “LF Encrypted Challenge” field is not populated as this data is not transmitted to the fob.

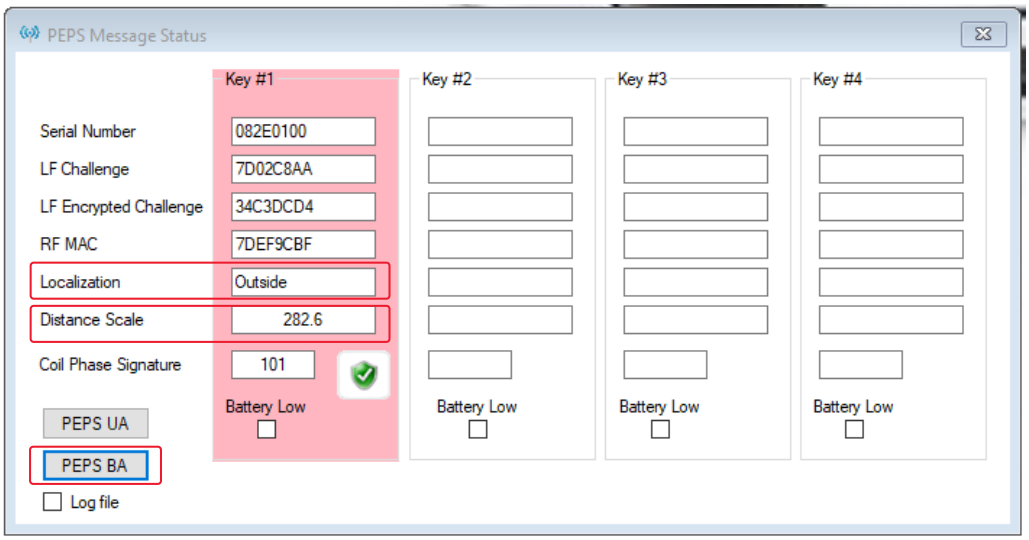
Example: The results of a PEPS unilateral authentication sequence display in the following figure. With the In/Out Threshold as *400.0* and the measured value distance scale as *451.3*, the fob is identified as *Inside* the vehicle and is highlighted in blue due to the distance scale value being greater than the threshold value.

Figure 5-16. PEPS Bilateral Authentication with Inside Localization



8. Move the fob further away from the LF antenna module, beyond the location used in step 3 but still within the PEPS operating range.
9. Click the **PEPS BA** button within the PEPS Message Status window to execute the bilateral authentication sequence. Confirm that the “LF Encrypted Challenge” field is now populated.
   Example: The results of a PEPS bilateral authentication sequence display in the following figure. With the In/Out Threshold as *400.0* and the measured value distance scale as *282.6*, the fob is identified as *Outside* the vehicle and is highlighted in pink due to the distance scale value being less than the threshold value.

Figure 5-17. PEPS Bilateral Authentication with Outside Localization



Notes:

- Either the **PEPS UA** or **PEPS BA** buttons can be used for either inside or outside localization.
- Each time the **PEPS UA** or **PEPS BA** button is clicked, a new PEPS wake-up signal is generated. Once the fob receives the wake-up signal, the LED on the fob blinks and the PEPS Message Status window information is updated.
- A continuous polling sequence can be achieved by selecting the “Polling” check box in the “PEPS Features” section of the System Configuration window. This polling feature can be used to dynamically determine the PEPS fob area coverage in real-time with the PEPS results displaying in the PEPS Message Status window.

6. Programming Instructions

Specific firmware (Flash) and, in some devices, configuration settings (EEPROM) are required to operate the system. These are found in the MCU (ATSAMC21-XPRO) and the RF transceiver (ATA5831-XPRO) on the vehicle side. The fob requires its own PEPS, IMMO and RKE firmware and configuration files. The following list describes exactly what type of files are needed for each device:

- Vehicle side:
  - ATSAMC21-XPRO: PEPS, IMMO and RKE firmware and configuration in Flash
  - ATA5831-XPRO: PEPS and RKE configuration in the EEPROM
- Fob side:
  - ATAB5702A fob board: PEPS, IMMO and RKE firmware in Flash and configuration in the EEPROM

