Automotive Compilation

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Atmel

Passive Entry Proximity Detection Using Atmel´s QTouch Fast Charge Proximity Acquisition Method

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Abstract

Technologies that were once thought of as high-end luxury features on only the most expensive vehicles are slowly finding their way into our everyday lives. Convenience systems like power door locks, passive entry, as well as touch-activated buttons and screens have become common features on the most basic of cars. Now we are beginning to see synergy between these technologies in the form of new and exciting products. Passive-entry proximity detection is one such melding of technologies that has applications in the car access marketplace. Atmel's® QTouch® fast-charge acquisition method can be used to design a passive-entry door handle with proximity detection to meet the ever-expanding needs of the automotive market.

A Short History of Car Access Security

Modern automobile security began with the simple key and door lock. The driver has a key and inserts it into the lock located on the door in order to gain access to the car (see figure 1).

Figure 1. Mechanical Automotive Security – Door Lock and Key

Next came the remote keyless entry (RKE), where a key was no longer required. The driver simply activates a button on a key fob and secret codes are wirelessly exchanged between the remote and the vehicle (figure 2). If the code sent by the key fob is correct, the doors are unlocked.

Figure 2. Wireless Automotive Security – Remote Keyless Entry

Today we have passive entry, and no driver intervention is required to unlock the vehicle. The driver carries a key fob which contains a low-frequency (LF) receiver and wireless transmitter. Pulling the door handle triggers a mechanical switch which initiates the generation of an LF magnetic field around the vehicle (see figure 3).

Figure 3. Wireless Automotive Security – Passive Entry

This field wakes the key fob from sleep and then security codes are wirelessly exchanged between the vehicle and the key fob. The exchange only takes several hundred milliseconds. If the security code is correct, the doors are unlocked before the door handle reaches full extension. If executed properly, there should be no noticeable delay or lag between the initial door handle trigger and the unlocking of the doors. The driver should be unaware of the key-fob-to-vehicle communication that just occurred. It's as if the car doors were never locked.

Car Access Evolution: Passive Entry Proximity Detection

The next step in the evolution of the passive entry car access application is the detection of the driver when approaching the vehicle. This can be accomplished by replacing the mechanical switch used to trigger the LF field with a touch proximity sensor located in the car door handle as shown in figure 4.

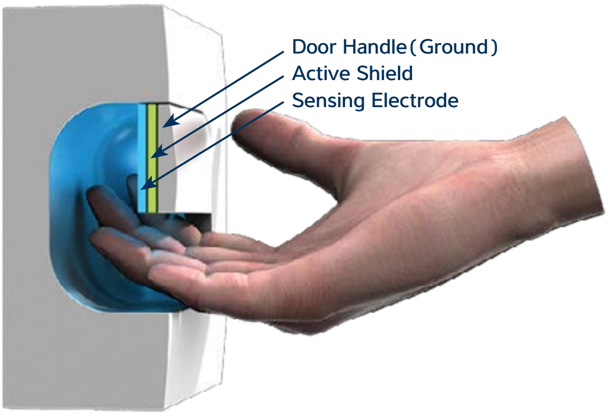


Figure 4. Car Door Handle with Capacitive Proximity Sensing

The capacitive touch sensor is comprised of a sensing electrode, active shield, and a chassis-grounded door handle. The active shield acts as an isolating barrier between the sensing electrode and the door handle. Without this barrier, the proximity detection range of the sensor would be greatly reduced due to the additional capacitive load placed upon the sensing electrode by the door handle itself. With the active shield, the sensor sensitivity is amplified. This increases the proximity detection range.

The sequence of events which lead to the detection of the driver's key fob transponder is much the same as the mechanically-triggered door handle application, except the manner in which the LF magnetic field is triggered. The passive-entry system is triggered by the proximity of the driver's hand to the sensor on the back side of the door handle as the driver approaches the vehicle and reaches for it with his or her hand. The LF field is triggered well before the hand touches the door handle. Triggering the LF field before the driver's hand makes contact with the handle allows for a much faster system response time and increased security through stronger communication algorithms compared to the old mechanically triggered system.

One example of how the passive entry proximity sensing system might be implemented is shown in figure 5. The sequence of driver detection and passive entry unlock of the vehicle doors is as follows:

1. As the driver approaches the car, the hand is detected once it is within range of the proximity sensor, typically 2cm.
2. The proximity sensor wakes the body control module from sleep.
3. The LF driver charges the LF antenna and briefly envelopes the car (or intended approach region) in a magnetic field with a range of 1 to 3 meters.
4. The key fob (carried by the driver) transitions from a very low power listening mode (to conserve battery life) to active mode in response to the field generated by the LF antenna.
5. The key fob wirelessly transmits a security code to the UHF receiver.
6. The RF receiver sends the demodulated security code to the body control module for processing.
7. If the security code is correct, the body control module instructs the door module to unlock the car doors.

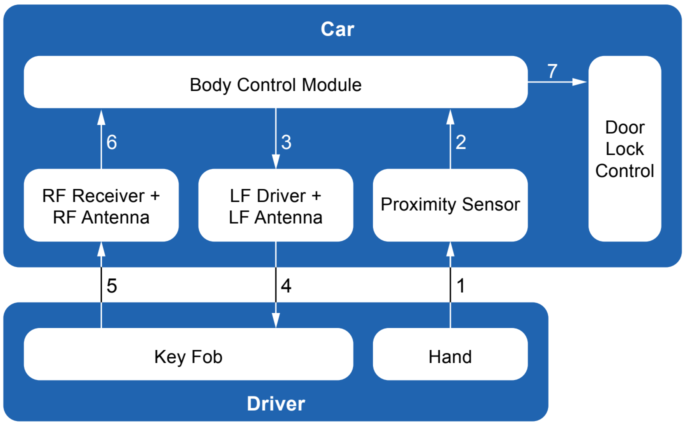


Figure 5. Proximity Sensing Door Handle Block Diagram

Proximity Requirements for Passive Entry Applications

While the specifications for an automotive passive entry proximity-enabled door handle may differ slightly between car manufacturers, the general performance requirements will be similar for most applications. The key requirements for a successful system implementation are:

- **Low Power Consumption –** The average current consumption for a single proximity detection node should be less than 100µA to avoid excessive drain on the battery when the vehicle is not running.
- **Fast Response Time –** The sensor scan rate, the time between sensor readings, should be less than 20ms. A fast scan rate means more sensor readings per second, which will result in earlier detection of the driver's hand as it approaches the door handle sensor. This will mitigate the delay induced by communication processing and enable the car doors to unlock quickly.
- **Simple, Low-cost Interface –** Standard networking interfaces such as CAN or LIN require excessive protocol/processing overhead and are too power-hungry for this low-power application. A simple, more streamlined approach is required, one that utilizes a single-wire, +12V power line data transfer protocol.
- **Robust Environmental Performance –** The proximity sensor must be able to withstand the harsh operating environment that the automobile exterior is exposed to. This means that the sensor must resist the effects of moisture, temperature and localized electromagnetic disturbances.

It is for these reasons that Atmel recommends QTouch fast charge mode as the preferred acquisition method for proximity detection of passive entry automotive applications as opposed to the other Atmel Touch acquisition methods – QTouch, QMatrix® and QTouch ADC.

Why QTouch Fast Charge?

Response Time – As the name implies, it is fast. QTouch fast charge is capable of measuring a single proximity touch sensor channel in **under 2ms**. The average response time is equal to the timer period plus the measurement time when used in conjunction with an Atmel AVR® microcontroller watchdog timer (WDT) as the polling timer for proximity sensing. For example, if the polling interval is set to 16ms, the fastest WDT wake-up period, then the overall response time for QTouch fast charge is approximately 18ms. Given the total response time from LF trigger to a door unlocking is around 200ms, the 18ms it takes to detect a proximity event leaves plenty of processing time for the LF authentication between the remote transponder and the BCM (body control module).

Low Power – The typical current required to measure and monitor a single QTouch fast charge sensor is **less than 100µA** with a 16ms polling period. Current consumption can reach levels as low as 20µA if the polling interval is increased.

Detection Range – With proper sensor design QTouch fast charge is capable of detecting proximity events **over 15cm** in distance. QTouch fast charge is a "self capacitive" sensing technology where the sensor is constructed of a single electrode, see figure 6.

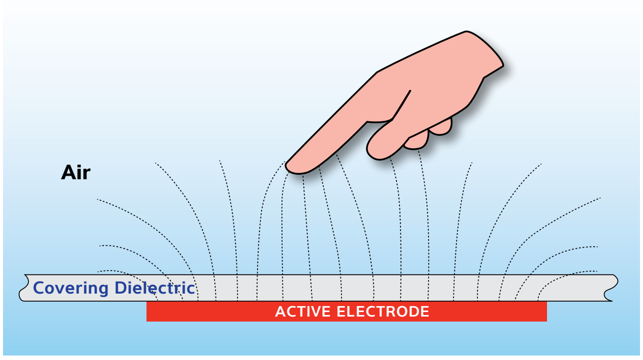


Figure 6. Self-capacitive Sensor Geometry

The electric field lines responsible for touch/proximity detection are generated away from the sensor uniformly in all directions. The generation of the electric field in this manner allows for the highest possible proximity detection of any sensor.

Flexible Sensor Tuning – Achieve the desired sensor sensitivity and proximity detection range required for the end application through simple hardware modifications and adjustable firmware settings.

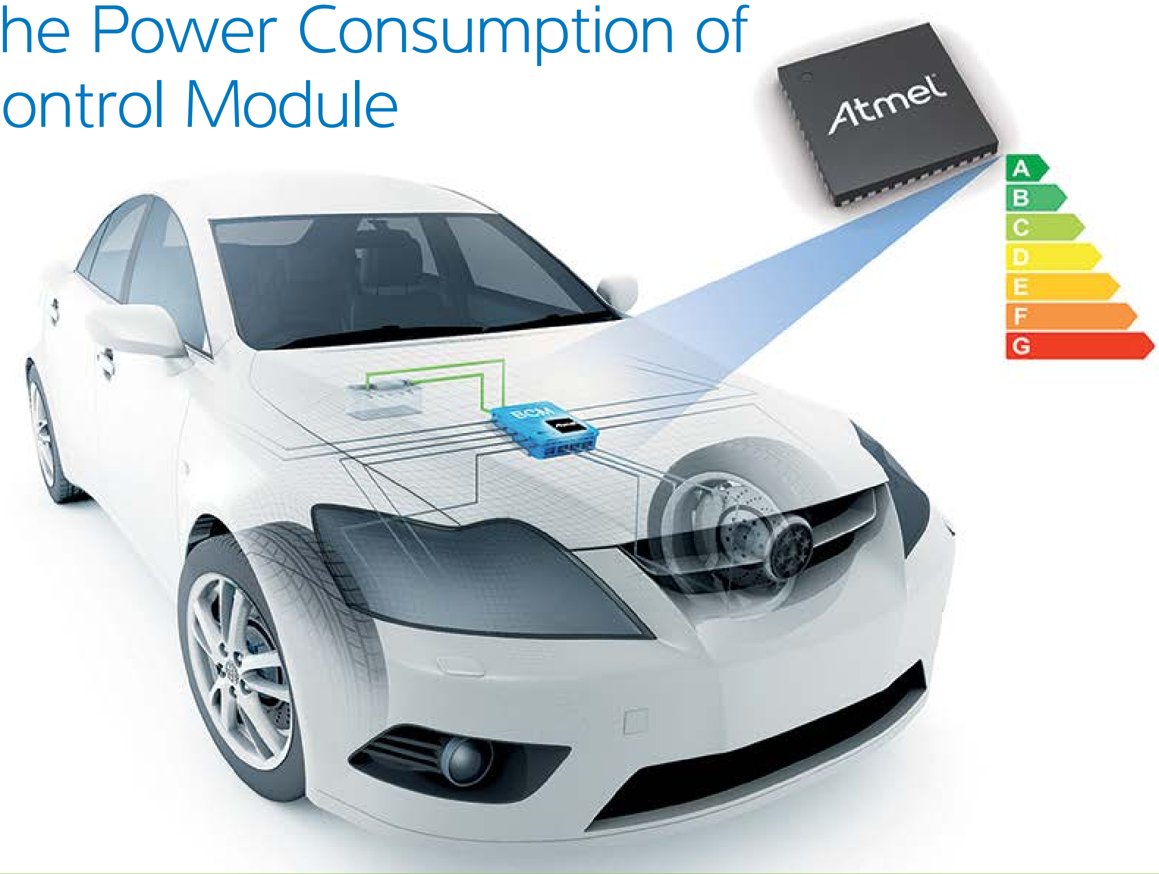
Environmental Performance – QTouch fast charge operates to the same high standards as the QTouch and QMatrix touch product lines. It has excellent immunity to noise and moisture.

Summary

QTouch fast charge is Atmel's preferred touch acquisition method for passive entry proximity detection applications. The QTouch fast charge proximity implementation has extremely low power consumption, fast response time, and provides exceptionally good proximity detection range. These features, when paired with Atmel's low-frequency transceiver product line, provide the foundation of a car access passive entry proximity detection system for the next generation.

How Smart UHF Receivers Help to Reduce the Power Consumption of a Body Control Module

Dr. Peter Sauer



Overview

The Atmel® families of ATA578x UHF receiver (reference 1) and ATA583x UHF transceiver devices (reference 2) use an integrated 8-bit AVR® microcontroller to perform the UHF front-end control and the data processing during reception and transmission. These receiver and transceiver families include derivatives which have an embedded user-programmable Flash memory enabling the development of individual applications with the built-in ROM (read-only memory) firmware. All devices are configured with settings stored in an internal EEPROM (electrically erasable programmable read-only memory).

The main automotive application areas for these devices are:

1. Key fob applications with standalone operation using an internal Flash application
2. Receiver applications within or attached to a body control module (BCM)

This article focuses on the second application area where the receiver is part of or connected to a BCM. The CPU which controls the BCM application is typically a 32-bit microcontroller (MCU) with embedded memory. In this BCM application the UHF receiver is always powered on and is scanning (i.e., polling) for an RF signal from an associated key fob. This application, known as remote keyless entry (RKE), will unlock the vehicle doors when a valid key signal is detected. In addition the UHF receiver will search for data telegrams sent out by a tire pressure monitor system (TPMS). Figure 1 shows a BCM with typical functionality and interfaces to other car modules using CAN and/or LIN buses. The UHF receiver is directly connected to the MCU to activate the MCU in case of a detected key signal.

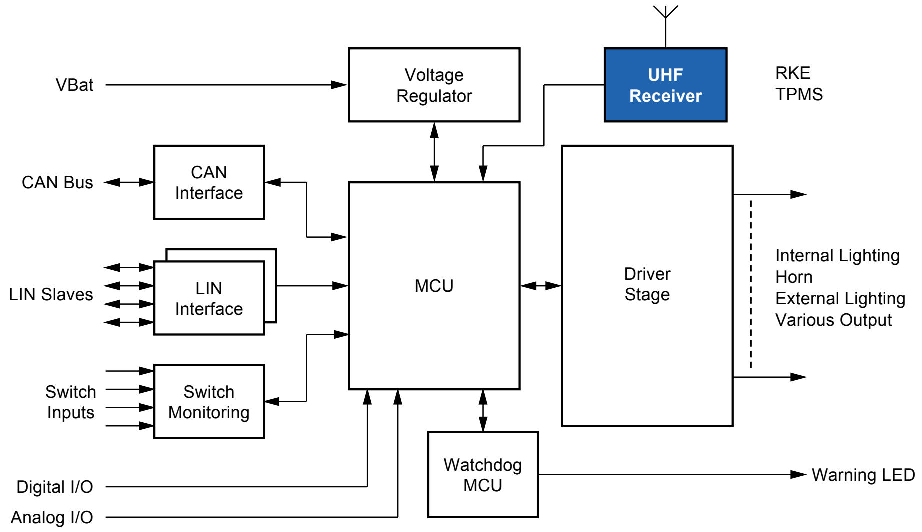


Figure 1. BCM with Integrated UHF Receiver for RKE and TPMS Signals

BCM Power Requirements During UHF Polling Mode

In the BCM example as shown in figure 1 the UHF receiver will receive two signals:

a) RKE: remote keyless entry signal to open the vehicle doors

b) TPMS: tire pressure monitoring system signal to receive the pressure values from the four vehicle tires

In the case of RKE, the signal is sent out from a key fob when the driver requests to unlock the car. In TPMS applications the signal is received at regular intervals where the interval time depends on the vehicle status. If the vehicle is moving, the TPMS signals are sent out more frequently than if parked. The TPMS signal is sent out as a burst sequence of data packets to ensure that the BCM will receive at least some of the data telegrams to validate the status of the tire pressure.

The critical parameter during the polling activity of the UHF receiver is the power consumption of the overall BCM system. When the car is locked and parked the BCM is in power-down mode where only the UHF receiver is polling for an RF signal. Once an RF signal with the correct data rate and data modulation scheme is detected in the expected RF channel, the BCM is switched into active mode to analyze the received data telegram. If a valid data telegram has been found the BCM unlocks the doors, otherwise it will return to power-down mode. The detection of false telegrams increases the overall power consumption which has to be avoided to save battery lifetime. The amount of detected false telegrams depends on the RF activity in the environment of the parked car. It will increase, for example, if the car is parked in the parking lot of a supermarket or at the car dealer.

The following example (see figure 2) details the power consumption over time with the following real-case data:

- UHF receiver:
  - Current consumption in active mode: Ia_{UHF} = 10mA
  - Polling cycle time: T_{poll} = 20ms
- BCM:
  - Current consumption in active mode: Ia_{BCM} = 150mA
  - Current consumption in power-down mode (including UHF receiver): Is_{BCM} = 2mA

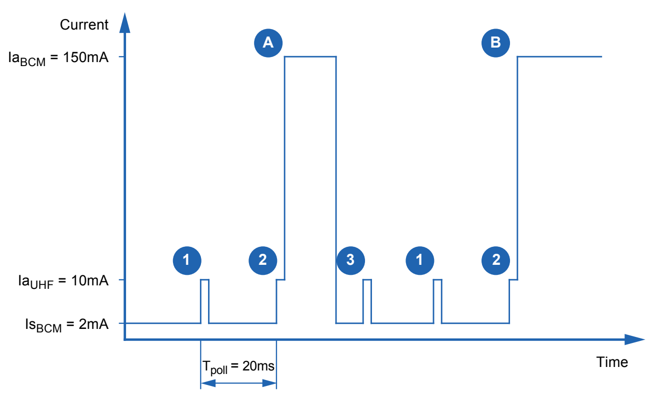


Figure 2. Current Consumption with Standard UHF Receiver Using BCM MCU for Data Processing

While the BCM is in power-down mode the UHF receiver operates in polling mode—"1", "2" and "3"—where the receiver is switched between standby mode and active mode every 20ms. Depending on the UHF receiver configuration, it will scan one or more UHF channels for a valid data telegram. The example in figure 2 shows the scanning of three channels "1", "2" and "3". This configuration is mainly defining the polling current, the mean current consumption of the UHF receiver. When the receiver detects a data telegram that fits the configuration with a correct RF channel, coding scheme, and data rate settings, the MCU switches to active mode ("A" and then "B") to analyze the data packet. If the data packet is not valid, the BCM will return to power-down mode "A", and the polling continues after this false wake-up. In case of a valid data packet "B" the MCU remains in active mode to open the doors and to activate the other car modules via the CAN and LIN buses.

BCM Power Improvement Using a Smart UHF Receiver

Car manufacturers define one main BCM requirement as low power consumption during power-down mode. To meet this requirement, BCM wake-ups caused by false telegrams need to be avoided. One way is by transferring the data validation task to the smart UHF receiver device. The current consumption of the active UHF receiver device is about 10-15 times less than that of the active BCM.

The smart UHF receiver includes an 8-bit Atmel AVR microcontroller with programmable Flash memory. The device is capable of carrying out the data pre-processing and analysis of the received data telegrams when you add or extend the integrated Flash application-specific software.

The following tasks can be performed by the UHF receiver device:

- Extend the ROM firmware with further control functionalities for the UHF front end; this will allow to implement enhanced data protocols
- Carry out data pre- or post-processing (AES data encryption and decryption)
- Perform control function, such as waking the BCM host up once the received data has been collected and validated
- Perform additional control functions for external devices such as using the GPIO (general purpose input/output) signals of the UHF receiver
- Add software-controlled data protocols such as the TWI protocol for external devices

The power consumption is improved if the smart UHF receiver takes over the data validation task from the BCM (figure 3) as compared to figure 2.

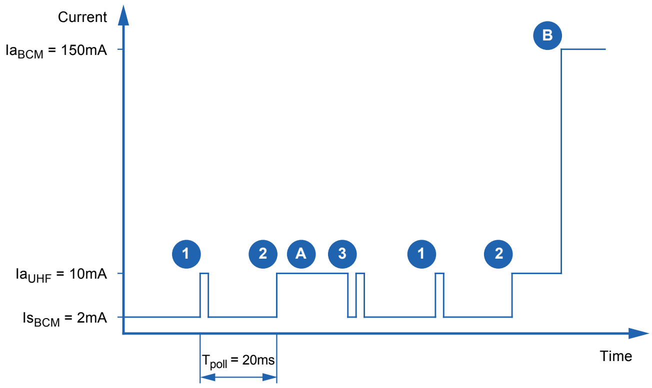


Figure 3. Current Consumption with Smart UHF Receiver Performing the Data Preprocessing

In this example, the smart UHF receiver checks the data packets "A" and "B". In case of an invalid data packet "A" the UHF receiver returns to polling mode without activating the MCU. If a valid data packet "B" has been detected, the MCU is activated to open the doors and to wake-up the other modules attached to the CAN and LIN buses.