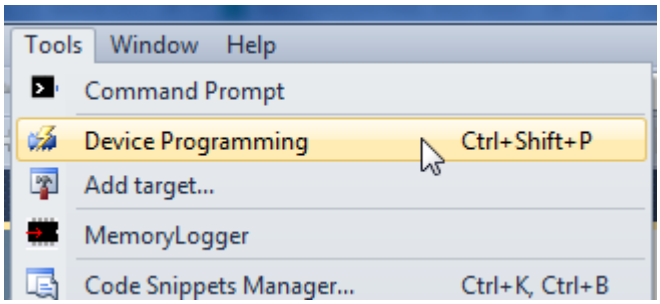
Note: All devices within this system are shipped unprogrammed; therefore, the programming procedure is described in the following sections. Programming is also required when the revised ATAK51005-V1 tool package software is available for download from www.microchip.com/developmenttools/ProductDetails/ATAK51005-V1 or when the source code has been modified or when a device becomes erratic or unresponsive in behavior.

6.1 Programming the ATA5702 on the ATAB5702A Fob Board

To program the ATA5702 on the ATAB5702A fob board, first connect the programmer (for example, Atmel-ICE or JTAGICE3) to the ISP header located near the center of the board. The following steps use an Atmel-ICE programmer and the ISP interface for programming:

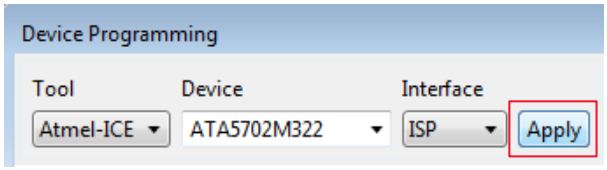
1. In Atmel Studio 7, navigate to *Tools* > *Device Programming*.

   Figure 6-1. Device Programming



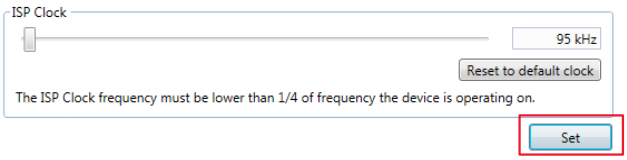
2. Select the Tool, Device and Interface, as shown in the following figure, then click **Apply**.

   Figure 6-2. ATA5702 Device Selection



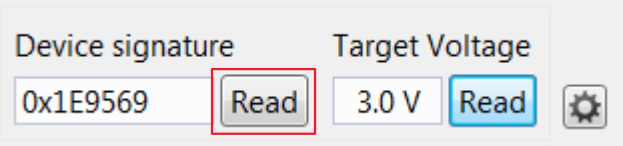
3. Ensure that the ISP frequency is less than 100 kHz. Click **Set**.

   Figure 6-3. ATA5702 ISP Clock Frequency



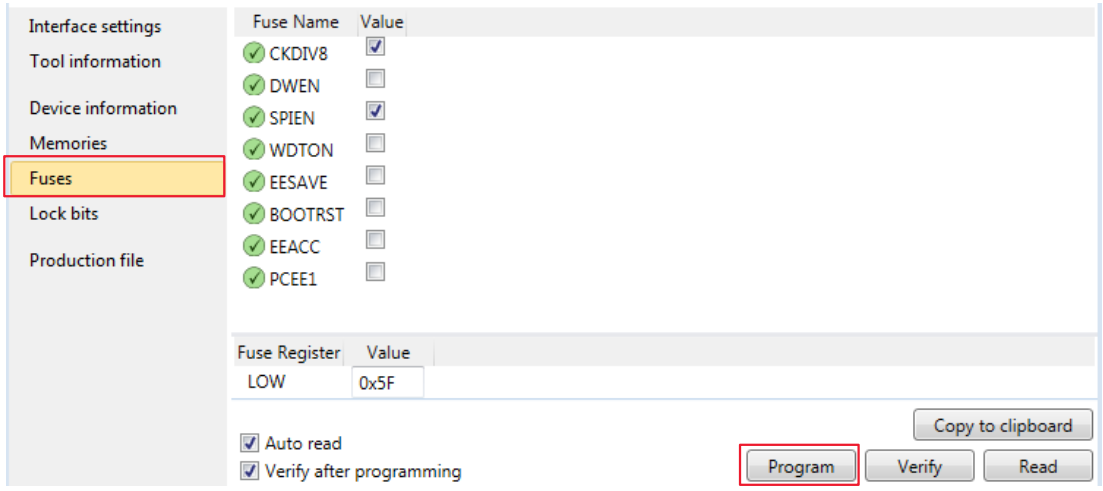
4. Click the **Read** button to ensure that the signature matches the selected device.