Data Decryption Using a Smart UHF Receiver

The exchanged data is encrypted to ensure that the door locking and unlocking is only performed for a valid key fob. The validation of the data packets requires some additional computation effort to decrypt the data telegrams. With the Atmel open protocol an AES 128-bit encryption scheme is used to validate the key fob message (reference 3). The decryption of such a message takes about 18ms computation time that is performed by the 8-bit AVR MCU within the UHF receiver device. Compared to the BCM's MCU, which typically has a 32-bit CPU, the decoding takes longer but the activation of the 32-bit MCU would take even more time due to PLL initializations and RTOS activation tasks. Using data encryption within the UHF receiver, the overall current consumption can be reduced by a factor of 5 to 10.

The additional memory consumption for the AES decryption function is

- 1.5 kByte of Flash memory for the AES program code
- 100 bytes of additional SRAM data memory

The overall memory usage for the Flash application using the internal ROM functions is

- 2.6 kByte of Flash memory for program code
- 250 byte for SRAM data memory

The basic principle of such an encryption scheme (see figure 4) uses a data message that includes a message authentication code (MAC) which is generated by the 128bit AES encryption to validate the message data. This requires a secret key which is stored both in the UHF receiver and in the key fob's EEPROM. The AES-128 encryption is explained more detailed in the application note (see reference 3).

Data Frame Collection and Validation Using a Smart UHF Receiver

The typical data protocol used for RKE and TPMS functions defines the reception of multiple data frames for the validation of the data content. This increases the reliability of the data transfer in case of external disturbers or weak UHF signals.

An RKE data protocol operates on the UHF channels "B" and "C" (figure 5). A valid data reception is defined when the three data packets "a", "b", and "c" have been received. This requires the detection and reception of data packets on different UHF channels with the correct parameter settings. The smart UHF receiver collects the data frames in the expected sequence "a" to "c". Only if this data sequence is valid the BCM's MCU will be activated to unlock the doors.

A TPMS signal also works on the UHF channel "A" (see figure 5). A valid data reception requires the detection of a minimum number of data telegrams within a TPMS sensor's data packet burst "1" to "7". Once the minimum required number of data packets has been received and validated (data packets "2", "3" and "4" in this example), the MCU of the BCM will be activated to check the tire pressure data.

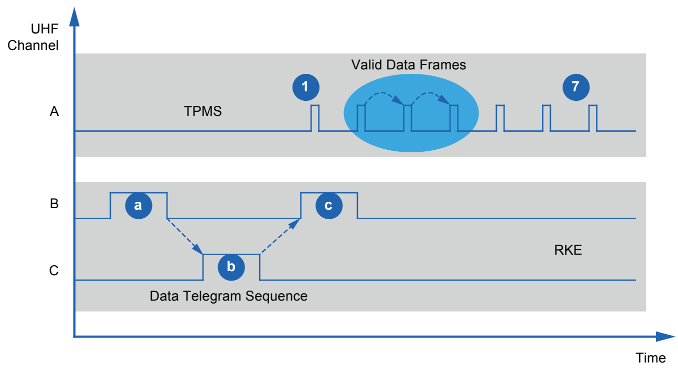


Figure 5. Collection of Data Frame Sequences for the Validation of RKE and TPMS Data

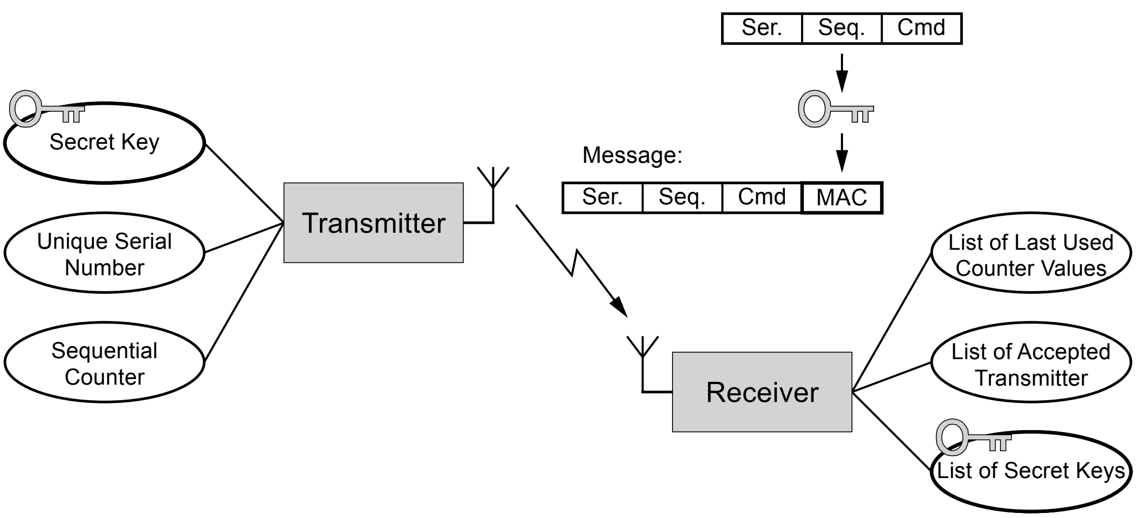


Figure 4. Basic Principle for an AES RKE Encryption Scheme (Reference 3)

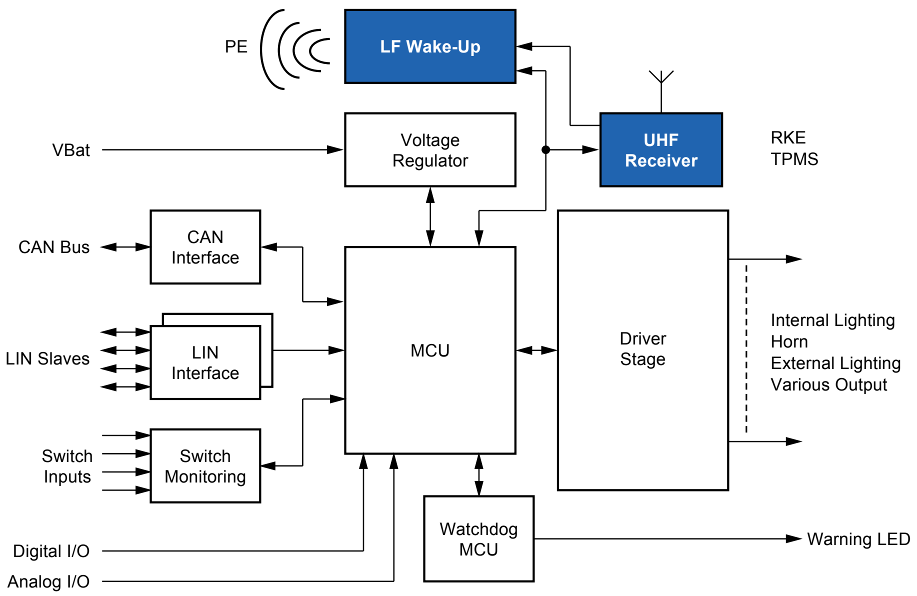


Figure 6. Passive Entry (PE) Functionality with the Smart UHF Receiver Concept as Shown in Figure 1

Passive Entry Systems Using a Smart UHF Receiver with LF Wake-Up

Future automotive passive entry systems may use the LF field to detect the approach of the driver carrying the key fob within a range of 2 to 3 meters. This requires an LF polling scheme to detect the approaching key fob. A typical LF data telegram will draw a current of up to 1A during LF field transmission. Such an architecture requires an even more sophisticated solution to keep the power consumption low.

Using the smart UHF receiver enables to initiate the LF polling sequence without the involvement of the BCM's MCU. An advanced LF driver circuit is needed that supports the automatic transmission of such LF data packets. The smart UHF receiver initiates the LF polling scheme by activating the LF driver device to send out the LF data telegram, and monitors the RF channels for a valid key-fob response. The smart UHF receiver and the LF driver device repeat this procedure autonomously in regular intervals without the activation of the MCU. For this scheme the LF driver device is connected to the smart UHF receiver (figure 6).

Summary

The smart UHF receiver and transceiver devices with their embedded microcontroller allow the implementation of application-specific programs in the user Flash memory. You can assign data transfer initiation and the validation of received data frames to these UHF devices. They perform pre-and post-processing at 10 to 15 times lower power consumption compared to handling these tasks in the BCM's MCU. Even in the case of upcoming car access applications such as using an LF wake-up, the Atmel UHF receiver/transmitter ICs combined with Atmel's smart LF devices will further reduce the power consumption.

References

(1) Datasheet ATA5781/2/3 family (http://www.atmel.com/Images/Atmel-9285s-Car-Access-ATA5831-ATA5832-ATA5833_Datasheet.pdf)

(2) Datasheet ATA5831/2/3 family (http://www.atmel.com/Images/Atmel-9285s-Car-Access-ATA5831-ATA5832-ATA5833_Datasheet.pdf)

(3) Application Note AVR411: Secure Rolling Code Algorithm for Wireless Link (http://www.atmel.com/Images/Atmel-2600-AVR411-Secure-Rolling-Code-Algorithm-for-Wireless-Link_Application-Note.pdf)

How to Achieve High Performance in Low-Cost Key-Fob Applications

Sascha Wagner

An RF transmission system for automotive applications must meet specific requirements to be successful. The most important technical criteria are the power consumption and the maximum radiated power. The RF system needs to react to environmental changes and adjust itself for maximum efficiency without any additional effort from the user. The automatic antenna tuning function in the ATA583x transceiver family from Atmel® is an easy way to achieve this. It ensures that the magnetic loop antenna matches the target frequency independent of environmental influences. The antenna tuning occurs completely autonomously with no extra effort by the auto manufacturer or the end user.

Automotive Application Requirements

In the automotive industry the on-going trend is towards smaller, more powerful, and cheaper electronics modules. This forces automotive suppliers to continuously develop new technologies and procedures to keep pace. Small size and lower costs often correlate closely. One example is the antenna in automotive key fob applications. External antennas are expensive and have a large footprint. Therefore, the industry uses cost-effective solutions such as printed magnetic loop antennas. However, with these antennas it is impossible to achieve the required high performance. So how can designers create small designs that are both cost-effective and realize high-performance? The solution is a chip that uses an autonomous algorithm capable of tuning the RF system. That way the application achieves the best possible performance independent of environmental influences.

Environmental Influences

A key fob application needs to operate properly and reliably even under the most difficult conditions. Temperatures may range from -30°C in winter and up to +70°C during summer. Direct solar exposure creates even higher temperatures. Humidity can vary from 100% to zero. During development of the device, the engineers match a printed magnetic loop antenna to the maximum RF output power. They specify the matching under laboratory conditions and then insure conformance during manufacturing. In real life, however, temperature and humidity change constantly. In addition, the capacitance will change when the user's hand touches the key fob. This strongly influences the magnetic loop antenna's electrical characteristics (see figure 1). Key fob designs using metal or chrome plating intensify this effect.

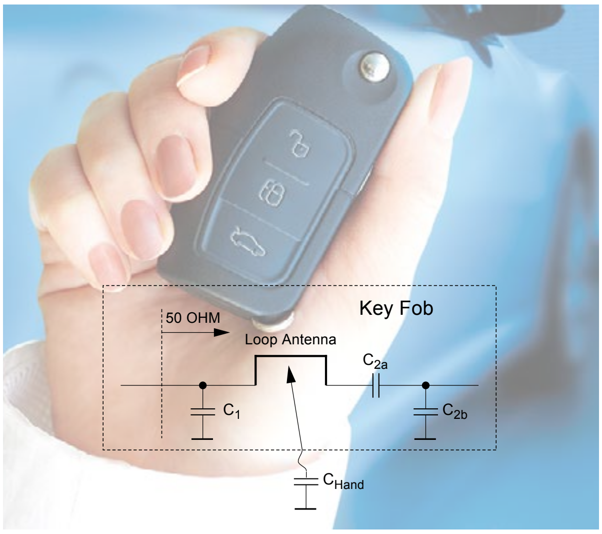


Figure 1. Influence of Human Hand's Capacitance on the Magnetic Loop Antenna

The increased capacitance affects the radiated output power, and the resulting weak radiation signal reduces the operating distance, which is a key criteria for every key fob application. Automatic antenna tuning helps to prevent the negative effects of environmental influences. A dedicated design adapted to the individual application ensures optimum results.

Application Set-up and Matching Network

The Atmel ATA583x RF transceiver family has an embedded RF switch for optimum matching during transmit and receive mode. For transmission mode, you only need the matching network consisting of L_3 and C_9. You add L_1 (L_2) and C_4 (C_3) for reception mode. Both networks result in a 50Ω matching at the output of the internal switch (SPDT_ANT). The firmware controls the switch to select the path for the

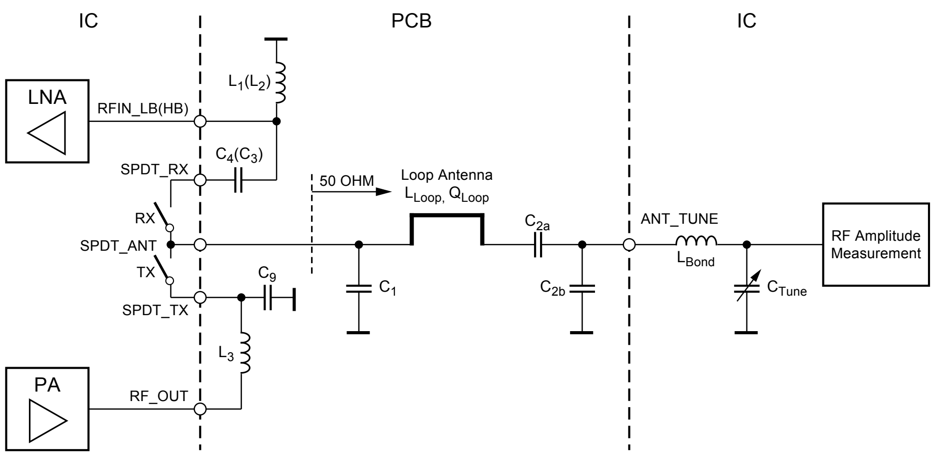


Figure 2. Typical Key Fob Application with a Magnetic Loop Antenna

reception or the path for the transmission. You set up the 50Ω matching by selecting the external capacitors C_1, C_{2a}, and C_{2b}, the parameters of the magnetic loop antenna, and the internal tuning capacitor C_{Tune} that is connected via the IC's bond wire inductance L_{Bond} (see figure 2). The C_{Tune} capacitor directly influences the matching at the end of the loop antenna and serves to adjust the system.

Automatic Antenna Tuning Function

The firmware located in system ROM controls the automatic antenna tuning function. This enables autonomic matching and tuning of the printed magnetic loop antenna to the required resonance frequency, no matter the prevailing ambient conditions.

As shown in figure 3, an amplitude detector, a comparator, and a DAC (digital-to-analog converter) perform the tuning.

The amplitude detector converts the maximum antenna voltage to a DC voltage. The DAC converts an internal reference value to a DC voltage. The comparator compares this to the measured value. The amplitude detector has four operating ranges that are automatically set by the firmware to cover the amplitude voltage range at the ANT_TUNE pin.

An approximation algorithm handles the tuning process. This algorithm uses the internal variable C_{Tune} tuning capacitor over a nominal range of 4pF to 9pF with a tolerance of ±15%. This is achieved with 16 steps at a maximum 0.33pF per step. During auto-tuning the value of C_{Tune} adjusts the matching at the end of the magnetic loop antenna. This occurs while the internal circuit measures the RF amplitude. The resulting capacitor value guarantees a maximum amplitude at the ANT_TUNE pin. This maximum amplitude provides the

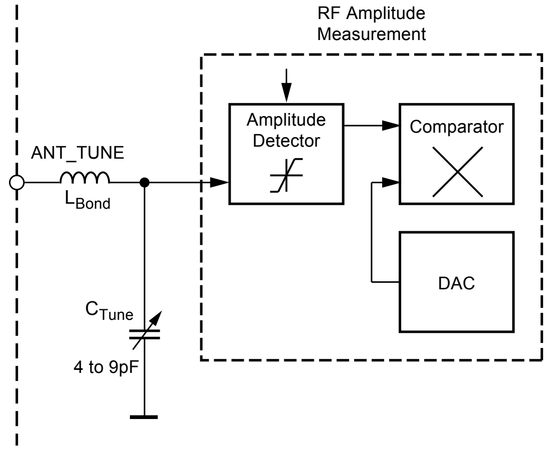


Figure 3. Tuning Circuit with Amplitude Detector, DAC and Comparator

maximum radiation of the magnetic loop antenna. The chip stores the tuning capacitor setting internally. It is used for further RF operation in RX mode, TX mode, and RX polling mode. The next tuning process or a system reset will adjust the capacitor accordingly.

To optimize the set-up you need to select the external components to provide the best effect of the tuning capacitor. One of the most important parameters is the maximum RF amplitude at the input of the level detector. If the input exceeds 3Vpp it may happen that tuning is impossible due to overload of the internal circuit. This overload may also cause a permanent change of the internal circuit. Figure 4 shows how to adjust the amplitude according to the transformation network between pin SPDT_AND and pin ANT_TUNE.

It is good practice to verify the required network values and the calculation results prior to actually starting the design.

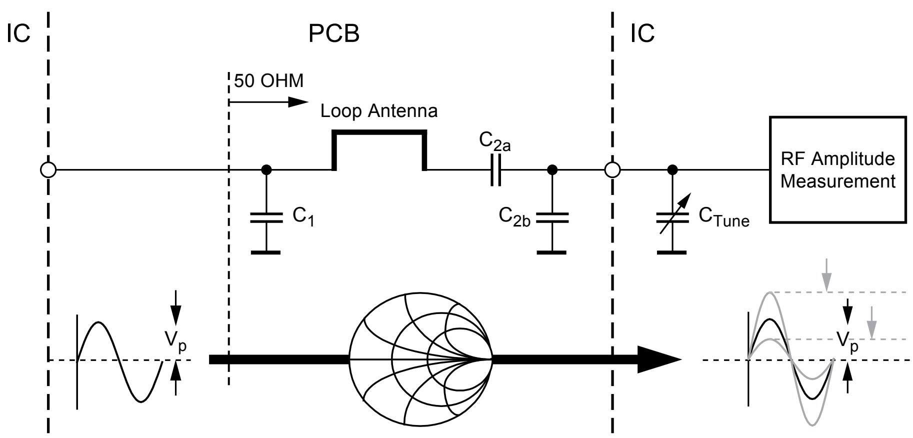


Figure 4. Amplitude Adjustment

Application Design and Calculation

You can calculate the matching values for the magnetic loop antenna by using the equations below. Based on that results, you can then define the maximum amplitude at the input of the level detector. This enables you to gain in-depth knowledge of the application and to set-up matching that guarantees a properly-operating application with the best possible performance. First convert the known output power from dBm to mW (equation 1).

$$P_{In}[mW] = 10^{\frac{P_{In}[dBm]}{10}} \qquad \text{(equation 1)}$$

You then calculate the amplitude voltage of the signal that is included in the radiation circuit (equation 2), where Z_{In} is the input impedance and PIn the load power. The amplitude voltage at the output of the SPDT switch is used to calculate the amplitude level at the end of the loop antenna (as given in equation 12) and at the input of the ANT_TUNE pin (see equation 13).

$$V_{In} = \sqrt{2 \times Z_{In} \times P_{In}} \qquad \text{(equation 2)}$$

The quality factor of the loop is needed to analyze the application. First calculate the loop resistance (equation 3):

$$R_{Loop} = \frac{l}{2w} \times 2.59e^{-7} \times \sqrt{f} \qquad \text{(equation 3)}$$

where w = geometrical width of the loop trace and l = loop length

Next, calculate the quality factor of the loop (equation 4). The angular frequency includes the overall target resonance frequency. You need to know this value, including all potential tolerances.

$$Q_{Loop} = \frac{\omega L_{Loop}}{R_{Loop}} \qquad \text{(equation 4)}$$

In case Q is known, you can simply adapt equation 4 so that R_{Loop} will be the result of the calculation. Several other equations are also available to obtain the three parameters used in equation 5.

Using the known parameters from the magnetic loop antenna allows you to calculate the required matching elements to achieve the maximum radiated power for the target frequency. Equations 5 to 7 help to obtain the target values for the matching elements. The first step is to calculate the parallel resonance impedance using equation 5.

$$Z_{ll} = Q_{Loop} \times \omega L_{Loop} \qquad \text{(equation 5)}$$

Knowing the impedance allows you to evaluate the transformation ratio Z_{In} to Z_{ll} by means of equation 6. This formula also helps to find out the voltage amplitude transformation.

$$r = \sqrt{\frac{Z_{ll}}{Z_{In}}} \qquad \text{(equation 6)}$$

Equation 7 enables you to calculate a loop capacitance that depends on the target frequency.

$$C_{ll} = \frac{1}{\omega^2 L_{Loop}} \qquad \text{(equation 7)}$$

With equations 8 and 9 it is possible to calculate the theoretical matching network (see figure 5).

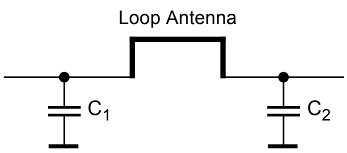


Figure 5. Loop Antenna Matching Circuit

$$C_1 = C_{ll} \times r \qquad \text{(equation 8)}$$

$$C_2 = \frac{C_{ll}}{1 - \frac{1}{r}} \qquad \text{(equation 9)}$$

C_2 is equivalent to a series-parallel matching circuit that includes C_{Tune} (figure 6).

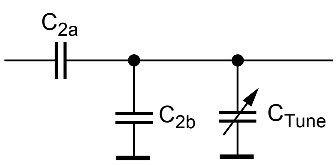


Figure 6. C2 Equivalent Circuit

You derive the values of C_{2a} and C_{2b} as a capacitive voltage divider where C_{2b} is in parallel with the internal capacitance C_{Tune} (equations 10 and 11).

$$C_2 = \frac{C_{2a} \times \left(C_{2b} + C_{Tune}\right)}{C_{2a} + C_{2b} + C_{Tune}} \qquad \text{(equation 10)}$$

$$C_{Tune} = \frac{C_2 \times \left(C_{2a} + C_{2b}\right) - \left(C_{2a} \times C_{2b}\right)}{C_{2a} + C_2} \qquad \text{(equation 11)}$$

You should dimension C_{2a} and C_{2b} so that equation 11 results in a C_{Tune} value that the IC can reach with its tuning capacity array. This is also the case for the threshold values of the target frequency.