Figure 6-4. ATA5702 Signature Verification



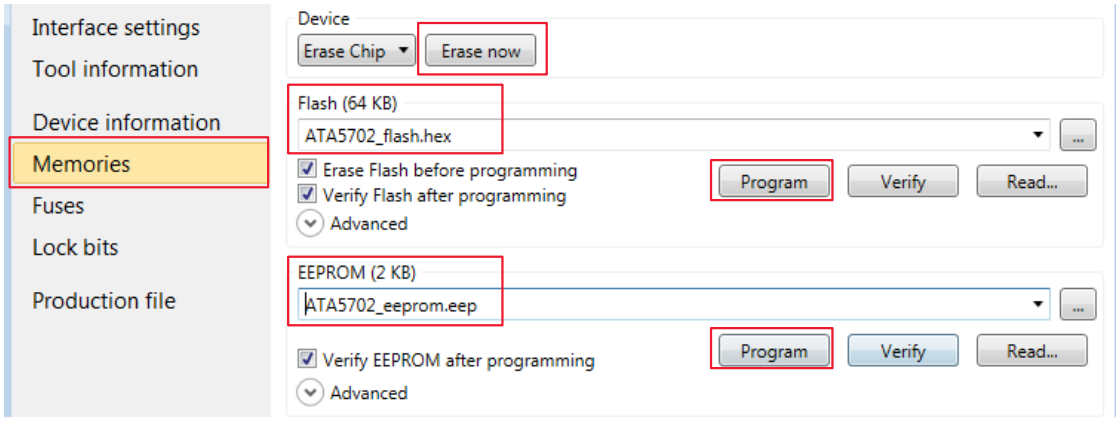
5. Select the **Fuses** tab, then verify that the proper fuse settings exist. If not, change them to match the following figure, then click the **Program** button.

Figure 6-5. ATA5702 Fuse Settings



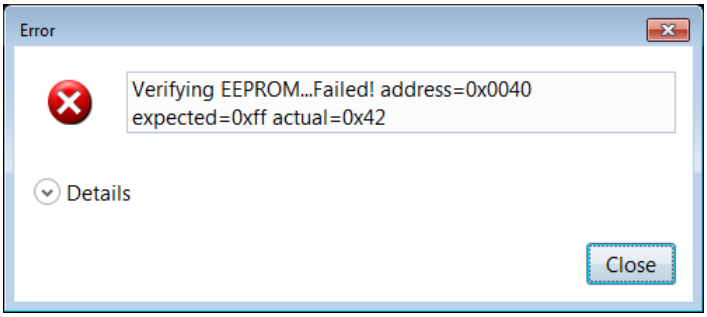
6. Select the **Memories** tab, then click the **Erase now** button.
7. Browse to locate the `ATA5702_flash.hex` file for the flash memory image.
8. Click the **Program** button, then wait for completion.
9. Browse to locate the `ATA5702_eeprom.eep` file for the EEPROM memory image.
10. Click the **Program** button, then wait for completion.

Figure 6-6. ATA5702 Memory Settings



Note: If the EEPROM verification fails (as shown in the following figure), repeat steps 1-10 to ensure the configuration is correct. If the error still occurs, then the ATA5702 IC version is outdated and the user must contact their local sales representative for an upgrade.

Figure 6-7. EEPROM Verification Failure

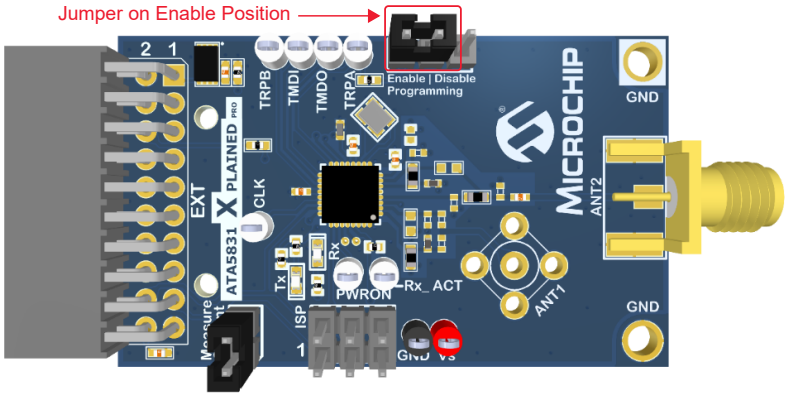


6.2 Programming the ATA5831 on the ATA5831-XPRO Board

Perform the following steps to program the ATA5831 on the ATA5831-XPRO board:

1. Insert the ATA5831-XPRO board in the EXT1 connector on the ATSAMC21-XPRO board.
2. Connect the micro-USB plug to the USB connector on the ATSAMC21-XPRO board, then connect the other end of the USB cable to an open USB port on the PC.
3. Connect the programmer (for example, Atmel-ICE or JTAGICE3) to the ISP header located near the edge of the board.
4. Place a jumper on the Enable position of the Enable | Disable Programming header, the two pins closest to the EXT connector, as shown in the following figure.