Independent of the matching, the transformation ratio helps to obtain the amplitude voltage at the end of the magnetic loop antenna using equation 12.

$$V_{C2a} = V_{In} \times r \qquad \text{(equation 12)}$$

With this result and the capacitive voltage divider consisting of C_{2a}, C_{2b} and C_{Tune}, you can evaluate the amplitude level at the level detector (equation 13).

$$V_{ANT\_TUNE} = \frac{V_{C2a} \times C_{2a}}{C_{2a} + C_{2b} + C_{Tune}} \qquad \text{(equation 13)}$$

Your application design is set up properly if the voltage at the level shifter input does not exceed the specified value.

A designer not only needs to do the entire calculation for the typical standard case but also for the tolerance values of the target frequency. It may occur that a frequency extreme has a higher amplitude at the level detector than with the nominal frequency. If all values have been thoroughly calculated, the resulting application is capable to handle any environmental influences without additional user involvement. For more details see the ATA5831 datasheet (a summary version is available at http://www.atmel.com/Images/Atmel-9285s-Car-Access-ATA5831-ATA5832-ATA5833_Datasheet.pdf, full version available under NDA).

Designing Next-Generation Car Access Receiver Modules

Michael Hahnen and Klaus Herhoffer

Introduction

In 1997 Atmel® launched an innovative car access system featuring the lowest current consumption. This was achieved through the self-polling capability of the ATA3741 receiver IC. ATA3741 derivatives and second-generation RF receivers like the ATA572x address new RF automotive application areas. These include tire pressure monitoring system (TPMS), remote start applications, and bi-directional RF links.

With leading RF performance and a very reliable RF link, the third generation ATA578x is yet another step ahead. This family includes transceiver and transmitter devices. There are Flash, user ROM, and ROMless versions that are pin, function, and RF-matching compatible. Maximum development re-use minimizes the design efforts for one- and two-way systems.

This article describes how to migrate from the earlier ATA3741/43 devices to the current ATA5723/24, or to directly create a new design with Atmel's latest generation ATA578x.

Migration to the ATA5723/24

Customers with an RF system based on Atmel's ATA3741/43 UHF receiver ICs can easily upgrade their design to the current generation ATA5723/4. The required modifications to the existing receiver system comprise some very minor software and hardware modifications.

Software Modifications

Both the ATA5743 and the ATA5723/4 are configured by the host controller via one bidirectional line. Both devices have the same internal registers with identical configuration content. You can easily migrate from ATA5743 to ATA5723/24 without any software changes in the host controller. Simply double-check the sleep time settings, since there are some minor timing differences that may require adaptation. Table 1 lists the detailed sleep time changes.

The ATA3741 (formerly named U3741BM) and the ATA5723/4 are likewise configured via one bidirectional line from the host controller. Two internal registers contain the receiver configuration, but the number of bits within the registers differs. To protect the ATA5723/4 against unwanted register content change, the serial communication includes one additional bit. To enable writing content to the addressed register, set bit 15 to low, and add it to the communication software routines in the host controller.

Most bits in the registers do have the same meaning and cause the same hardware behavior. Tables 2 and 3 show the two devices' internal registers.

	ATA5743		ATA5723	ATA5724
Sleep	315 MHz T_{sleep} [ms]	433 MHz T_{sleep} [ms]	T_{sleep} [ms]	T_{sleep} [ms]
0	cont. On	cont. On	cont. On	cont. On
1	2.12	2.09	2.09	2.12
2	4.24	4.17	4.17	4.24
3	6.36	6.26	6.26	6.36
4	8.48	8.35	8.35	8.48
5	10.60	10.44	10.44	10.60
6	12.72	12.52	12.52	12.72
7	14.84	14.61	14.61	14.83
8	16.95	16.70	16.70	16.95
9	19.07	18.78	18.78	19.07
10	21.19	20.87	20.87	21.19
11	23.31	22.96	22.96	23.31
12	25.43	25.05	25.05	25.43
13	27.55	27.13	27.13	27.55
14	29.67	29.22	29.22	29.67
15	31.79	31.31	31.31	31.79
16	33.91	33.40	33.40	33.91
17	36.03	35.48	35.48	36.03
18	38.15	37.57	37.57	38.15
19	40.27	39.66	39.66	40.27
20	42.39	41.74	41.74	42.39
21	44.51	43.83	43.83	44.50
22	46.63	45.92	45.92	46.62
23	48.75	48.01	48.01	48.74
24	50.86	50.09	50.09	50.86
25	52.98	52.18	52.18	52.98
26	55.10	54.27	54.27	55.10
27	57.22	56.35	56.35	57.22
28	59.34	58.44	58.44	59.34
29	61.46	60.53	60.53	61.46
30	63.58	62.62	62.62	63.58
31	cont. Off	cont. Off	cont. Off	cont. Off

Table 1. Sleep Time Settings

Bit1	Bit2	Bit2	Bit4	Bit5	Bit6	Bit7	Bit8	Bit9	Bit10	Bit11	Bit12	Bit13	Bit14
OFF Command													
1													
OPMODE Register													
0	1	BR_Range		$N_{Bitcheck}$		V_{POUT}	Sleep					X_{Sleep}	
0	1	Baud1	Baud0	BitChk1	BitChk0	POUT	Sleep4	Sleep3	Sleep2	Sleep1	Sleep0	$X_{Sleep\ Std}$	$X_{Sleep\ Temp}$
(Default)		0	0	1	0	0	0	1	0	1	1	0	0
LIMIT Register													
0	0	Lim_min						Lim_max					
0	0	Lim_min5	Lim_min4	Lim_min3	Lim_min2	Lim_min1	Lim_min0	Lim_max5	Lim_max4	Lim_max3	Lim_max2	Lim_max1	Lim_max0
(Default)		0	0	1	1	1	0	0	1	1	0	0	0

Table 2. ATA3741 Register Content

Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8	Bit 9	Bit 10	Bit 11	Bit 12	Bit 13	Bit 14	Bit 15
OFF Command														
1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–		**OPMODE Register**												–
0	1	BR_Range		$N_{Bit\text{-}check}$		Modu-lation	Sleep					X_{Sleep}	Noise Suppression	0
		Baud1	Baud0	BitChk1	BitChk0	ASK/_FSK	Sleep4	Sleep3	Sleep2	Sleep1	Sleep0	$X_{SleepStd}$	Noise_ Disable	
Default values of Bit 3...14		0	0	0	1	0	0	0	1	1	0	0	1	–
–		**LIMIT Register**												–
0	0	Lim_min						Lim_max						–
		Lim_ min5	Lim_ min4	Lim_ min3	Lim_ min2	Lim_ min1	Lim_ min0	Lim_ max5	Lim_ max4	Lim_ max3	Lim_ max2	Lim_ max1	Lim_ max0	0
Default values of Bit 3...14		0	1	0	1	0	1	1	0	1	0	0	1	–

Table 3. ATA5723/4 Register Content

Bit 7 in the OPMODE register is different. The ATA3741 uses bit 7 to control output pin 17, whereas the ATA5723/4 uses bit 7 to switch between ASK and FSK mode. This switching is done in ATA3741 by pin 2.

With the ATA3741, bit 14 in the OPMODE register extends the sleep time by a factor of 8, whereas the ATA5723/4's bit 14 allows optional additional noise suppression.

The upgrade to ATA5723/24 includes a different timing of the programming start pulse. You may also need to do some slight software modifications in the host controller. Please refer to the datasheet section "Programming Start Pulse".

Hardware Changes

The ATA5723/24 is the direct upgrade of the ATA5743. Both devices are available in SSO20 packages with the same footprint, whereas the ATA3741 package is an SO20. Due to the ATA5723/24's hardware improvements you also need to do some hardware modifications on your board when migrating (table 4).

- Faster external oscillator start-up with a negative resistor up to 1.5kΩ (only valid for migration from ATA5743 to ATA5723/24)
- The ATA5723/4 requires a crystal with a different frequency
- Less external components on the ATA5723/24 board due to integration of the filter circuit
- The antenna matching elements have to be modified

Pin	ATA3741	ATA5743	ATA5723/4
2	FSK/ASK		IC_Active
6	GND	GND	Open (RSSI)
7	VS	VS	GND
8	GND (with filter)	GND (with filter)	GND
9	Antenna matching	Antenna matching	Antenna matching
10	NC	NC	GND
11	VS	VS	NC
12	Filter circuit	Filter circuit	GND
13	GND	GND	XTAL2
14	XTAL	XTAL	XTAL1
17	POUT		Data clock
19	Enable High = polling on Low = sleep		Polling High = polling on, Low = receiving active

Table 4. List of Hardware Differences

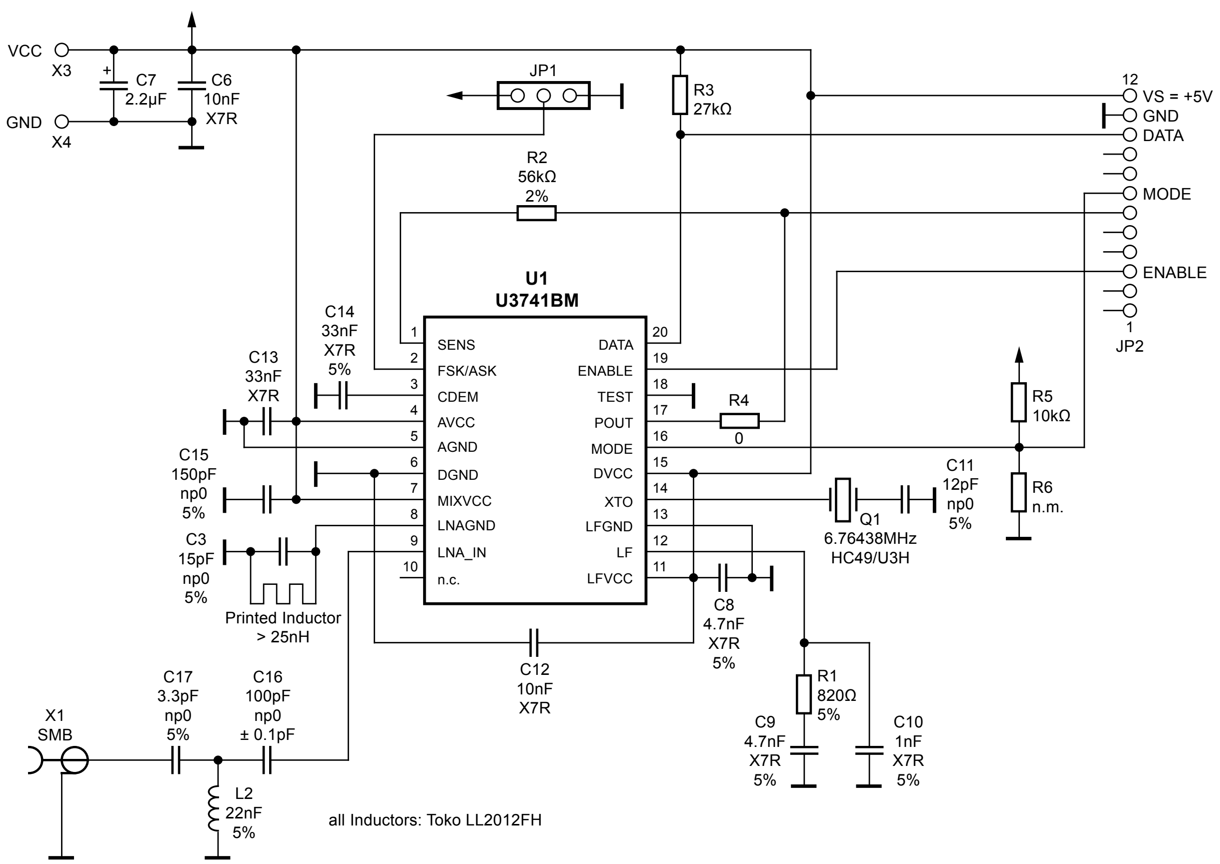


Figure 1. Typical Application ATA3741

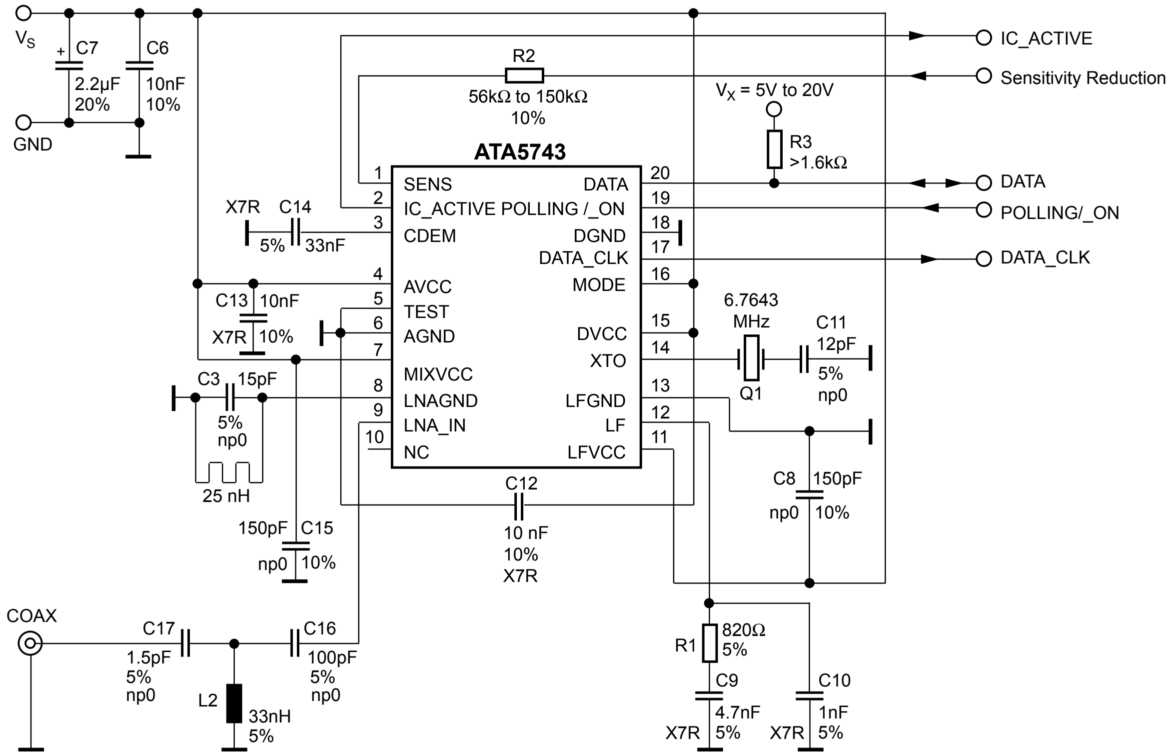


Figure 2. Typical Application with ATA5743

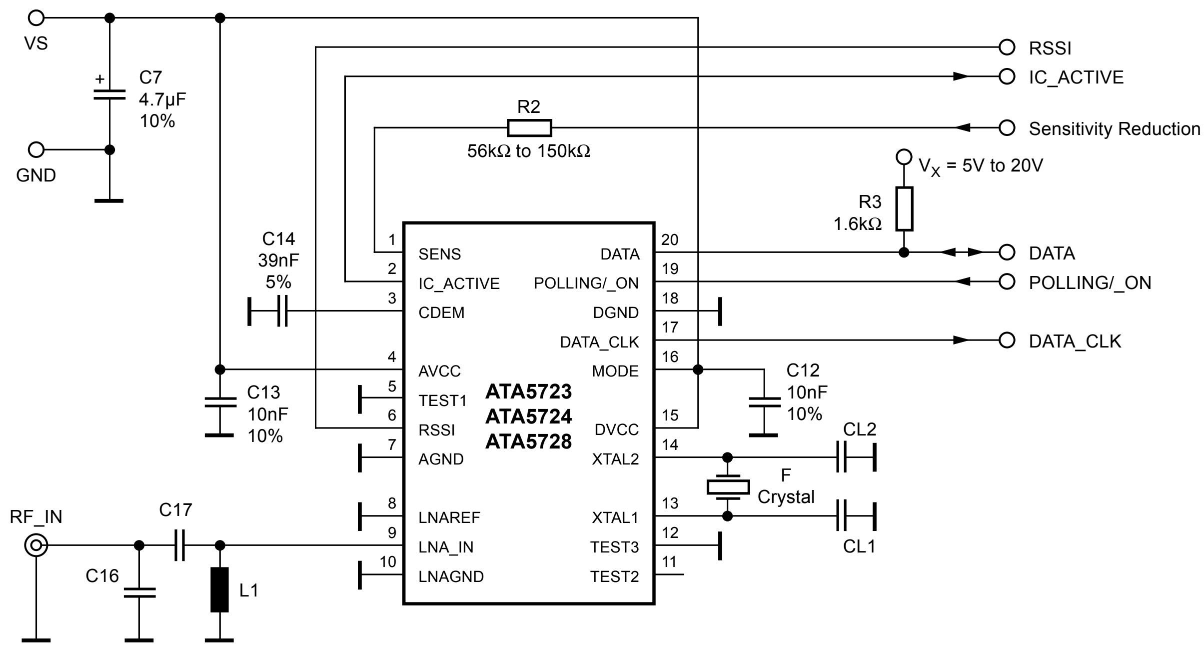


Figure 3. Typical Application with ATA5723/24

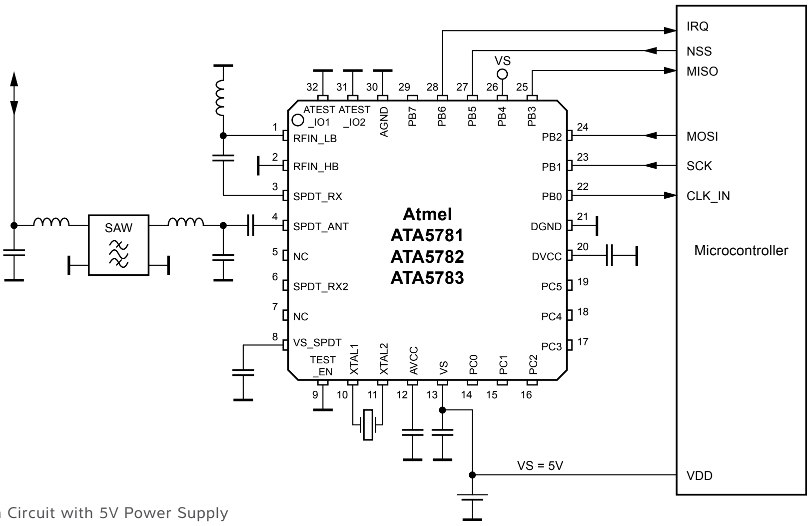


Figure 4. Typical Application Circuit with 5V Power Supply

Automotive UHF Receiver Design Based on ATA5781/2/3

All members of Atmel's ATA5781/2/3 family include an AVR® microcontroller core. Designed for the ISM frequency bands (310-318MHz, 418-477MHz and 836-956MHz), these parts feature excellent RF receiving sensitivity. In FSK mode, the sensitivity reaches –122.5dBm (at 433.92MHz, 0.75kbit/s and BWIF = 25kHz), in ASK mode sensitivity is –125dBm (at 433.92MHz, 0.5kbit/s and BWIF = 25kHz).

The autonomous self-polling mode and good blocking performance help you to design robust automotive RF receiver systems with very low power consumption, since only a valid RF signal activates the host controller. Excellent RF performance, a short bill of materials, and flexibility to adapt the receiving behaviour to all known RF protocols and market needs make the ATA578x family the best choice for new RF receiver designs.

Configuration

The AVR microcontroller's ROM includes firmware that allows you to configure the device according to the configuration stored in the EEPROM. You can control the receiver via an external host controller by using the SPI interface. User Flash and user ROM (available in ATA5782 and ATA5783 only) enable you to write additional software. For example, to protect the external host controller, or to adapt the firmware to any RF protocol. The receiver families have different program memory capabilities (see table 5).

Part Number	ROM Firmware	User Flash	User ROM
ATA5781	24KByte		
ATA5782	24KByte	20KByte	
ATA5783	24KByte		20KByte

Table 5. Program Memory

5V Power Supply Application

In automotive remote keyless entry (RKE) systems, you use the ATA578x as an UHF receiver inside the vehicle. Such applications typically connect to a regulated 5V power supply (see figure 4). The host MCU controls the RF receiver via the SPI interface. The receiver operates autonomously. The host controller just enables the receiving mode, either polling RX mode or standard RX mode, by sending the corresponding command over the SPI lines.