Figure 6-8. Jumper Placement on the ATA5831-XPRO Board for EEPROM Programming



Note: For better clarity, the ATSAMC21-XPRO board is not shown.

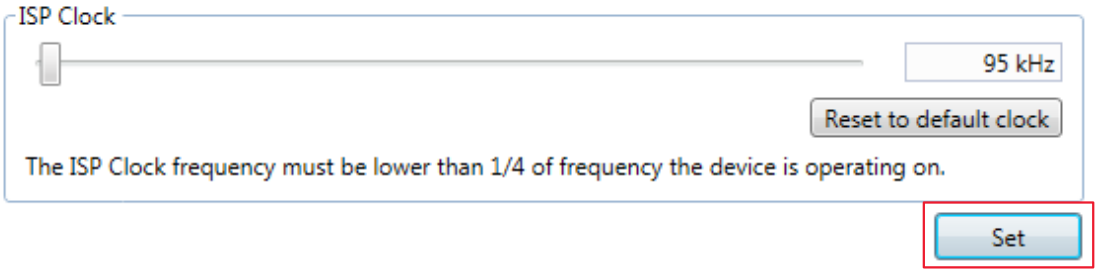
The following steps use an Atmel-ICE programmer and the ISP interface for programming:

1. In Atmel Studio 7, navigate to *Tools > Device Programming*.
2. Select the Tool, Device and Interface, as shown in the following figure, then click **Apply**.