RF Settings

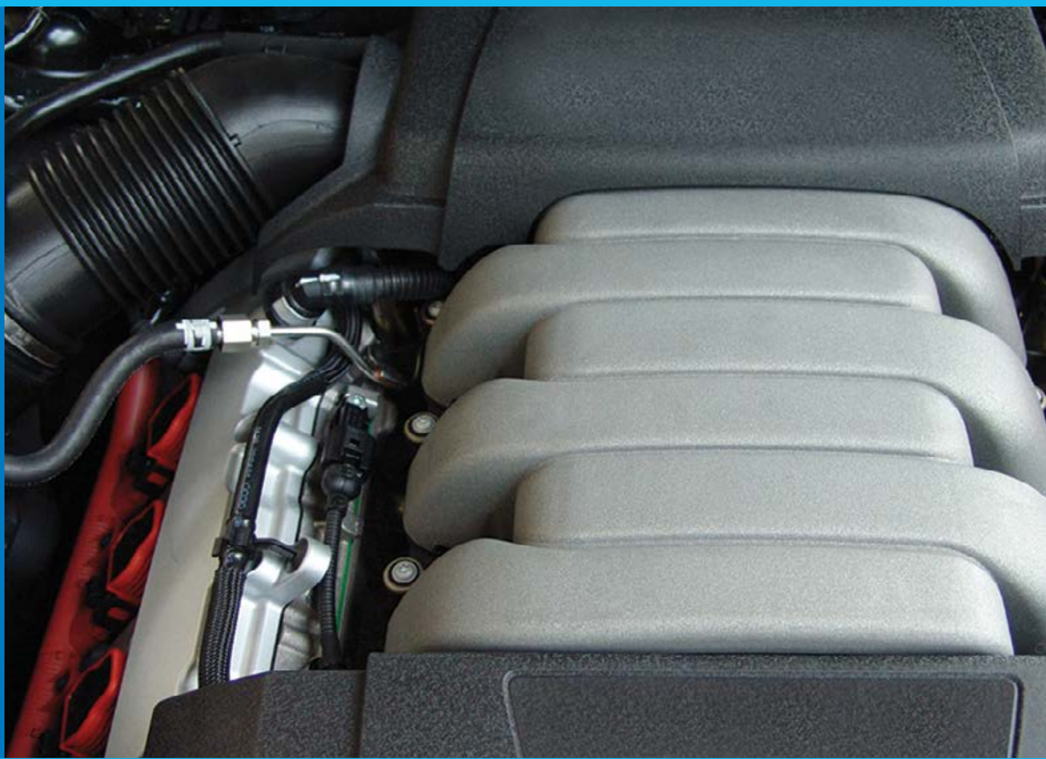
In modern vehicles an RF receiver must be capable of receiving different RF protocols from different transmitters. This includes RKE key fobs, tire pressure monitoring systems, and remote start controls. Because these systems transmit their messages with different modulation, baud rate, and bandwidth, the ATA578x family offers five different RF settings to let you define the RF protocol and the wake-up conditions via the EEPROM configuration GUI (graphical user interface).

Reception Modes

You can use two different reception modes. During standard Rx mode the receiver checks for a desired RF telegram at a particular time. Polling mode means that you define the telegram settings in advance. The receiver automatically and continuously checks for this defined setting. Once the receiver detects the beginning of a valid signal it switches to standard Rx mode and receives the message. In case of no valid message, the receiver switches off for a defined period, and the entire procedure starts over again.

BLDC Motor Control in Automotive Environment

Rainer Boehringer



Abstract

Automotive environments that approach the operational limits of semiconductor devices are a challenge for system designers. Under-the-hood applications require a wide supply voltage range and have high maximum junction temperatures. Designers must integrate increasing functionality within their electronic units, hence the ICs need to provide higher device integration levels. The environment is also subject to stronger EMC radiation levels. Actuators close to the turbocharger are typical examples for such high-temperature applications. These actuators serve to adjust the flaps of exhaust gas recirculation systems, the so-called waste gate. Further examples are coolant or oil pumps operating at 125°C and more.

Remove Belt-Driven Actuators

With limited engineering resources and more stringent CO_2 emission requirements, designers need to consider all the power appliances within a car. It is no longer sufficient to optimize just the engine. Continuously operating loads waste a lot of energy. Loads driven by the engine's belt are using power, even if not needed. It would be preferable to operate the water pump or the cooling fan, for example, according to actual requirements. Driving uphill the fan and water pump must dissipate plenty of heat. When driving downhill the motor is running in fuel cut-off and minimal heat is generated. Unlike belt-driven devices, you can control electronic actuators according to real demand while considering all relevant parameters.

Unlike DC motors, BLDC (brushless DC) motors allow precise control over a wide dynamic range of revolution speed. BLDC motors help to efficiently and flexibly control loads according to the power actually needed. This is why electronically-commutated actuators should be your first choice for automotive applications such as power steering, HVAC (heating, ventilation and air conditioning) fans, power windows, and all kind of pumps.

Automotive Requirements

High Integration Level

A typical BLDC motor control application comprises various functions. There is the microcontroller (MCU), high-current external MOSFETs, a pre-driver to switch those external MOSFETs, the power supply plus a voltage regulator for the digital supply of the ECU (engine control unit), and a communication interface to the car (see figure 1).

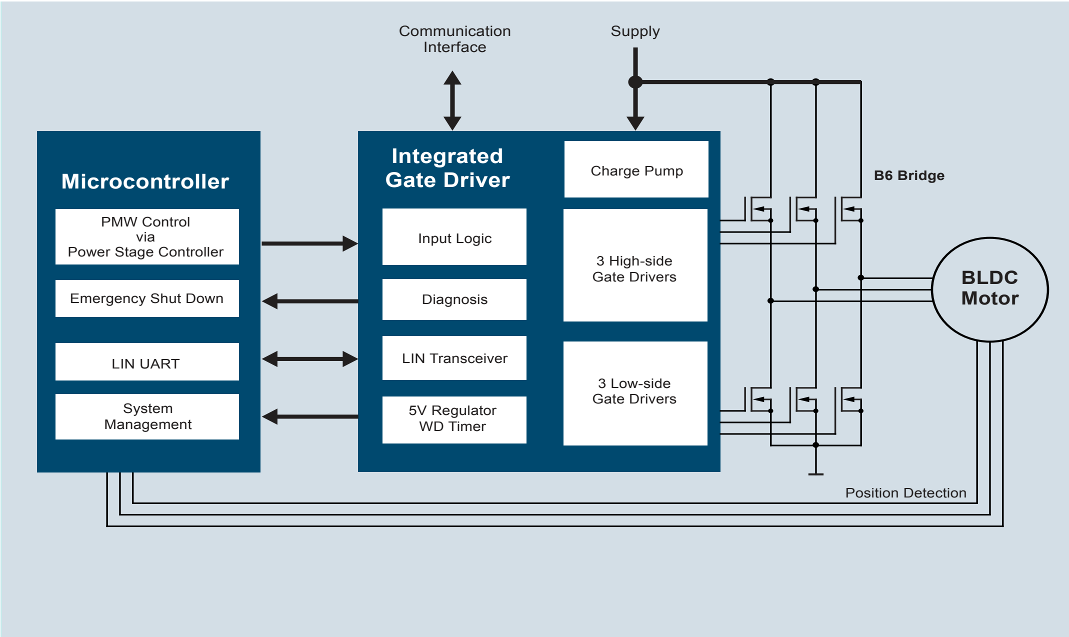


Figure 1. BLDC System Architecture

IC manufacturers integrate as many functions as possible to ease your design effort. A higher integration level also saves space. If the chip has an integrated LIN (local interconnect network) physical layer function, it does not need a discrete LIN transceiver. If you reduce the size of the electronic park brake control, you might have room to add ESP (Electronic Stability Control) functions on your ECU.

A watchdog timer is mandatory in automotive safety applications. For failsafe reasons, it needs to be on a different die than the MCU. Since the watchdog timer consists of digital logic and a counter, Atmel® integrated this function onto the MOSFET gate-driver chip to save cost and space.

Automotive Supply Voltage Range

A wide supply voltage range is a key criterion for applications within an automotive environment. Both high as well as low battery voltages are a challenge for the ECU. It needs to withstand a high operating voltage during operation conditions such as jump-starting and load dump.

Starting an engine with an external starter battery is called jump start. The worst-case jump start is off a 24V truck battery with 12 instead of 6 lead acid cells. This creates a maximum voltage requirement of 28V. Load dump occurs when a mechanic disconnects the battery while the engine is still running. The inductance of the alternator windings creates high-energy pulses with voltage peaks up to 120V. This voltage is limited by a central load-dump protection unit. The protected load dump output voltage depends on the individual OEM requirements (typical example 36V).

Low operating voltages also challenge electric motor controller systems. The most critical low-voltage condition occurs during car start. Activating the ignition key or starting the engine after the start/stop function can drop the battery voltage as low as 4.5V. This is called crank pulse (figure 2). The ECU must function properly during this crank pulse. You can achieve this with electrolytic capacitors that you size according to the lowest voltage and longest time expected for the crank pulse.

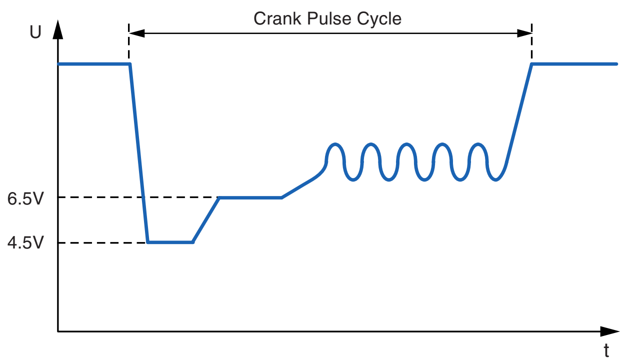


Figure 2. Typical Crank Pulse Waveform

External MOSFETs

There are both N-channel and P-channel high-current MOSFET switches. For the same die size, an N-channel MOSFET will have half the on-resistance (R_{DSon}) compared to a P-channel device. Since die size is the fundamental factor of the part's cost, N-channel MOSFETs are the preferred solution in most cases.

The control voltage that begins to turn on a MOSFET is called the gate threshold V_{Gth}. This voltage drops at high temperatures. In a hot engine compartment, logic-level MOSFETs may not switch off completely, whereas non-logic-level MOSFETs guarantee safe and proper switch-off.

Gate Drive

To turn on a high-side MOSFET, you need to raise the gate voltage above the supply voltage the MOSFET is switching (see figure 3).

Closing the high-side switch increases voltage on motor phase A to the level of the battery supply voltage V_{Supply}. This means the voltage on the source pin of the MOSFET is at V_{Supply}. The gate threshold voltage, V_{Gth}, is always relative to the FET source pin. Hence, the gate voltage V_{GSH} needs to reach a level of at least V_{Supply} plus V_{Gth}.

To create this gate drive voltage, chip designers use an integrated charge pump (figure 4). In addition, the charge pump helps to stabilize the drive of the external low-side MOSFETs. Non-logic-level MOSFETs require a gate voltage of 8V. If you derive the low-side gate drive directly from the battery you cannot maintain 8V during a crank pulse event. A 2-stage charge pump solves this issue. The charge pump output voltage is transferred by the VG regulator to the low-side gate circuitry (see figure 3).

Integrated Charge Pump vs. Bootstrap

The ATA6843/44 charge pump is similar to a Dickson charge pump with its 2-stage architecture (see figure 4). You can generate the output voltage of a 2-stage charge pump to a maximum value two times higher than the input supply voltage. The 2-stage configuration enables a reliable gate supply voltage range for the external MOSFETs. The MOSFET gates are protected from load dump and the gate drive voltage is maintained during a crank pulse event.

Competing products often use bootstrap gate drive techniques. Bootstrap circuits will double the power supply voltage. But bootstrapping will not maintain gate drive during a low-voltage crank pulse condition. Bootstrap circuits need an oscillating motor drive output to work. If the motor output is fully on or fully off the bootstrap circuit cannot keep its

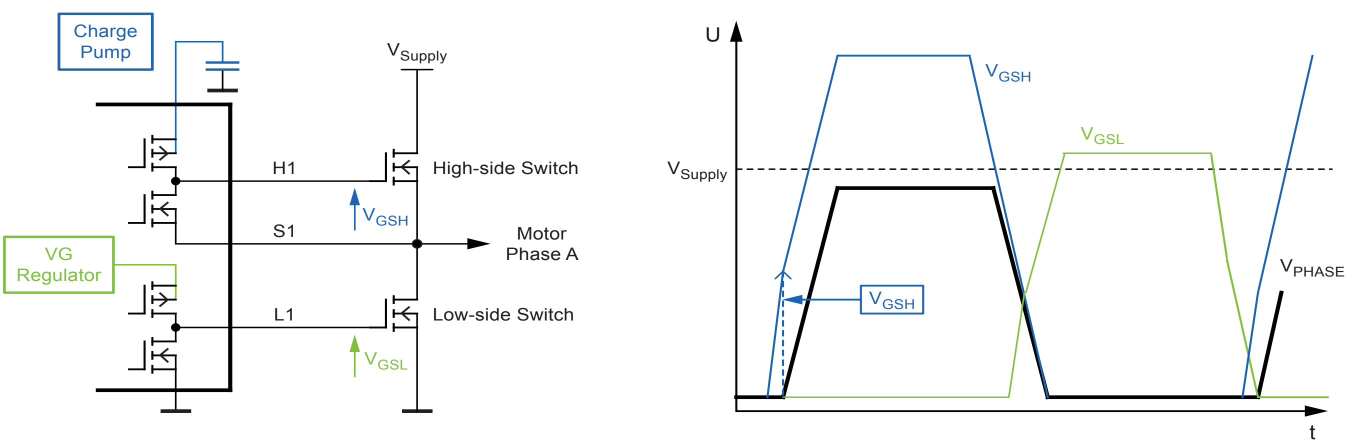


Figure 3. Gate Drive

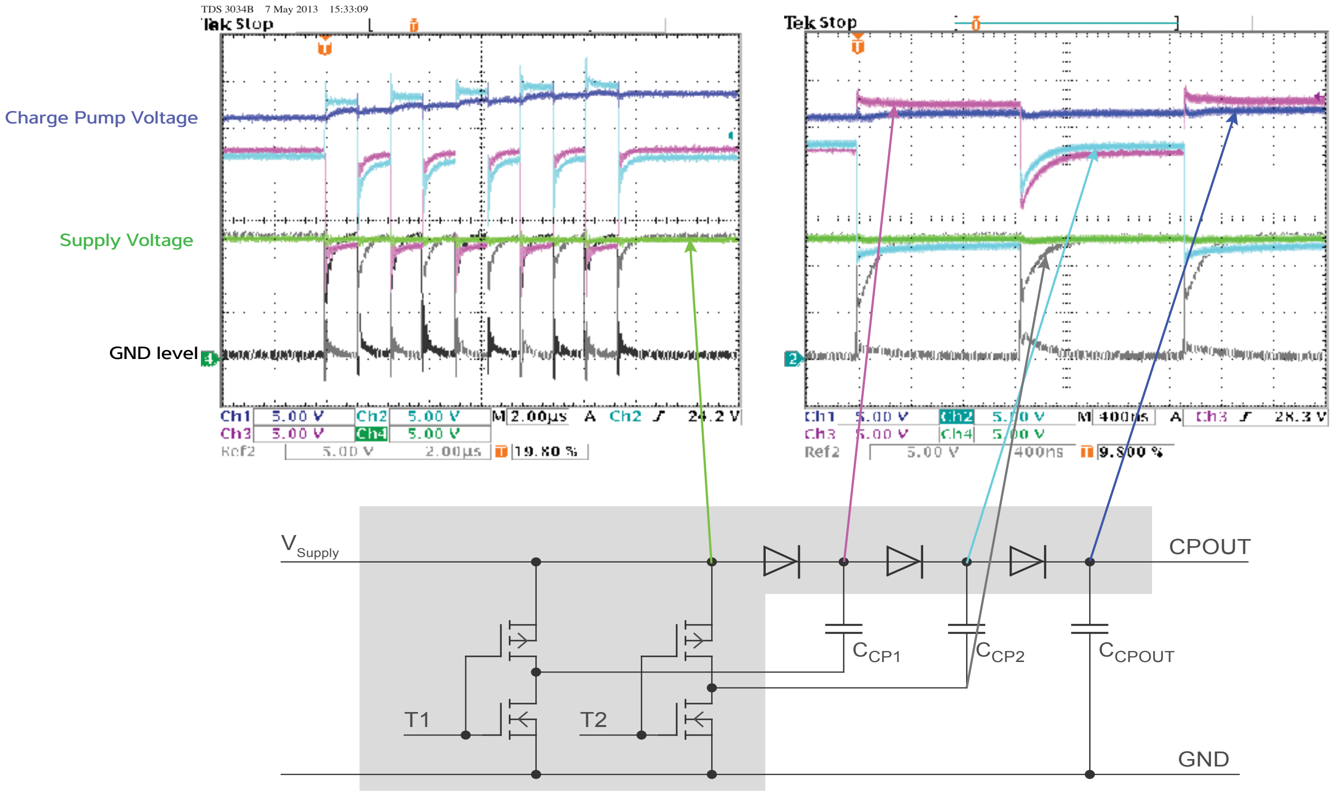


Figure 4. ATA6844 Charge Pump Wafeforms

storage capacitor charged. Only a free-running charge pump is able to provide a stable output voltage above battery supply no matter what the motor duty cycle is.

Engineers often believe that a charge pump is a complicated device and difficult to design into their application. Atmel developed the ATA6843/44's integrated charge pump to drive six N-channel MOSFETs. The chip only requires three external ceramic capacitors. The on-chip charge pump guarantees to easily create a reliable BLDC gate drive system. There is no additional effort for comparators, chopping, or switching. You don´t have to agonize over complex design issues. The Atmel engineers considered EMC (electromagnetic compatibly) radiation when they developed the ATA6843/44's internal push/pull stages. They included sufficient cross-conduction times to keep emissions low so you can meet strict automotive regulations.

Reverse-Voltage Protection

The integrated charge pump allows you to implement a reverse-voltage protection circuit (figure 5). This requires a single external N-channel MOSFET wired in the reverse direction. At power-on the N-channel MOSFET conducts via its intrinsic body diode. This starts the integrated charge pump. Since the motor is not operating, the supply current is low. The intrinsic body diode can power the chip without overheating. As soon as the charge pump voltage exceeds the protection MOSFETs' gate threshold, the MOSFET is driven into active mode and conducts through its low on resistance. The charge pump can now also provide the gate drive voltage to the motor MOSFETs.

An NPN transistor plus a diode in series protects against fast negative voltages. When the battery input goes negative relative to chassis common, it turns on the NPN transistor. The transistor then clamps the MOSFET gate and source together.

Atmel

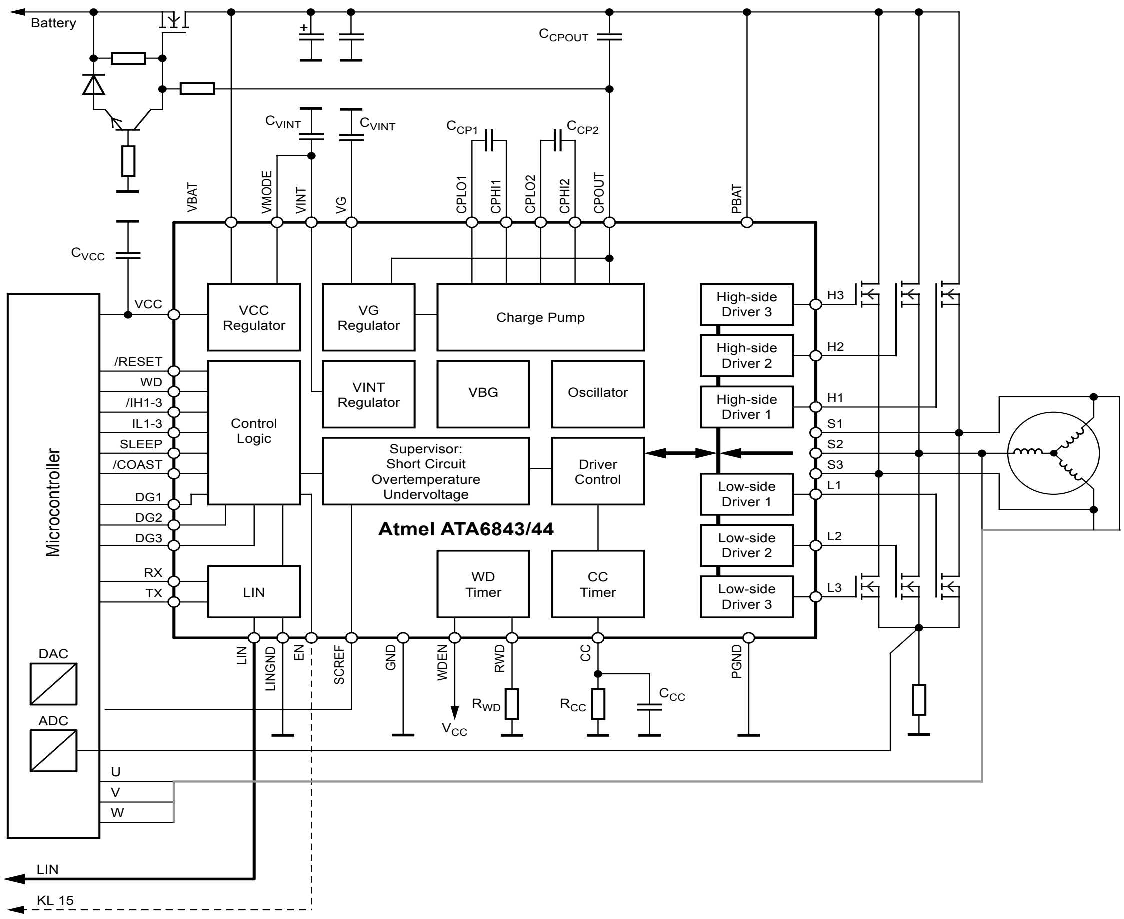


Figure 5. ATA6843/44 Application Schematic

High-Temperature Operation

The AEC-Q100 standard defines ambient temperature ranges for automotive applications. Grade 1 covers ambient temperatures of -40°C to 125°C, grade 0 is suitable for under-the-hood applications up to 150°C ambient temperature.

Atmel manufactures motor driver ICs on its own BCD-on-SOI (bipolar/CMOS/DMOS on silicon-on-insulator) technology. This enables the IC to operate at junction temperatures up to 200°C and ambient temperatures up to 150°C. SOI technology offers specific design advantages. There is significant cross-talk reduction between power and digital circuits on the same die, as well as easy integration of high-quality power devices, and immunity to radiation. Compared to devices manufactured with existing bulk technology, devices manufactured with SOI wafers achieve a higher level of integration and processing speed at reduced power consumption. The isolation of devices through an oxide layer eliminates problems of parasitic capacitance and latch up, thus minimizing internal coupling. This helps to simplify the design and reduce risks.

Switching the MOSFETs

MOS gate threshold voltages typically decrease at higher junction temperatures. This disturbs the IC-internal timing and may prevent the MOS switches from turning off. Atmel adjusts the gate threshold voltage of the high-temperature BCD-on-SOI process to meet these high-temperature gate threshold requirements.
Likewise, the decreasing gate threshold voltage affects the external MOSFETs. The higher the temperature the lower the MOSFET gate threshold voltage. One solution is to apply non-logic level MOSFETs with higher gate threshold voltages instead of P-channel MOSFETs. At the same die size, N-channel MOSFETs have only half the R_{DSon} resistance. The reduction of thermal dissipation is an important benefit, in particular for applications in hot environments.

Diagnostics and Monitoring

In automotive applications monitoring and diagnostic functions are mandatory. Voltage failures, thermal overload, or overcurrent are events that require immediate action, for example, instant stop or motor driver unlock, independent of any microcontroller operation. In addition, ECUs must provide feedback on malfunctions to the host controller, and record them in central failure protocols to enable appropriate countermeasures.

One emergency shut-down function is the coast feature. The ATA6844's COAST pin enables the motor to rotate in coasting mode by activating a single input pin. In case of emergency, all six output gate drivers immediately switch to off mode, the external MOSFETs are deactivated, and the motor will coast to a stop.

Support Tools: The Development Kit

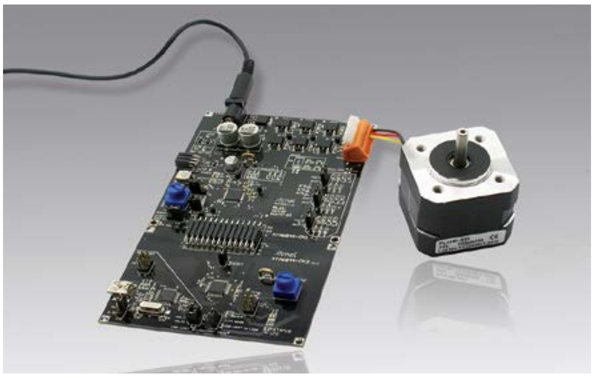


Figure 6. Development Kit ATA6844-DK

The ATA6844-DK development kit enables designers to take first steps in high-temperature BLDC motor control. It consists of two connected boards plus a standard BLDC motor. The

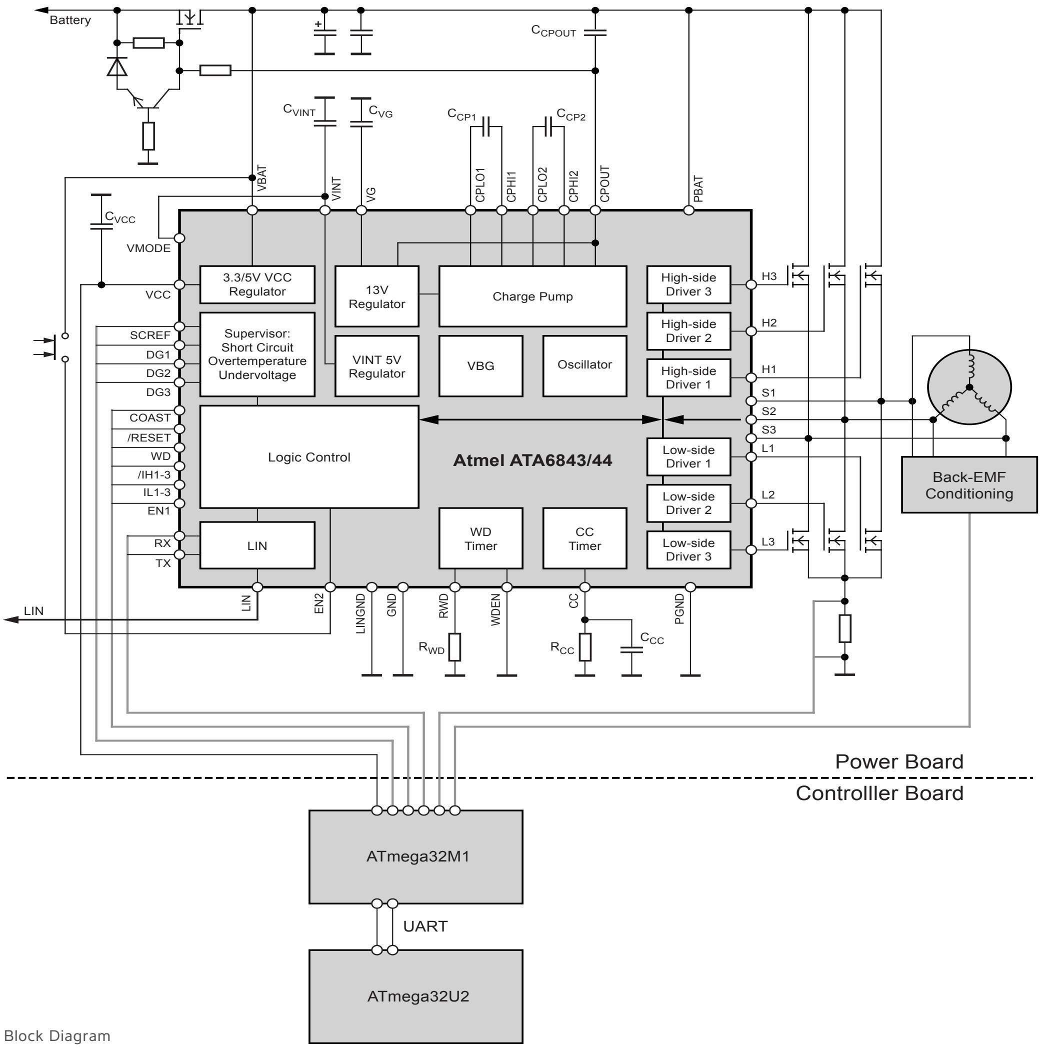


Figure 7. Evaluation Kit Block Diagram

power board handles all BLDC functions except the MCU microcontroller unit. Six discrete N-channel FETs are arranged in a BLDC bridge architecture. An Atmel SBC ATA6844 handles the basic electronic control unit functions, a low-dropout regulator, LIN transceiver, and window watchdog. The controller board features the Atmel ATmega32M1 8-bit AVR® MCU dedicated to BLDC motor control. An ATmega32U2 microcontroller is on the board for debugging.

Power Board

The power board comprises all the BLDC motor control functions:

- Six N-channel MOSFETs arranged as a B6 bridge supply the motor current. The output terminals U, V, and W attach to the motor connector to operate the included BLDC motor.
- For emergency purposes, you can adjust the short-circuit shutdown current with potentiometer SCREF.
- For EMC purposes, you can modify the serial resistors to achieve gate voltage shaping to adjust the slew rates of the discrete MOSFETs.
- 82mOhm shunt for motor current measurement can be adjusted for various motor current loads
- Charge pump for external gate voltage supply
    - 3 capacitors for complete charge pump function
    - Test pin CPOUT allows access to the charge pump output voltage
- The charge pump output voltage is also used to implement reverse battery protection. Typical supply voltage is 12V. A seventh MOSFET the same size of the B6 bridge MOSFETs is controlled by the charge pump output. The reverse voltage protection control circuit ensures fast switch off during any negative supply voltage spikes.

Motor position feedback is a key feature of BLDC applications. The ATA6844-DK offers both Hall sensor feedback and B-EMF (back-electromotive force) feedback. The option can be set via jumpers.

For Hall sensor feedback the jumpers directly connect the motor Hall sensor output signals to the microcontroller. The microcontroller uses these digital Hall signal outputs for commutation. A resistor and capacitor network provide for B-EMF feedback position detection. For this mode the jumpers connect 3 motor control signals and their dedicated neutral point signals to the microcontroller interface.

Controller Board

While an actual automotive application will have the BLDC microcontroller placed close to the gate driver chip, this kit has the MCU on a separate board to increase flexibility. All MCU signals required to drive the power board are available on the interface connector. This approach enables the customer to use any motor control MCU by simply connecting the relevant control signals to the interface connector. All Atmel MCU evaluation boards, e.g. STK®600, can be used.

The controller board provides three debugging methods. The standard debug interface is a UART interface. The Tx and Rx connections are accessible via jumper connectors. Since the ATA6844 has a LIN transceiver, diagnostics can also be done via the LIN interface. Thirdly, the on-board ATmega32U2 enables RS232 interfacing. The MCU's output USB interface can be directly connected to a PC and controlled by a hyper terminal application.

For further information please refer to the ATA6844-DK application note at http://www.atmel.com/tools/ATA6844-DK.aspx.

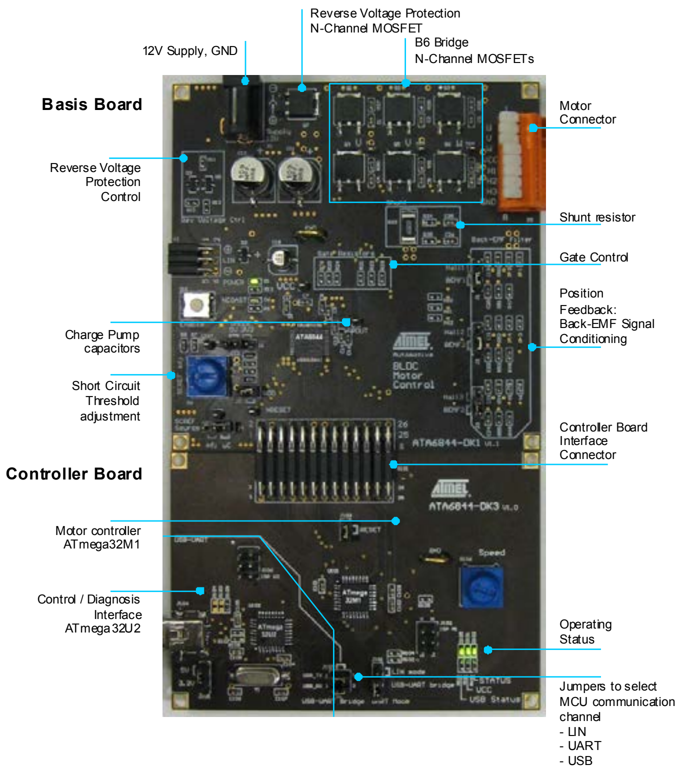


Figure 8. Application Board Top View, Functional Blocks

Summary

The Atmel ATA6843/44 integrated gate driver enables to overcome the challenges of present day automotive BLDC designs. It lets you design such applications utilizing fewer external components. These motor driver devices feature a high maximum junction temperature to meet the strict automotive grade 0 requirements for under-the-hood-applications. The IC has an integrated 2-stage charge pump ensuring that designers can easily create a reliable BLDC gate drive system without any additional design effort. The development kit allows engineers to quickly get familiar with high-temperature BLDC motor control.

For further information on AVR motor control designs, see http://www.atmel.com/products/AVR/mc/?family_id=607.

Turn-Key Passive Entry/ Passive Start Solution

Dr. Jedidi Kamouaa

Atmel® provides a passive entry/ passive start (PEPS) system with a complete set of basic building blocks, including hardware and software. This system allows designers to get more familiar with PEPS systems and Atmel's PEPS solution. The basic building blocks are a great help for engineers without experience in PEPS systems to shorten their development time, and time-to-market. The system demonstrates the principles of wake-up and ID screening, command and data, security authentication, and basic localization. It addresses application-related issues such as calibration at end-of-line, post-processing of RSSI (received signal strength indication), accuracy of the localization, and multiple key fobs. You can easily enhance this system for your own prototype development.

This article describes the complete Atmel PEPS system including the orientation-independent LF (low frequency) wake-up functionality. The system also provides key localization and one- or two-way RF communication. It includes immobilizer LF communication according to the Atmel open immobilizer protocol, and keyless entry functions with Atmel's secure rolling-code protocol. All functions needed for uni- and bi-directional authentication, key fob localization and field supply are also implemented by software.

General System Description

Atmel's PEPS system enables hand-free interaction with the vehicle (figure 1). It allows the driver to lock/unlock the vehicle doors and to start/stop the vehicle engine without performing any manual action either with the key fob or a mechanical key. Although the key fob still includes the conventional RKE (remote keyless entry) buttons, PEPS will pave the way to a more natural and convenient way to enter and start the vehicle while maintaining a high level of safety and security.

System Functions

The PEPS system provides the following car access functions: immobilizer, remote keyless entry, passive entry (PE), passive start (PS) and passive lock (PL). In addition, it also includes the following system configuration functionalities: a learning procedure for pairing vehicle and key fob, RKE rolling code synchronization, and end-of-line parameters (RSSI compensation, etc.).

When the driver approaches the vehicle, a secure wireless communication between the key fob and the vehicle control unit authenticates the fob. Bi-directional wireless communication authenticates the key fob and the vehicle in both one-way and two-way systems. In one-way RF systems the LF downlink serves to wake up the key and to receive commands as well as data for the authentication process. The fob then sends the response to the vehicle via RF uplink. In two-way RF systems the LF downlink only serves to wake up the key fob and to establish the RF up-/downlink. The bi-directional RF link handles the entire communication during the authentication process.

Vehicle LF antennas detect the key fob location and determine if the key fob is inside or outside the vehicle cabin. The system is flexible. You can adapt the position and the number of antennas to any type of vehicle.

Passive Entry (PE)

The passive entry function allows the driver to unlock the vehicle's doors without activating the key fob. However, some user action is needed to trigger the system such as approaching the door, or touching or pulling on the door handle. When the vehicle detects such an activity, it starts to search for the key fob outside the vehicle cabin. This is called localization. Once the fob has been authenticated, the doors unlock automatically.

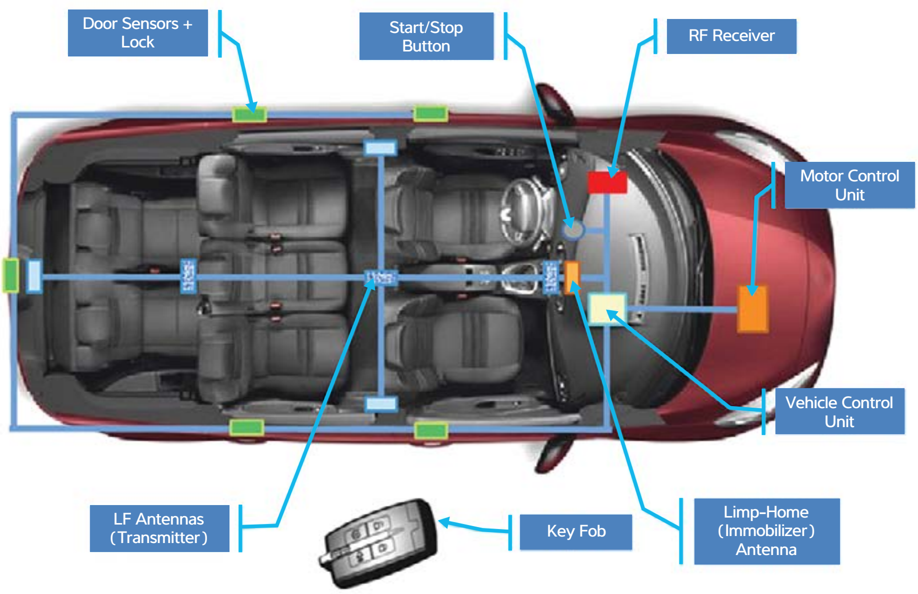


Figure 1. System Architecture

Passive Start/Stop (PS)

The passive start function allows the driver to start or stop the vehicle engine without activating the key fob. Replacing the lock cylinder, the start/stop engine button in the vehicle cabin activates the PS function. Once the driver pushes the start/stop button, the vehicle starts to localize the key fob inside the car.
The communication between vehicle and fob is almost identical to PE systems, except that PE systems search fobs outside the vehicle, whereas PS systems search for fobs within the vehicle cabin. If at least one paired key fob is localized inside the vehicle cabin, and has been successfully authenticated, the vehicle starts or stops the engine.

Passive Lock

The passive lock function allows the driver to lock the vehicle doors without activating the key fob. Prior to the introduction of PEPS systems, the driver locked the car doors by pressing a dedicated button on the key fob. With PEPS systems, a lock button or a sensor on the door handles eliminates the need for key fob manipulation. The driver only needs to push this button or touch the handle to lock or unlock the doors.

The vehicle system starts automatically to search the key fob outside and inside the car, and initiates key fob authentication. If at least one key fob is authenticated and localized outside the cabin and no paired key fob has been authenticated and localized inside the cabin, the vehicle locks its doors. Instead of keeping the doors unlocked if keys have been detected inside the cabin, it is also possible to blacklist those keys and disable them for the next passive entry request.

RKE

In addition to the lock and unlock function, you can include supplemental remote functions in the key fobs even with the PEPS system. When doing so, take care to avoid unwanted interaction between PEPS and RKE. For example, if the driver wants to lock the doors via RKE, the vehicle needs to check for active keys inside the vehicle cabin. If a paired key fob is detected inside the cabin, it must be disabled for the next passive entry request.

Immobilizer

The immobilizer function is an emergency procedure in case the passive start does not work properly or the key fob's battery is empty. It uses the same basic procedure as passive start but via short-range LF-to-LF communication. The LF field generated by the vehicle's base station supplies the key fob with power via antenna coupling. This magnetic field serves as bi-directional communication channel. See http://www.atmel.com/devices/ATA5580.aspx for more information on Atmel's highly secure, ultra-low-power AES-128 transponder with this immobilizer function.

Key Fob Wake-Up

In a hand-free PEPS system the key never knows in advance when a communication sequence requires the PEPS controller to actively respond to a request. An MCU that is permanently active consumes a lot of power and thus reduces battery lifetime. The Atmel MCU remains in sleep mode until a wake-up occurs. The highly sensitive 3-axis LF amplifier has a very low-power listening mode that constantly checks for a valid LF signal. Once it has received a valid LF signal containing the correct vehicle-specific wake-up ID, it generates a signal to wake up the PEPS controller.

Key Fob Localization

Localization is an important feature of any passive entry/passive start system. It detects if the key is near the vehicle, and, depending if it is a PE or a PS system, if the key is inside or outside the vehicle. A car has typically four to six LF antennas. These produce an LF magnetic field covering both the car interior and the car's vicinity. The key fob measures the LF signal level during the communication with the vehicle. It acquires the RSSI and sends it back to the vehicle, which analyzes the RSSI to determine the fob's position. As the spatial orientation of the key fob is unknown, the key fob uses three discrete antenna coils or one 3D-coil to determine the x-, y- and z-axes. The RSSI measurement accuracy depends on the hardware device and on the precise calibration of all key fobs during end-of-line manufacturing. Atmel's car access devices contain several technical innovations to assist in this critical process. For example, they measure all three axes simultaneously which reduces the overall RSSI measurement time.

Vehicle-Cabin LF Coverage

When defining the antenna placement within the car, insure that the most common locations of a key fob (such as seats) are covered. You can omit very untypical places such as under the roof. In most cases it is sufficient to place three antennas centered inside the vehicle to cover both vehicle sides (figure 2). The location, orientation, and amount of antennas vary depending on the car's size. To obtain constant field strength that does not exceed the cabin borders, you can adjust the LF power of each antenna individually.

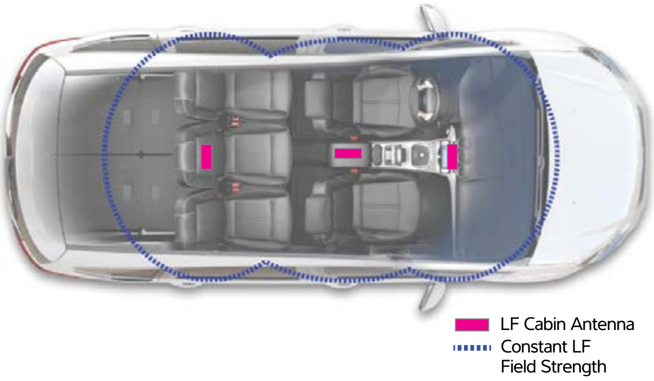


Figure 2. Inside Cabin Antennas

Vehicle-Outside LF Coverage

To design a passive entry function, you need to place the LF antennas close to the car's doors and trunk. A typical configuration is to place one LF antenna in each door and one in the trunk. With more powerful antennas having a higher driving current, only one antenna per side is required to cover both the front and rear door. In this case, place the antenna inside the "B" door pillar between the front and rear door (figure 3).

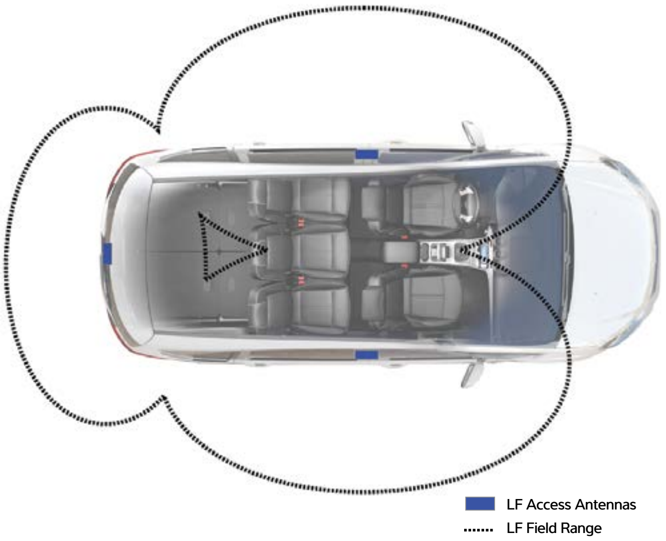


Figure 3. Outside Cabin Antennas

Trigger Sequence for Inside Localization

Passive start systems use only the cabin antennas for the inside localization process. The cabin antennas are activated one after another. The generated LF field covers the vehicle cabin as well as the perimeter close to the vehicle. The key fob measures the LF field RSSI of each vehicle cabin antenna trigger, and sends it to the vehicle. The vehicle gathers all RSSI values for further computation. They are either compared to an interior threshold or computed together to determine whether or not the fob is inside the vehicle cabin. The vehicle manufacturer must know the vehicle LF cartography to define the threshold value.