   Figure 6-9. ATA5831 Device Selection

3. Ensure that the ISP frequency is less than 100 kHz. Click **Set**.

Figure 6-10. ATA5831 ISP Clock Frequency

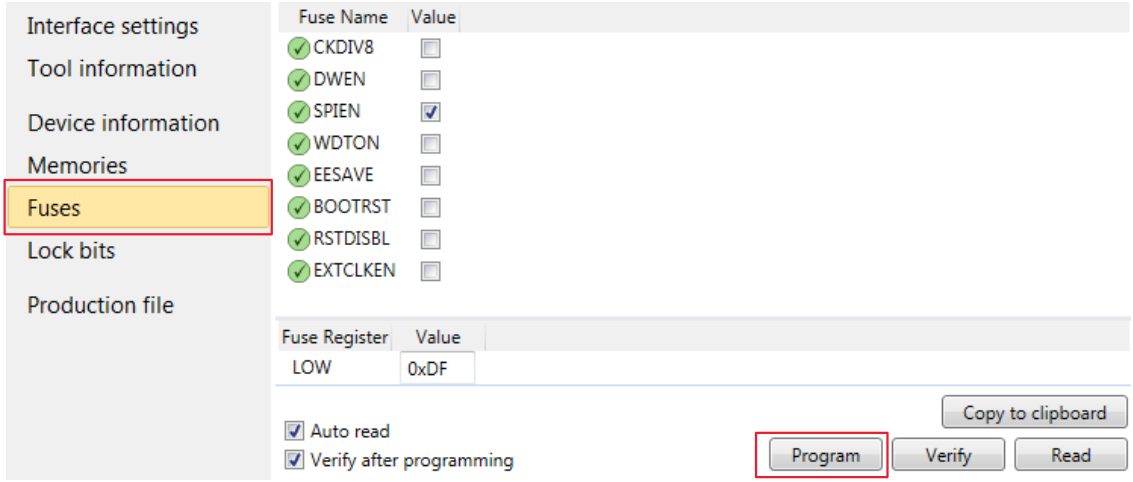


4. Click the **Read** button to ensure that the signature matches the selected device.

Figure 6-11. ATA5831 Signature Verification

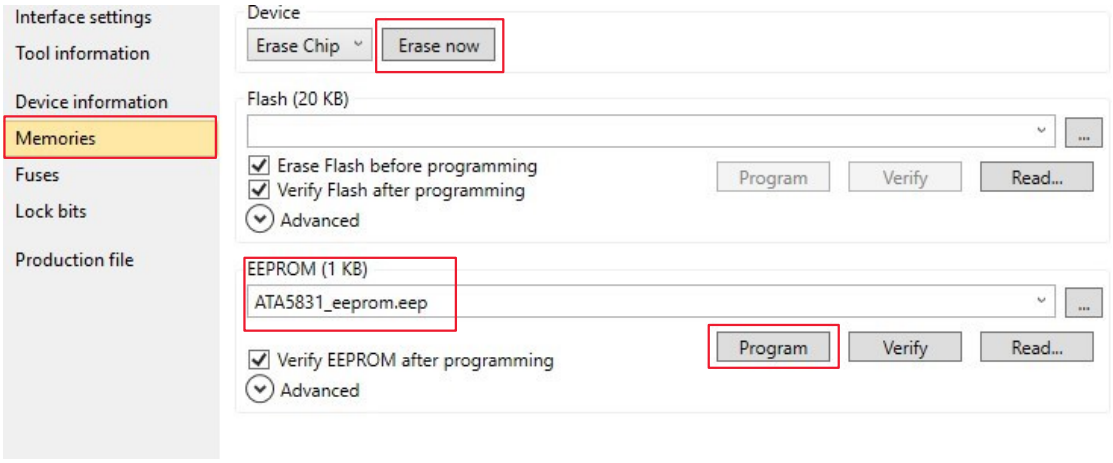
5. Select the **Fuses** tab and verify that the proper fuse settings exist. If not, change them to match the following figure, then click the **Program** button.

Figure 6-12. ATA5831 Fuse Settings



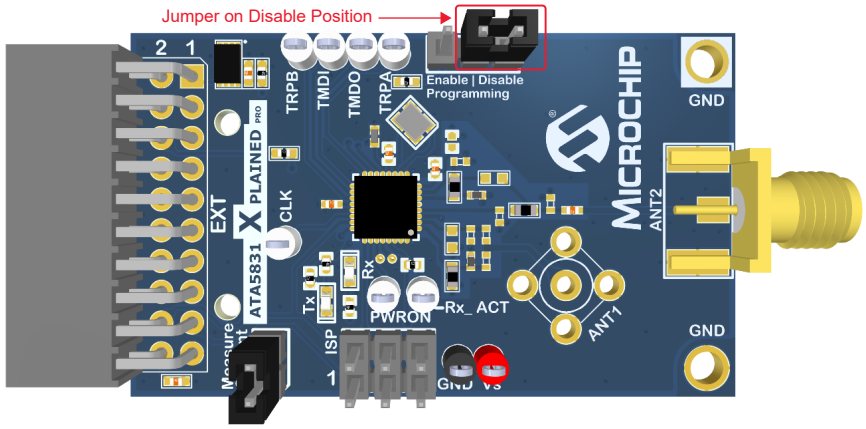
6. Select the **Memories** tab, then click the **Erase now** button.

Figure 6-13. ATA5831 Memory Settings



7. Browse to locate the `ATA5831_eeprom.eep` file for the EEPROM memory image.
8. Click the **Program** button, then wait for completion.
9. Place the jumper on the Disable position of the Enable | Disable Programming header, the two pins closest to the ANT2 connector.

Figure 6-14. Jumper Placement on the ATA5831-XPRO Board to Disable Programming Mode



Note: For better clarity, the ATSAMC21-XPRO board is not shown.

6.3 Programming the SAMC21J18A on the ATSAMC21-XPRO Board

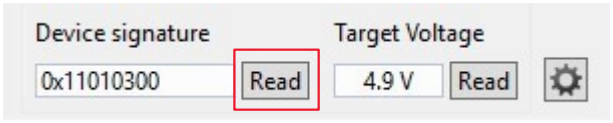
To program the SAMC21J18A on the ATSAMC21-XPRO board, ensure that the USB connection from the computer to the ATSAMC21-XPRO board is in place. The following steps use the embedded debugger (EDBG) on the board for programming:

1. In Atmel Studio 7, navigate to *Tools* > *Device Programming*.
2. Select the Tool, Device and Interface, as shown in the following figure, then click **Apply**.