Trigger Sequence for Outside Localization

Passive entry, passive lock, and passive approach use an outside localization procedure.

Depending on the access strategy for PE systems, the chip activates one or more antennas (figure 4). There are several access strategies you can implement (see table 1).

Event	Access Level Selected	Access Antenna Used
User pulls door handle at drivers door (Antenna 1)	Vehicle looks for fobs on all access points	Antennas 1/2/3/4/5
	Vehicle looks for fobs on all access points except trunk	Antennas 1/2/4/5
	Vehicle looks for fobs on the same side as access point triggered	Antennas 1/2
	Vehicle looks for fobs on the access point triggered	Antenna 1

Table 1. Access Strategies

Protocol timing is one of the most critical parameters for PE systems. You should adjust the antenna trigger to get the fastest possible reply during passive entry. The antenna that covers the surround of the pulled door handle is activated first, since there is a much higher probability to locate a key fob next to the door triggering the passive entry process. The vehicle antenna activation sequence depends on the key fob location probability. For example, if the defined access level is "vehicle looks for fobs on all access points except trunk",

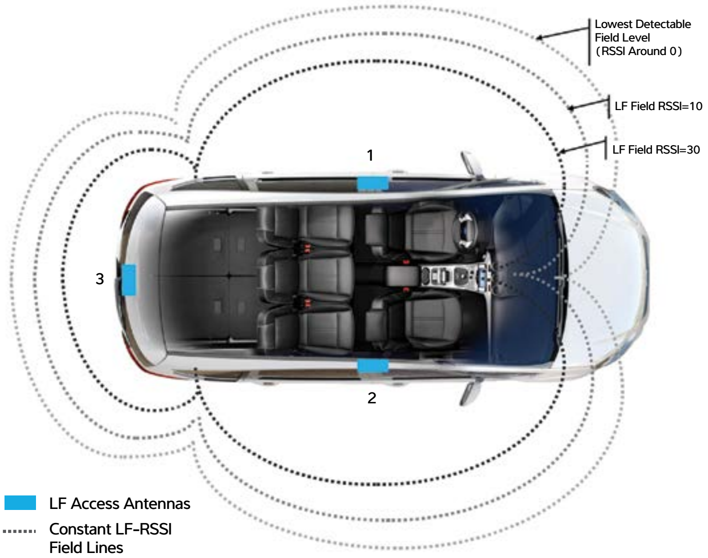


Figure 4. Thresholds for Outside Localization

pulling the driver handle initiates the antenna sequence 1 – 5 – 2 – 4 (driver door, passenger door, rear door left, and rear door right). If a fob successfully replies following antenna 1 activation, there is no need to check the other next antennas. Other functions such as passive lock, passive approach, or walk away do not require a specific trigger order sequence.

For each vehicle antenna trigger, the fob sends the measured LF-RSSI to the vehicle. Once enough RSSI values have been sent to the vehicle, the vehicle determines if the fob is located outside the vehicle cabin by:

- Checking if a fob has replied without checking a RSSI value as long as the fobs location is known from the previous action such as passive entry or walk-away.
- Comparing the RSSI value with an external threshold such as passive approach or walk-away. Different threshold values can be used to verify if the fob is located near or far from the vehicle. The vehicle manufacturer must know the vehicle LF cartography to define these threshold values.

At the end of this procedure there is a list of all fobs that have replied and that meet the outside localization criteria. However, the field generated by these antennas also covers part of the vehicle cabin. Fobs located within the car may send the same RSSI value as fobs located outside the vehicle. To address this issue, a good approach would be to create a list of all fobs found inside the vehicle before locking the vehicle and remove these fobs from consideration when performing the passive entry function.

Authentication

Protection against car theft or theft of property from vehicles is one point that requires special treatment in PEPS systems. Before a key fob can gain access to the vehicle or start the engine, the system requires a successful authentication between key fob and car.

The authentication process is based on Atmel's open-protocol AES 128-bit encryption. AES-128 is included as hardware module in the Atmel ATA5790N and ATA5791 PEPS controllers. During system configuration the vehicle and fobs exchange one or two 128-bit secret keys, depending on the authentication procedure. Both uni- and bidirectional authentication conform to the same challenge/response principals. In any case, it is always the vehicle that starts to communicate with a key fob.

Uni-Directional Authentication

In uni-directional systems, the vehicle authenticates the key fob. The vehicle generates a random number (Nonce) and transmits it via LF as challenge to the key fob. The fob encrypts the challenge and returns that via RF as response to the vehicle. The vehicle does the same and encrypts the Nonce. If the encrypted Nonce and the received response are identical, the key is authenticated and the door unlocks.

Bi-Directional Authentication

The bi-directional procedure offers increased security compared to uni-directional authentication. The fob authenticates the vehicle before replying, and in a second step, the vehicle authenticates the fob. Both steps use different secret keys.

The vehicle generates a Nonce, encrypts it using secret key 1 to get *Nonce*, and sends both via LF to the key fob along with a command to indicate that bidirectional authentication is used. The fob encrypts the Nonce with secret key 1 and compares it to *Nonce*. If both are identical the vehicle is authenticated to the key fob. Then, the key encrypts this first encryption result by using secret key 2, and sends it as response via RF to the vehicle. The vehicle performs the same procedure and compares its own result with the received response. If these are identical, the fob also is authenticated to the vehicle, and the doors unlock or the vehicle starts.

As this procedure requires additional data to be exchanged and two encryption steps, it takes slightly longer than the uni-directional authentication.

If the timing requirements for passive start are less critical than for passive entry, you might use bi-directional authentication for passive start systems, and uni-directional authentication for passive entry systems.

Communication Interfaces

A PEPS system communicates bidirectionally via three different communication channels:

- Bidirectional, short-range (4 to 5cm) LF communication
- Unidirectional, medium-range (about 2 to 3m) 3D-LF communication
- Long-range (10 to 30m) RF communication, both one- and two-way RF

Short-Range LF Communication

The short-range bidirectional LF communication serves for immobilization according to the AES-128 protocol and for system configuration. In learning or pairing mode, it transfers the authentication data(i.e. secret keys, or communication parameters) from the car to the key where the EEPROM stores this data. In both cases the circuit operates independently from the battery. The ATA5272 base station applies the magnetic field that supplies the circuit with power for bidirectional communication.

Medium-Range LF Communication

The medium-range LF interface within the key fob consumes extremely low power in listening mode. It permanently checks if a vehicle requests to wake up the key PEPS controller. This interface consists of 3 channels equipped with three separate orthogonal antenna coils or one 3D-coil in case of unknown spatial key orientation. Triggered by a user action such as touching the door handle, the ATA5279C LF driver in the vehicle sends LF commands to initiate the search for an associated key. If a key wakes up, it replies using the RF channel.

Long-Range RF Communication

Both RF configurations need an anti-collision method. Standards prescribe that a PEPS system must support up to eight key fobs (four with one-way RF) simultaneously. If more than one key replies at the same time, the receiver within the car can not decode the signal. The time domain method can avoid such collision. The engineers assigned time slots to each fob and also a fob index to each key during configuration. This way, the keys can determine in which time slot they need to respond, and no two fobs are allowed to emit at the same time. This is called anti-collision functionality. The Atmel anti-collision method is designed so that the first time slot is assigned to every key. In case there is only one key near the car, the vehicle receives the reply faster. If more than one fob is present, four to eight slots assigned to individual keys following the first common time slot. In addition, the vehicle can modify the sequence of fob replies by using the fob index.

One-Way RF

Atmel's ATA5791 single-chip PEPS controller with a fully-integrated fractional-N PLL (phase-lock loop), VCO (voltage-controller oscillator) and a 315/433MHz loop filter performs the one-way RF communication. In addition to the RF transmitter function, the IC contains the immobilizer circuit and the 3D LF receiver.

Two-Way RF

The 2-way-RF communication requires two ICs in the key fob: the ATA5790N PEPS controller without RF transmission function, and the ATA5831 RF transceiver. With one 24.305MHz crystal, the ATA5831 operates at 315MHz, 433MHz, 868MHz, and 915MHz frequencies.

Atmel Evaluation Kits

Car Access Reference System (CARS)

The car access reference system (CARS) demonstrates all functions of the aforementioned PEPS system. The body control computer emulation uses an ATmega2560 on a base board and application boards plugged on top.

The PC-GUI comes up with a start screen. It visualizes the individual design steps and enables you to modify parameters. The software allows easy modifications and adaptations to customer needs.

ATAK51003-V1: One-Way Multi-Channel Passive Entry

This kit is for second-generation PEPS systems and contains reference designs for the ATA5782 and ATA5791. It uses the AES-128 open immobilizer protocol (RF and LF). You can operate it via PC GUI or in standalone mode. For 3-channel operation, three frequencies are available (433.47MHz, 433.92MHz, 434.35MHz). Single-channel application is also supported with the ATA5774C.

ATAK51002-V2: Two-Way Multi-Channel Passive Entry

Similar to the one-way kit, this kit serves for second-generation PEPS systems and uses the Atmel AES-128 encryption. The included reference designs are based on ATA5831 and ATA5790N. It uses the AES-128 open immobilizer protocol (RF and LF). Designed for multi-channel operation, the RF frequency ranges 315 MHz to 956 MHz. Again, you can operation it via PC GUI or in standalone mode.

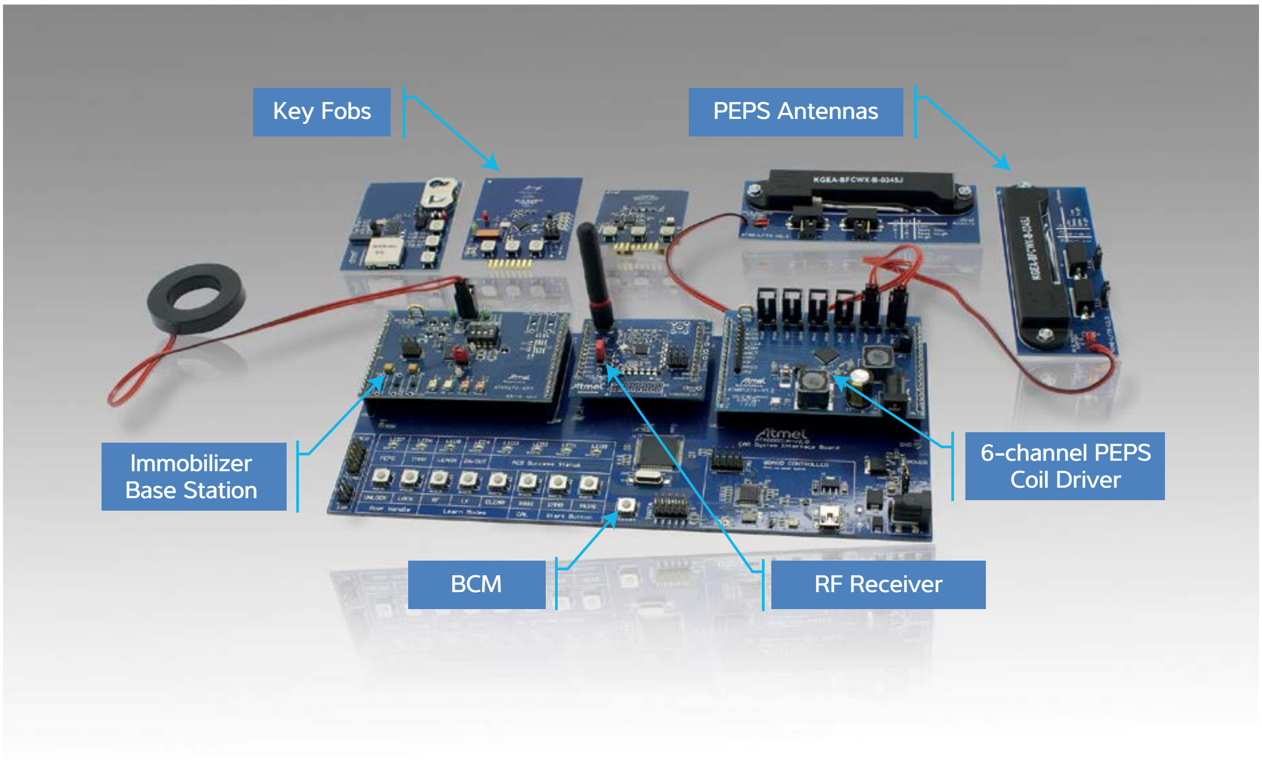
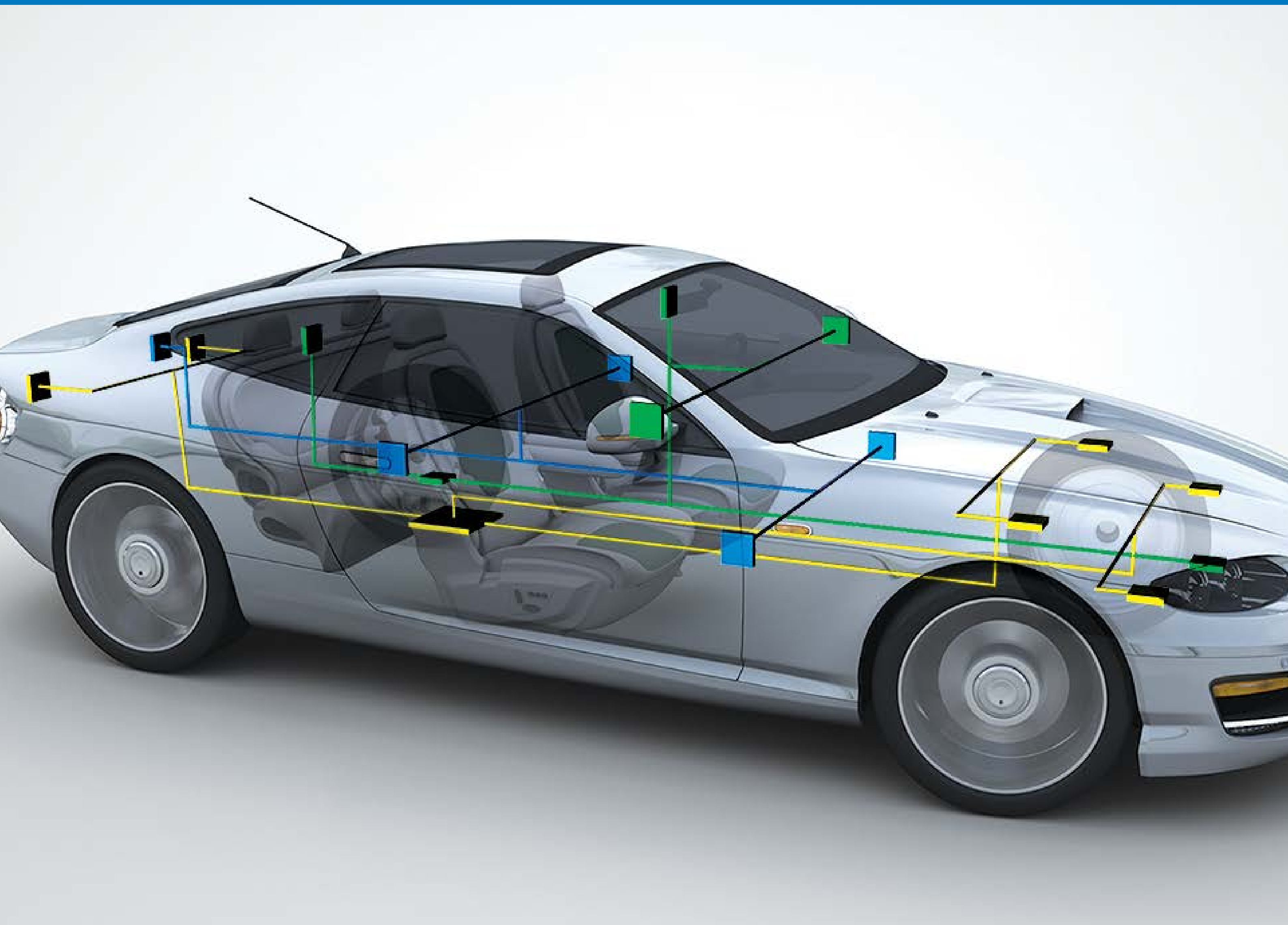


Figure 5. ATAK51003-V1 One-Way Multi-Channel Passive Entry Kit



CAN-FD and Ethernet Create Fast Reliable Automotive Data Buses for the Next Decade

Y.B. Pradeep

The automotive industry has seen explosive growth of electronic control units (ECUs) in vehicles. These ECUs evolved from stand-alone units to intelligent nodes in networks using both proprietary protocols and industry-wide standards. Automotive networks have brought down cost and increased reliability and performance. The last decade saw the establishment of data buses as in-vehicle network standards. The next decade will see expansion of existing vehicle network protocols and adaptation of standard networking into cars. This article analyzes two of the new automotive networking protocols, CAN-FD and Ethernet.

Why New Data Buses?

New automotive features such as advanced driver assistance systems, parking aids, lane departure systems, blind-spot detection, and infotainment systems have triggered the need for new data buses. These new buses must provide faster speed, bandwidth scalability, and a seamless upgrade path, while helping to reduce power consumption, weight, wire count, and deployment costs.

CAN with Flexible Data Rates (CAN-FD)

CAN-FD improves the bandwidth utilization of the dominant bus system in the automotive industry, the CAN protocol (figures 1, 2, 3). The increase in bandwidth utilization is achieved by:

1. Dual Bit Rate: CAN-FD frames support dual-bit-time capability
   a. Normal Bit Time
      - The bit time is identical to the existing CAN protocol. This includes those fields where multiple devices can transmit simultaneously – at the arbitration start and acknowledgement end.
      - The fields are as below:
        - Start-of-frame bit (SOF), arbitration field (12 bits), and 2 control bits
        - Acknowledge bit, acknowledge delimiter bit, end-of-frame (EOF) bits (7 bits) and inter-frame gap (3 bits)
   b. Reduced Bit Time
      - To achieve higher data rates CAN-FD allows bit times for certain fields that are shorter than the current CAN bit time.
      - Timing requirement for these fields are less stringent as it is guaranteed that the devices only transmit one after another. Bit-wise arbitration is not needed.
      - These fields are: 2 control bits, payload length (4 bits), payload data, and CRC (17 or 21 bits).

2. Pay Load Increase:
   a. The message length is 64 bytes compared to previously 8 bytes, improving the efficiency of the CAN protocol.
   b. To take advantage of this improvement in CAN-FD, you also need to update the system software.

Figure 1. Standard CAN Message

Figure 2. CAN-FD with Reduced Bit Time

Figure 3. CAN-FD with Reduced Bit Time and Increased Payload

CAN Frame Formats

CAN-FD is an evolution of the current CAN protocol and supports all existing CAN frame formats.
See figure 4 for a general CAN frame format.

Figure 4. General CAN Frame Format

CAN 2.0 – Standard Frame(s)

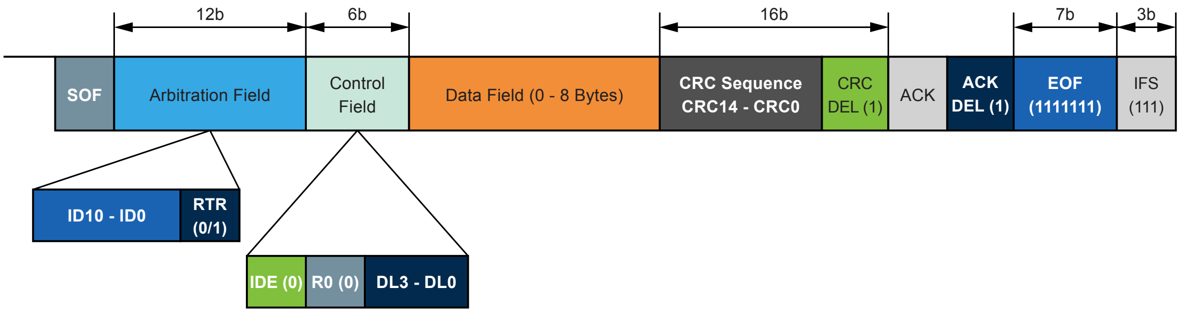


Figure 5. CAN 2.0 Standard Frame

The two bits as described below identify a standard frame (11-bit identifier):

- 13th bit – identifier extension (IDE) bit – dominant (0)
- 14th bit – reserved bit (R0) – dominant (0)

Another important bit is bit 12, the remote transmission request (RTR) bit.

- Dominant (0) – a data frame
- Recessive (1) – a remote frame

CAN 2.0 – Extended Frame(s)

The CAN 2.0 protocol also supports extended frames (figure 6).

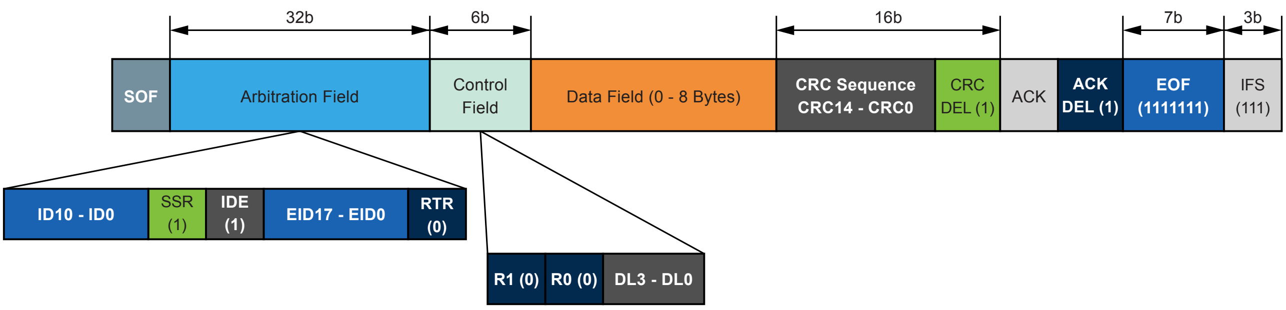


Figure 6. CAN 2.0 Extended Frame

The two bits as described below identify an extended frame (29-bit identifier):

- 13th bit – IDE field – recessive (1)
- 12th bit – SRR field – recessive (1)

The new position of the RTR bit is bit 32.

The extended frame includes two reserved bits (R0 & R1).

CAN-FD Standard Frame Format

You can see the larger data payload in the CAN-FD protocol (figure 7).

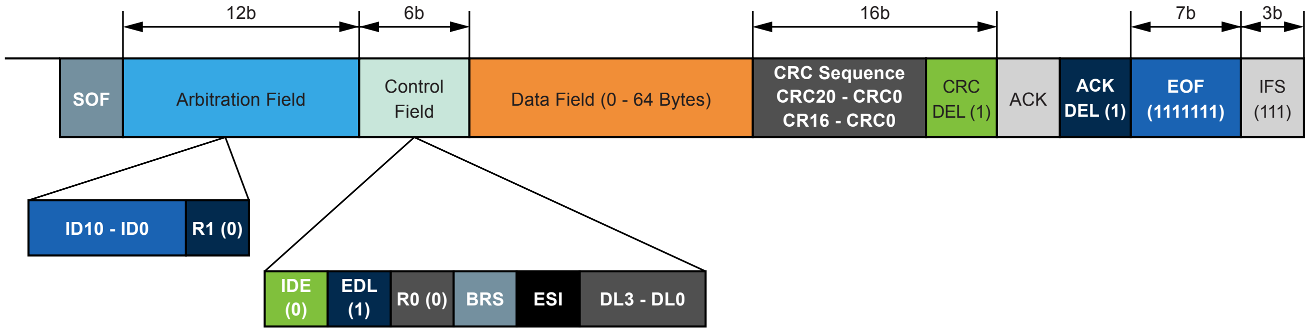


Figure 7. CAN-FD Standard Frame

The two bits as described below identify a CAN-FD frame:

- 13th bit – identifier extension (IDE) bit – dominant (0)
- 14th bit – R0 bit in standard frame is now extended data length (EDL) bit – recessive (1)

This implies that the CAN-FD specification should apply to the data length code (DLC) and the CRC sequence.

Bit 16 is a new bit - bit rate switch (BRS)

Note that there is no RTR bit.

New Features in CAN-FD

- Extended data length (EDL) bit, distinguishes CAN-FD frame from a standard CAN frame
  - Dominant – standard CAN frame format
  - Recessive – CAN-FD frame format
- Bit rate switch (BRS) bit: the CAN-FD rate immediately starts at the sampling point of BRS
  - Dominant – do not switch to new bit rate
  - Recessive – switch to new bit rate
- Error state indicator (ESI) bit
  - Dominant – error active transmitter
  - Recessive – error passive transmitter
- Two bits reserved for further protocol revisions – R0 (bit 15) & R1 (bit 12) – but the bit positions differ from earlier versions
- Modified CRC to maintain the same hamming distance for the longer frames as with standard CAN frames

CAN_FD Use Cases

Fast Software Downloads

CAN-FD serves to speed up end-of-line programming of vehicle ECUs. GM stated that with the use of CAN-FD, the ECU programming time is only one-third or even one-fifth of the current programming time [1]. Likewise diagnostics or software upgrades in repair garages are also faster.

Error Status

A transmit node error may result in a sudden stop of the message, thus affecting safety-critical systems. Every CAN-FD message includes the condition of the transmit node in the error status information (ESI) bit. This way, the receiver can monitor the transmit node and take fail-safe actions prior to any actual issues.

Increased Data Payload

CAN-FD enables message lengths of up to 64 bytes to avoid splitting long messages. This results in a very simplified transport layer of the CAN stack. Implementing complex flow control mechanisms involving multiple messages is not needed.

Faster Communication Between ECUs

The increasing amount of automotive features leads to a drastic augmentation of data exchanged between the automotive ECUs. CAN-FD can easily handle the higher amount of data due to its higher bandwidth, and it enables speeds similar to FlexRay.

Reduced Bus Loads

As a result of the higher communication speed, the ECUs can send and receive data more quickly using CAN-FD frames rather than the standard CAN frames. This directly reduces bus loading.

Example: An instrument cluster informs the driver of many vehicle parameters. It has to drive three to seven gauges, control 20 to 30 tell-tales, generate chimes, and display signal warnings to indicate status or system malfunction. This node receives and transmits information via many CAN messages from multiple ECUs. The CAN load on such a system can be as much as 75% - 80%. CAN-FD alleviates this problem by reducing the CAN bus load.

Transmission Line Length

In case of networks in trucks or articulated buses, the bus is as long as 9 to 20 meters. The arbitration field limits the speed of the entire network.

The J1939-14 standard defines a maximum bit rate of 500kbps. However, CAN-FD enables much higher speeds. The arbitration fields may remain at 500kbps whereas the data payloads can be exchanged at much higher data rates. This increases the throughput of the network.

Migration from CAN to CAN-FD

The introduction of CAN-FD will not affect today's vehicle networks such as LIN and MOST. Migration paths are necessary to include CAN-FD into existing CAN networks. This is because a CAN-FD compliant node can accept current CAN frames in addition to CAN-FD frames without any errors. A normal CAN node, however, will generate an error frame on the network in the presence of CAN-FD frames. OEMs can mitigate migration efforts to a true CAN-FD network by several measures.

A typical scenario:

- New ECUs deployed in the network must be CAN-FD compliant while still operating within the current CAN communication frame format.
  - The MCUs need to be CAN-FD compliant.
  - When upgrading the software, integrate new CAN drivers only with minimal or no impact on upper layers.
- Achieve higher data rates with a software update to incorporate CAN-FD frame format.
  - Limiting the payload to 8 bytes can restrict software change to CAN driver only.
  - Experiments at Bosch have shown that current transceivers help to achieve an average data rate of 2.5Mbps [2].
  - Use of "partial networking": during a CAN-FD operation. The transceivers of the existing CAN network remain passively disconnected or switched off.

You can realize a true CAN-FD-compliant network by software updates to support payload sizes of up to 64 bytes for high bandwidth utilization, or by using CAN-FD-qualified transceivers for much higher data rates.

Summary

- CAN-FD provides increased throughput at costs comparable to existing CAN networks.

- CAN-FD provides additional bandwidth and faster speeds. This helps to reduce the number of nodes within the network.
- CAN-FD maintains the reliability of the existing CAN due to changed CRC polynomials.

Automotive Ethernet

In 2008 BMW was the first OEM to start using Ethernet for on-board diagnostics (OBD) with the car's head unit [3].

There are many advantages of using Ethernet as an automotive network:

- Mass production of Ethernet-enabled devices drastically reduces cost
- Bandwidth scalability with no negative impact on safety, functionality, or performance
- Connectivity options both inside and outside the vehicle
- Galvanic isolation due to transformer coupling

BMW used Ethernet only in the garage service bays and not as a data bus within the car. Ethernet was never seen as a core automotive data bus. Two recent developments supported the rise of Ethernet:

- The recently released MOST150 standard also integrates an Ethernet channel
- The development of low-cost, high-speed PHY (physical interface ICs) capable of sending up to 100mbps over an unshielded twisted pair cable

Bosch predicts that Ethernet can become the de-facto electrical/electronic backbone in the near future [4].

Ethernet Use Cases

Infotainment Systems

Current infotainment systems are proprietary and non-scalable. Automotive Ethernet addresses this issue, and the very first demonstrated use case was the transfer of audio/video data.

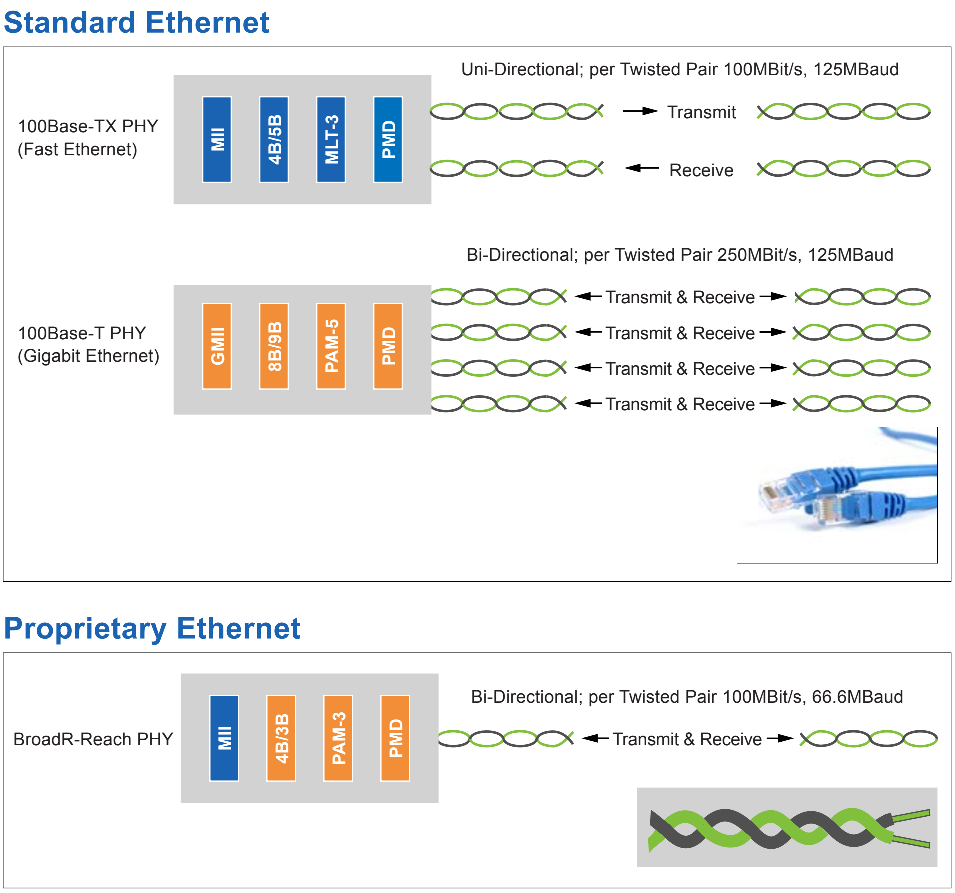


Figure 8. Standard Ethernet vs. Proprietary Ethernet

To improve the deterministic behavior of Ethernet's asynchronous data transfer, IEEE released the Ethernet AVB protocol (IEEE 802.1 AS, QAT, QAV, and BA). Ethernet AVB defines a mechanism for synchronized audio and video data transfer with guaranteed latency.

To implement AVB, the Ethernet MAC peripherals must contain dedicated features:

- Time stamping of Ethernet packets
  - Capability to differentiate the various IEEE1588 messages
  - Support hardware time stamping of specific IEEE1588 messages to achieve high accuracy
  - High-resolution timer to achieve nanoseconds accuracy
- Credit-based traffic shaper
  - Credit-based traffic shaping is mandatory for any transmission on an AVB network
  - Considering the high packet-transmission rate (once every 125µs in case of Class A networks), it would add a large burden on the CPU to shape each packet in software. A hardware-implemented traffic shaper can greatly reduce CPU load.

The actual transfer of real-time audio/video data is handled via IEEE P1722 packets (figure 9).

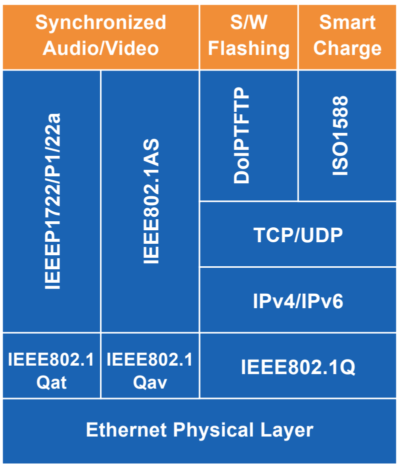


Figure 9. IEEE AVB Standard Stacks

Advanced Driver Assistance Systems

Ethernet is able to integrate infotainment, telematics, and advanced driver assistance system (ADAS) features such as surround view parking and lane departure warning. The current LVDS (low voltage differential signaling) single-camera system will develop into applications with multiple high-resolution cameras. Images from these cameras, radars, and mapping services will merge into a bird's-eye view of the vehicle surrounding. Scalable Ethernet is ideal to transfer such huge data from multiple sources.

The ISO17215 Ethernet standard is currently in development. It will standardize communication protocols for on-board camera systems with driver assistance functions.

Energy Efficient Ethernet (EEE)

IEEE802.3az is the energy-efficient Ethernet (EEE). It introduces low-power modes and wake-up functionality to save energy when the devices are not used. It also allows for less power consumption during periods of low data activity. The Ethernet MAC supports the EEE features.

Electric Refueling Station – Smart Charging

ISO15118 is the vehicle-to-grid communication standard. It describes the mechanism to establish connection to the charging station, authentication by certificates, metering data exchange, charging status/profiles, and payment modalities. The use of Ethernet eliminates the need for any gateway ECUs to communicate with the charging station.

Diagnostics

There are many standards in development to use Ethernet for diagnostic purposes. Ethernet is well-suited for diagnostics as it can be easily connected to any PC/tablet-based tool. The related standards are ISO/PAS 27145 and ISO13400.

Connected Car

The smart phone has brought connectivity into a car, and vehicles shall interact with the surrounding eco-system. Cars exchange real-time information on traffic conditions, terrain, climate conditions, as well as mapping systems. They combine all this information to propose routes, calculate driving time, estimate distances, display 3D city models, and stream audio/video data. Ethernet can be the simplest way to plug into the internet highway.

Ethernet as Network Backbone

A network backbone interconnects various sub-networks with different protocols and/or operating speeds. With a 1500-byte payload limit and speeds up to 100mbps, Ethernet is suitable to aggregate multiple messages in a single packet. You can use

IEEE1722 and P1722a to encapsulate the sub-net protocols. You can aggregate multiple CAN-FD messages from a subnet sent across gateways in a single Ethernet message. As an asynchronous protocol Ethernet's sheer speed overcomes the need for strict timing tolerances. Message buffers reduce timing jitters and increase latency tolerance.

Migration to Ethernet

The new PHY with MII or RMII interface has enabled semiconductor vendors to introduce automotive microcontrollers with Ethernet MAC peripheral. This provides OEMs with scalable bandwidth, faster speeds, and an effective alternative to the proprietary MOST network.

The automotive industry has also started working to standardize Ethernet platforms for use in diverse systems including driver assistance, infotainment, and safety. This will help to reduce costs, ease integration, and simplifies sourcing from multiple vendors.

Summary

When it comes to high-bandwidth data transmission, car manufacturers can chose between LVDS and MOST. LVDS is fast but expensive since it requires shielded cables. MOST is also fast and has excellent EMC characteristics, but its optical wiring is very expensive and difficult to handle during production. Today, Ethernet replaces the expensive LVDS systems, in particular for driver assistance cameras and infotainment systems. Current 100mbps links are sufficient to connect endpoints in a vehicle. The automotive industry, however, will soon face the need for gigabit links to ensure Ethernet becomes the backbone of the car electronic architecture.

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LIN-Based Bootloader Implementation on ATA6616/17

Tiantian, Shi, and George Gong

Designers can program a microcontroller with an external chip or they can have the microcontroller program itself using a bootloader program contained in its own memory. External programming adds cost, requires long programming times, and must have the proper interconnections to the target MCU. The chip's programming ports may not be available when it has been integrated into a system module. Alternatively, a bootloader program can update the module's firmware by loading the new code via a standard serial port.

The designer first loads the bootloader program via conventional means, perhaps before the MCU chip is soldered into the module. Then the chip can reprogram its remaining Flash program memory over its LIN, CAN, UART, or TWI interface. The chip can do this even after the system is deployed to the end user. Bootloaders implement “in-system programming” (ISP). This means that the user can program or re-program the microcontroller on-chip Flash memory without removing the device from the system and without the need of an external programmer chip or system. The scope of this article is the implementation of a LIN-based bootloader.

The Automotive LIN Bus

Electronic modules have improved the comfort, safety, and fuel economy of today's vehicles. Manufacturers have developed different bus network standards to guarantee that these modules can communicate at the required speed and safety levels. Buses such as CAN (Controller Area Network), and LIN (Local Interconnect Network) minimize cost while maximizing the performance. LIN was developed as the low-cost and low-speed complement to CAN. Engineers use LIN primarily in comfort applications. This allows them to interconnect an increasing number of comfort functions. More and more companies provide LIN-related product since the LIN bus is now accepted on all new development platforms.

Atmel® is one of the most successful LIN-related product providers. We offer a modular LIN2.0/2.1 family with products at all integration levels. The products range from simple transceiver ICs to complex system basis chips (SBC). At higher integration levels, Atmel provides complete System-in-Package (SIP) solutions. A single package includes an Atmel AVR® MCU, a LIN transceiver, a voltage regulator, and a watchdog timer (figure 1). The ATA6616/17 is a complete LIN bus node application. The part integrates an ATA6624 LIN SBC die with an AVR ATtiny87/167 MCU into a 5mm x 7mm QFN package.

Once you integrate a LIN SIP into a module to make a LIN node, it becomes problematic to upgrade the firmware. Unless you unsolder the SIP IC, there is no possibility of accessing the conventional programming ports with a hardware programmer. Since the module is part of a LIN network, it is natural to think of operating a bootloader through the LIN bus.

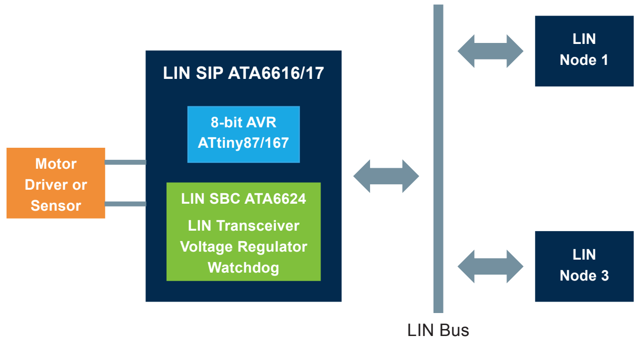


Figure 1. The ATA6616/17 LIN System-in-Package

Bootloader Implementation

The MCU integrated into the ATA6616/17 lacks a separate bootloader section in program memory. To bootload an ATA6616/17, you use the LIN interface of the LIN SBC die with its associated protocol to download the program code. The self-programming mechanism of the MCU writes the updated code into the program memory.

Designers initially connect to the LIN module with a PC and converter device (see figure 2). The PC has AVR MCU programmer software installed. The AVR Open Source Programmer (AVROSP) is a good option. The hardware converter changes the UART signals coming out the USB interface to the LIN standard. The converter device does communication with the SIP as a LIN slave, and delivers the bootloading commands as boot master. It can also deliver real-time operation commands as a LIN master.

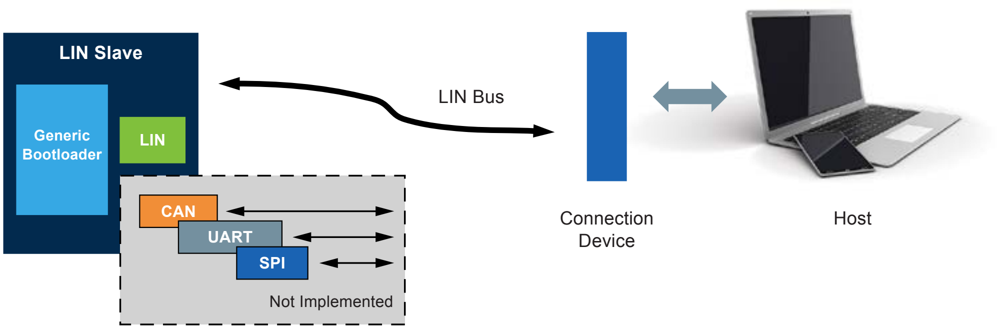


Figure 2. LIN Bootloading Physical Environment

You use the ISP programming interface to load the bootloader code into Flash memory. Then the bootloader can be used to update the application Flash section in the future without using ISP. The bootloader has the ability to read, erase, and write the flash memory. Additionally, it supports a command jump from the bootloader to the application code.

The bootloader uses the SPM (Store Program Memory) instruction of the ATA6616/17. The bootloader updates the program memory in a page-by-page fashion. The Store Program Memory Control and Status Register (SPMCSR) manages the SPM operations (figure 3).

Bit	7	6	5	4	3	2	1	0	
	-	RWWSB	SIGRD	CTPB	RFLB	PGWRT	PGERS	SPMEN	SPMCSR
Read/Write	R	R	R	R/W	R/W	R/W	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	

Figure 3. The Store Program Memory Control and Status Register

Only the combinations "10 0001$_b$", "01 0001$_b$", "00 1001$_b$", "00 0101$_b$", "00 0011$_b$", or "00 0001$_b$" in the lower six bits will have an effect. You employ the Z register to address the operation targets of the SPM commands, such as page erase, page write, or instruction write (figure 4). Here the MSBs (the Most Significant Bits) are used for addressing the pages. The LSBs (the Least Significant Bits) address the words within the page. A more detailed description of the SPM instructions and applications is available in Atmel application notes.

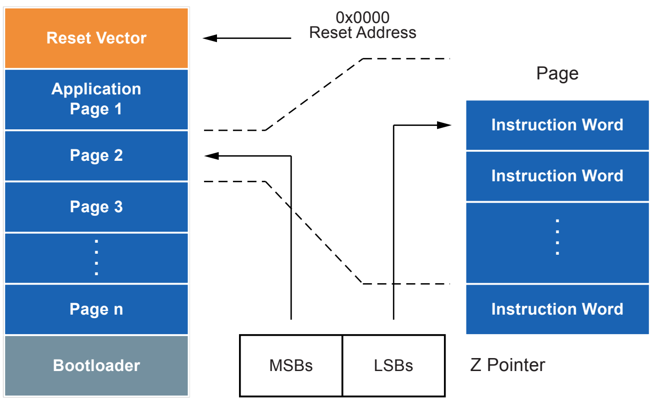


Figure 4. Flash Organization and Z Pointer Addressing

The bootloader works with the help of SPM (figure 5). There is only one entry point to the bootloader. Unlike some MCUs, this integrated MCU has no special boot Flash section. It is not possible to enter the bootloader by setting the fuses. For this reason the initial programming should load and organize the program memory according to the scheme in figure 4. You define the reset vector to always initiate the bootloader program. Figure 5 shows this as the "boot process", which occurs after a reset event. The boot process checks and decides whether the configured boot section starts executing or the program in the application section starts executing. The bootloader has separate commands to write to the application section and to execute a jump into the section. If the jump to the application section is not performed, the application will never execute, even if the application section is programmed. The "protocol identification" of the bootloader selects what protocol to use. This could be LIN, CAN, a UART, or other protocols. The first confirmed communication on the network starts the initialization of the corresponding peripheral.