Figure 6-15. SAMC21J18A Device Selection

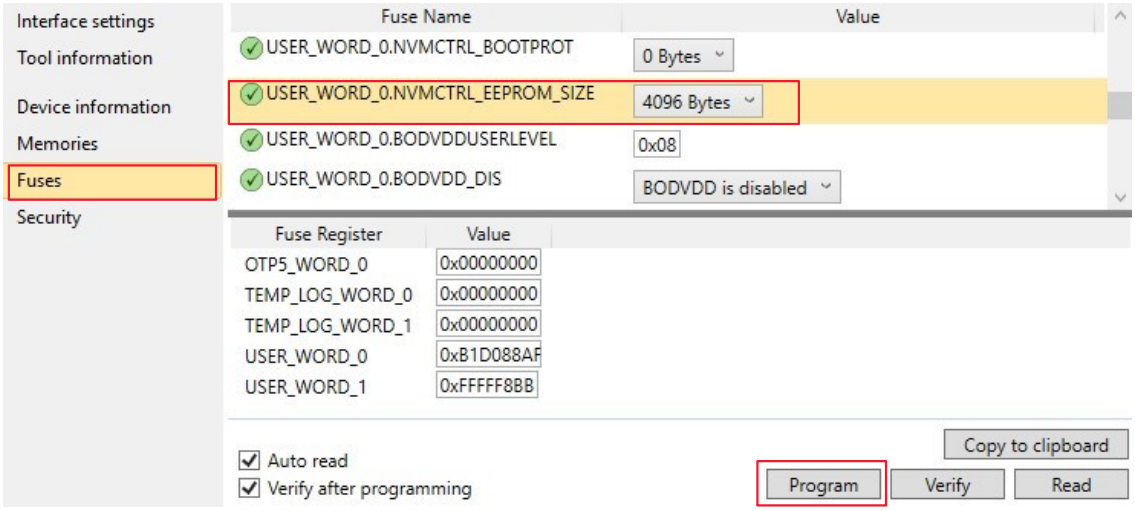
3. Click the **Read** button to ensure that the signature matches the selected device.

Figure 6-16. SAMC21J18A Signature Verification



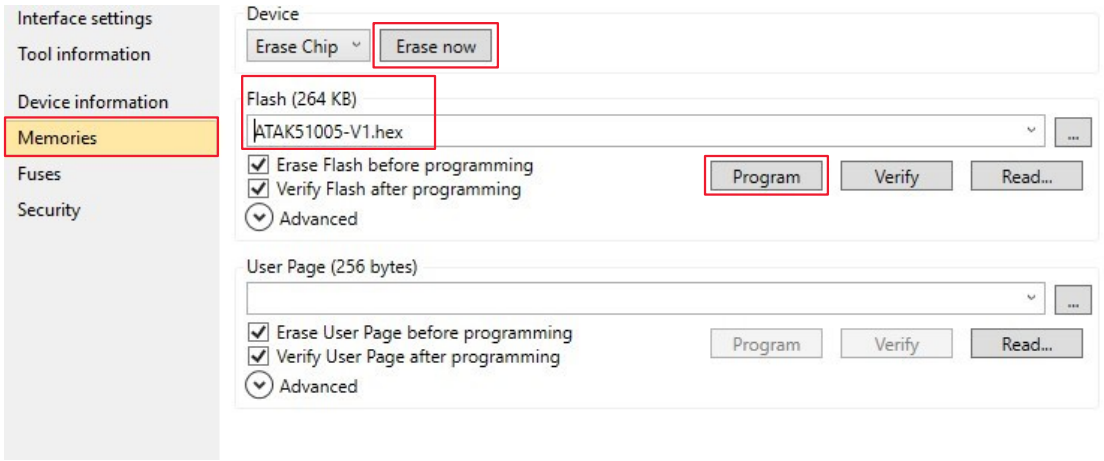
4. Select the **Fuses** tab, then verify the proper fuse settings. The default fuse values are used except for the User Word 0.NVMCTRL EEPROM SIZE, which must be set to 4096 bytes. Click the **Program** button.

Figure 6-17. SAMC21J18A Fuse Settings



5. Select the **Memories** tab, then click the **Erase now** button.

Figure 6-18. SAMC21J18A Memory Settings



6. Browse to locate the `ATAK51005-V1.hex` file for the flash memory image.

7. Click the **Program** button, then wait for completion.

7. XPRO USB Driver Installation

The necessary USB drivers to interface with the ATSAMC21-XPRO are included with the Atmel Studio integrated software development environment (www.microchip.com/mplab/avr-support/atmel-studio-7). Download and install this software development utility to get the USB drivers needed for the CARS kit evaluation utility.

8. Document Revision History

Revision	Date	Section	Description
A	10/2020	Document	Initial revision

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