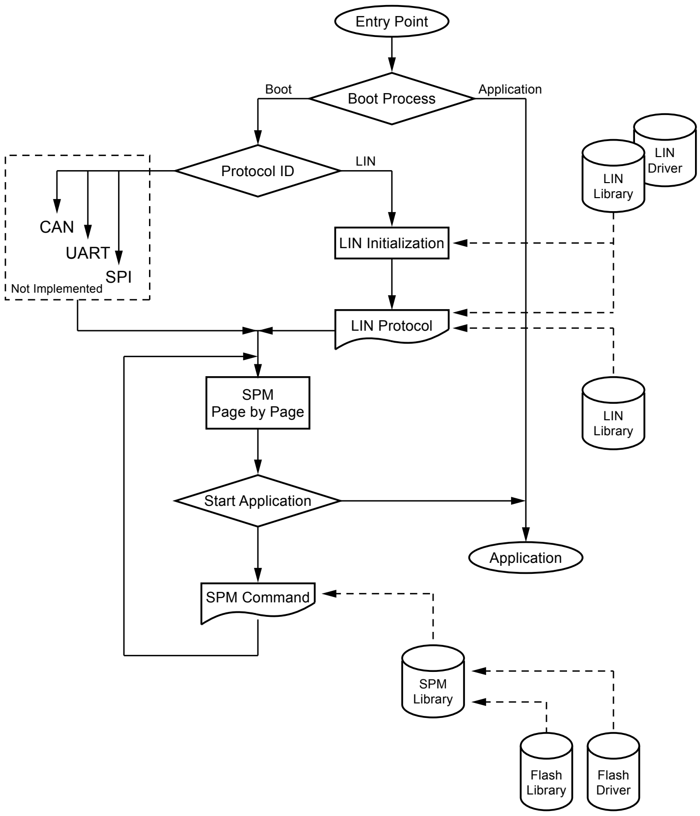


Figure 5. Bootloader Flow Chart

The LIN bootloader application performs an initialization process after each device reset. The LIN protocol is a high-level protocol, which is described in the LIN standard documents. The host initiates the communication by sending 0x55 as a synchronization character to help the slave LIN SIP to find the baud rate. At the end of this character the bootloader should have its LIN initialization done. The LIN protocol decodes the incoming commands. If the command received is to update the Flash, the received data is written into the program memory as if it was written by a programmer device. The bootloader performs the SPM instructions to update the Flash on a page-by-page fashion.

Once the entire incoming data stream has been written into program memory you send a command to execute the application code. The output from the bootloader jumps to the first instruction of the application program. The bootloader erases a page and then writes the incoming data into the page (figure 6). There is also a Read – Modify – Write operation. This is suitable for updating small parts of the Flash, such as a constant string.

Conclusion

This article highlights the bootloader implementation on an Atmel ATA6616/17 LIN chip. The bootloader application lets you update firmware in the field through the LIN bus. This is done without using the traditional programming ports. More detailed information is available at the Atmel website and corresponding AVR application notes.

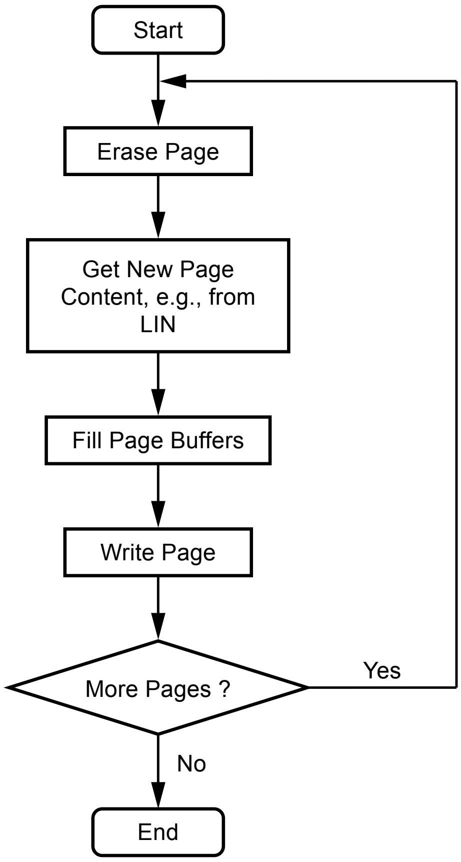
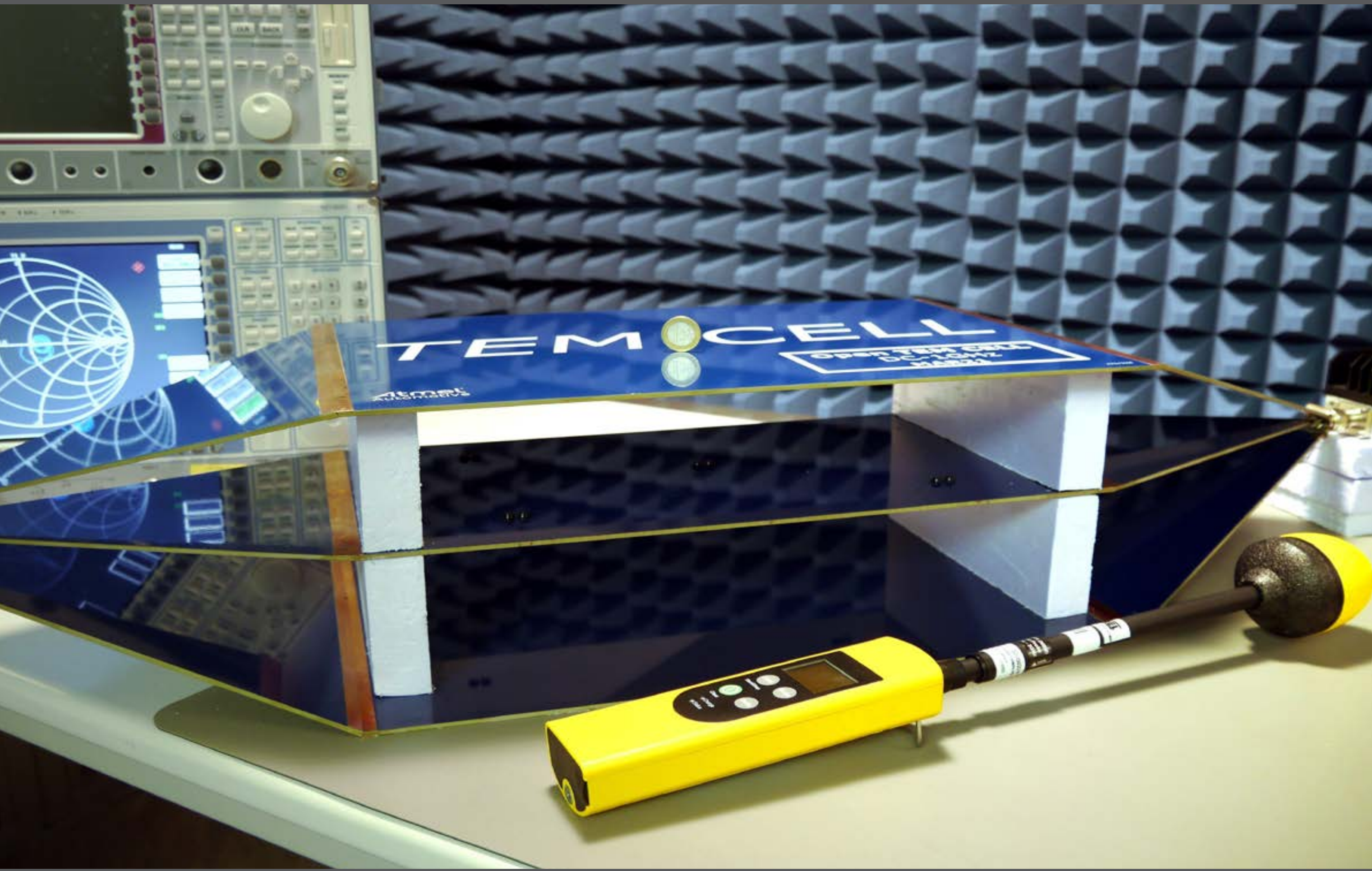


Figure 6. Typical Update Flowchart



Open TEM Cells Ease EMC Testing of Large Devices

Stephan Gerlach and Juergen Strohal

Introduction

Designers use transverse electro-magnetic (TEM) cells for radiated emission and susceptibility testing. This assures their integrated circuits and electronic modules are in compliance with EMC (electromagnetic compatibility) rules. This article describes an open TEM cell construction designers can use for their own pre-compliance measurements to achieve EMC performance improvements.

Atmel® has developed an open TEM cell to perform these tests on larger DUTs (device under test). The cell can test devices up to 30 x 25cm. It requires low RF power during immunity tests that generate field strengths up to 200V/m. The TEM cell consists of inexpensive dual-layer PCB material (FR4). Each end has N-type RF connectors, and typically one side terminates with a high-power 50Ω load (figure 1).

Atmel engineers optimized the TEM cell dimensions to achieve a precise 50Ω design with low reflection coefficients. The internal fields exhibit high homogeneity at a frequency range between DC to 1GHz, and are usable up to 3 GHz. The uniform RF fields provide maximum field strengths with the available RF input power. Atmel has performed validation measurements to ensure proper function of the cell.

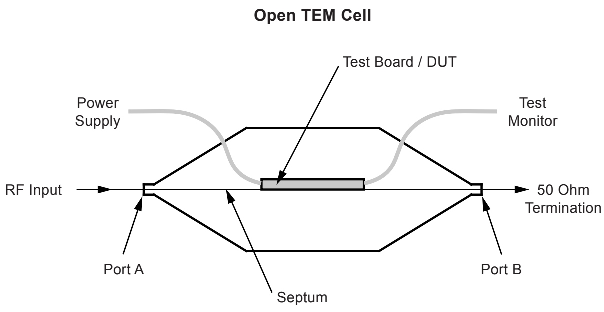


Figure 1. Cross Section of the Atmel Open TEM Cell

The TEM Cell

Benefits of an Open-Cell Design

A TEM cell is similar to a coaxial cable, just with a remarkably larger size. There are both open and closed TEM cells. One disadvantage of the closed type is that the E-field orientation changes from vertical in the center to horizontal at the corners of the dividing septum. Although the sum of the vertical and horizontal vectors is always constant, the E-field's influence on the DUT is not constant. The usable area is limited to 1/3 of the septum area. With an open TEM cell the exposure to the E-field orientation is fixed. The usable surface area of an open TEM cell is much bigger. This is very beneficial for larger DUTs such as an LCD display.

Another advantage of an open-cell design is its large open area. Designers can insert bigger devices without problems caused by cable connections on various sides of the DUT. A closed TEM cell hampers the insertion of larger DUTs with cables and also creates severe inner-field non-uniformity that affects the homogeneity and repeatability of the measurements.

Because the overall dimensions determine the cell's cut-off frequency, the TEM cell size limits the usable frequency range. Designers can still use the cell at a higher cut-off frequency, but this increases the uncertainty regarding the usable inner area. A scale is given in figure 6.

The N-type connectors provide the best trade-off between mechanical robustness and stability, while giving good electrical performance in the upper frequency range.

Evaluation and Verification

A Rohde & Schwarz ZVM network analyzer evaluated the S parameter and reflection coefficients of the cell (see figures 2, 3, 4). The test used a Narda 520 broadband field meter with an EF0391 E-field probe. This probe is rated at 100 kHz to 3GHz and is used to perform the E-field measurements inside and outside of the TEM cell.

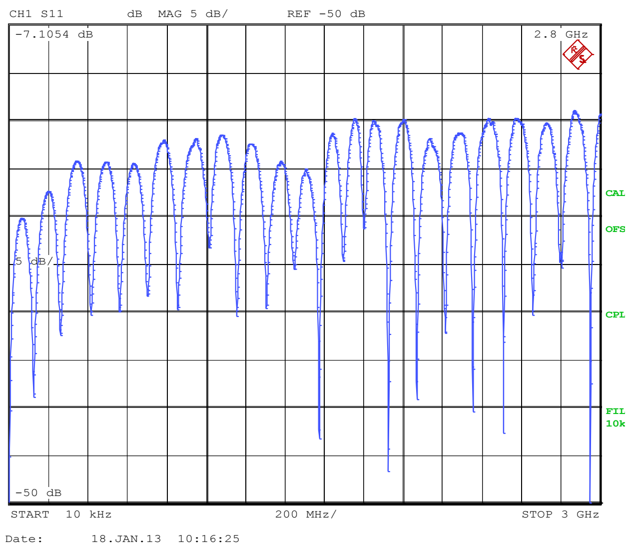


Figure 2. Measurement 1 (S11, 10kHz to 3GHz, Magnitude in dB, Port 2 Terminated with 50Ω)
Impedance Matching is Better Than 12dB up to 1GHz

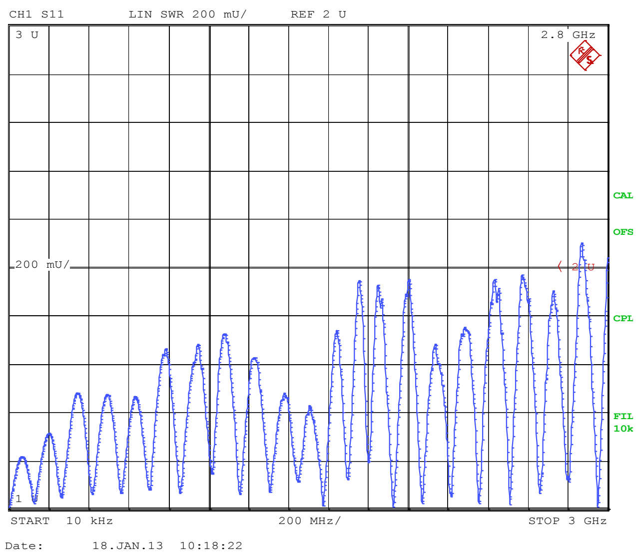


Figure 3. Measurement 2 (S11 VSWR, 10kHz to 3GHz, Port 2 Terminated with 50Ω)
VSWR is Better Than 2:1 up to 3GHz with One Exception at 2.85GHz

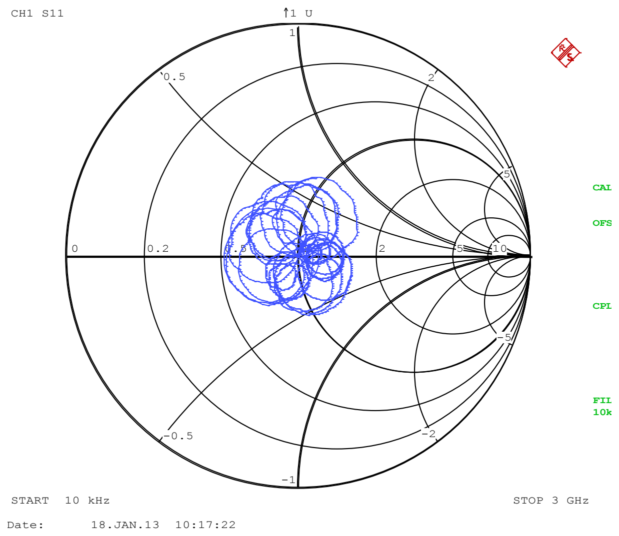


Figure 4. Measurement 3 (S11, 10kHz to 3GHz, Port 2 Terminated with 50Ω)
The Smith Chart is Well Centered Around 50Ω

E-Field Measurement Inside the TEM Cell

Atmel engineers used a Narda 520 broadband field meter for the measurement of the five test points at each side of the dividing septum inside the cell (figure 4). The applied power level is +13dBm. The cell is terminated with a 50Ω load. The results were taken over two frequency ranges (figures 6 and 7).

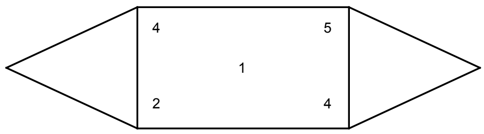


Figure 5. E-Field Measurement Test Point Location within TEM Cell

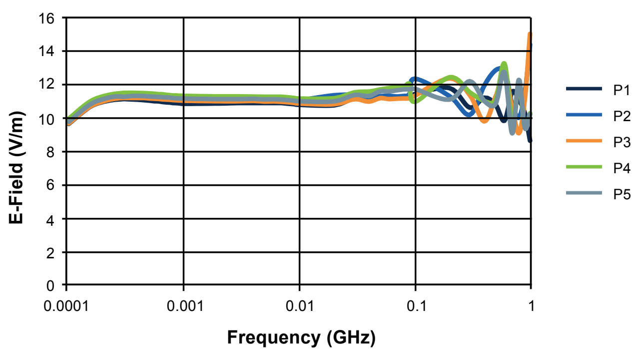


Figure 6. Measurement 4
100kHz to 1GHz, at the Test Points of Figure 5

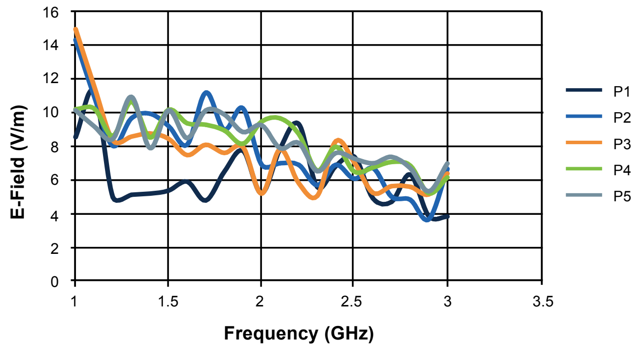


Figure 7. Measurement 5
1GHz to 3.3GHz, at the Test Points of Figure 5

E-Field Measurements Outside of the TEM Cell

Safety Distance

If you apply 6W input power the cell will create field strengths of up to 200V/m. You should ensure a safety distance of at least 200mm around the TEM cell.

Atmel engineers conducted two measurements with two different safety distances to verify this recommendation (figure 8). Measurement 1 was made at a distance of 40mm to the septum, measurement 2 at 80mm. The input power was 13dBm, applied over a frequency of 100kHz to 3GHz.

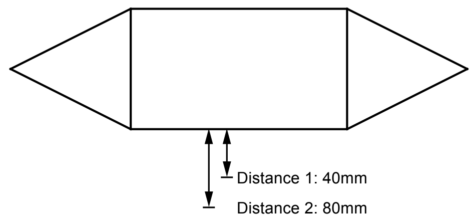


Figure 8. E-Field Measurement Points of Safety Distances

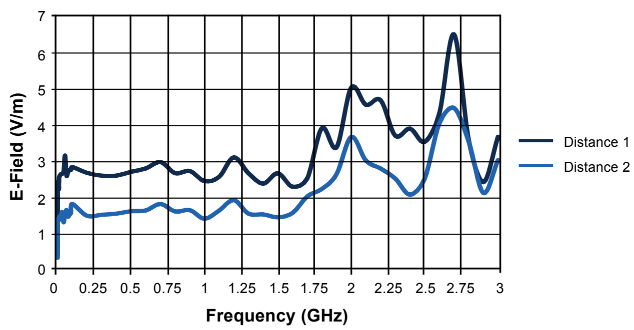


Figure 9. Measurement 6
E-Field (V/m) Over Frequency (100kHz to 3GHz) at the Safety Distances of Figure 8

The measurements prove that field strengths at a safety distance of 80mm are 5 to 10 times lower than those within the cell (figure 9). Nevertheless, we recommend a safety distance of at least 200mm during measurements when field strengths up to 200V/m. Test engineers should carry out their own evaluation to potentially further increase the safety distance if necessary.

Technical Parameters and Dimensions

The TEM cell specifications:

- Conversion factor: 0dBm (1mW) ≙ 2.5V/m
- Example: 38dBm (6.31W) ≙ 200V/m
- Dimensions: 100cm (L) x 35cm (W) x 22cm (H)
- Material: FR4 double-side plated
- Connectors: N-type

Open TEM Cell—Power Conversion

The open TEM cell provides a good conversion of RF input power to the measured E-field strength (see figure 10). The tabulated results expressing power both in mW and dBm come in handy when setting up test protocols (table 1).

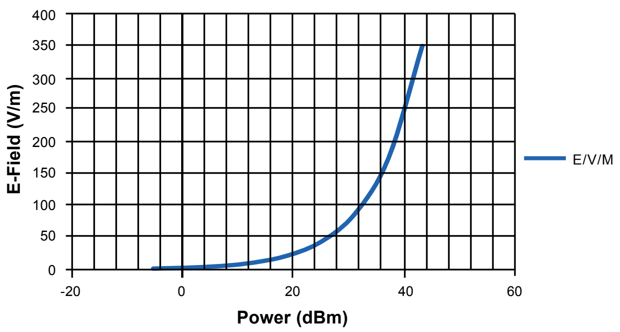


Figure 10. Electrical Field Strength (V/m) vs. Input Power (dBm)

P/mW	P/dBm	E/V/m
0.32	-5	1.375
1.26	1	2.75
5.01	7	5.5
19.95	13	11
79.43	19	22
316.23	25	44
1258.93	31	88
5011.87	37	176
19952.62	43	352

Table 1. Power Conversion Table and Resultant Field Strength

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