

## Features

- RF configuration options
- SAW filters
- Low noise amplifiers (LNA)
- Implementation tradeoffs

## Description

Atmel®'s ATA583X/578X family of devices features an RF pin out scheme that accommodates multiple RF configurations. These configurations include operation in multiple frequency bands, minimized component count or maximized sensitivity. This application note will evaluate several chip and external device configurations and the tradeoffs involved.

Additionally, the use of external RF components to tailor system performance to increasingly stringent automotive requirements is becoming the standard. Commonly used external components that will be reviewed in this article are the surface acoustic wave (SAW) filters used to limit RF frequency exposure and low noise amplifiers (LNA) used to enhance system sensitivity. As wireless devices become more common and the RF spectrum denser SAW filters are needed to achieve specified performance levels in the presence of RF interferers. LNAs are used to preamplify RF signals thereby enhancing sensitivity and range performance.

## 1. Atmel ATA583X/ATA578X Device Overview3

The Atmel® ATA583X/ATA578X is a highly integrated, low power UHF ASK/FSK RF transceiver/receiver family utilizing an integrated AVR® Microcontroller. The part is capable of operating in all three ISM bands, 310-318MHz, 418-477MHz and 836-956MHz using a single crystal. The device family is characterized in [Table 1-1](#).

**Table 1-1. Atmel ATA583X/ATA578X Family**

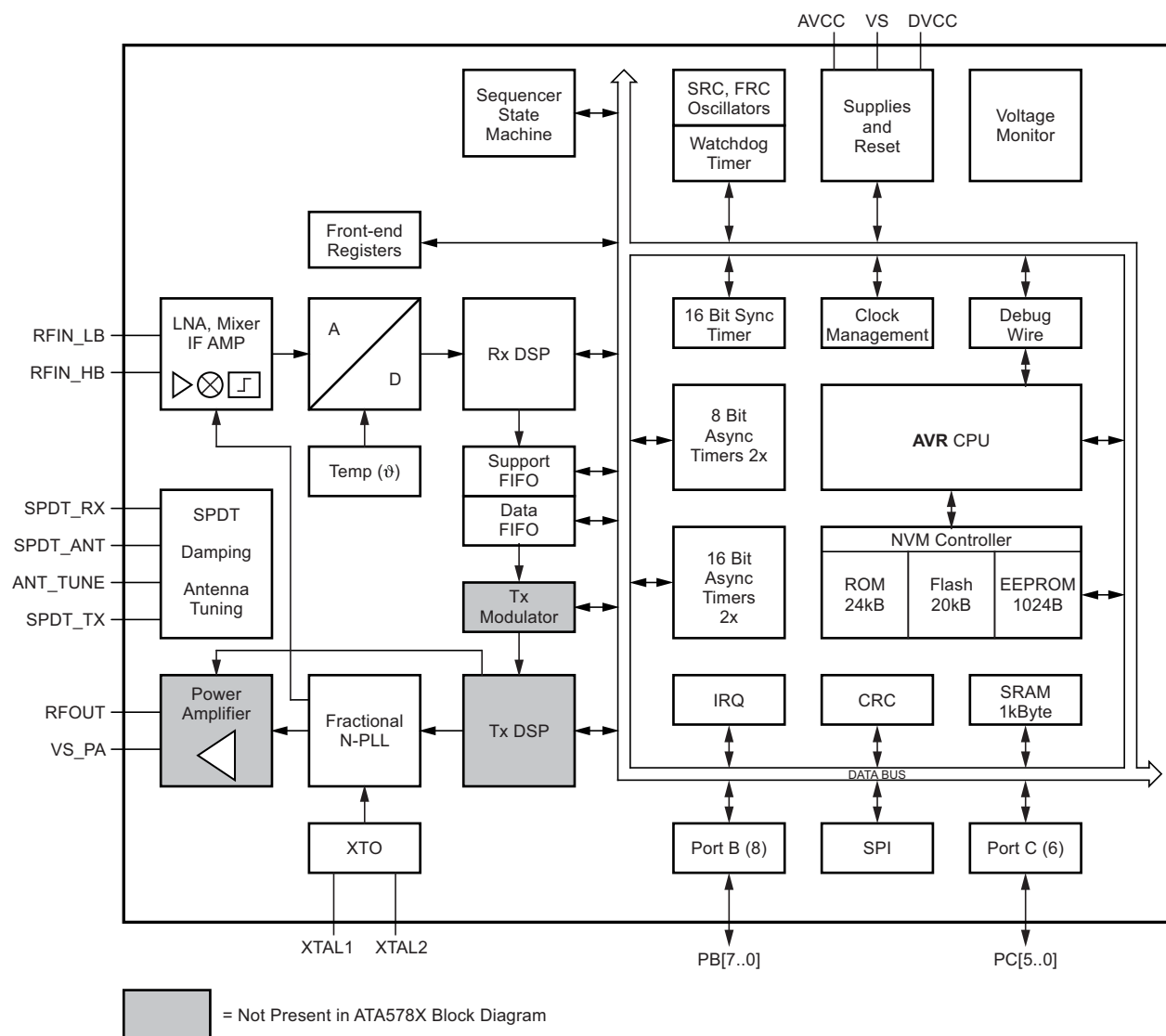
	ATA5831	ATA5832	ATA5833	ATA5781	ATA5782	ATA5783
ROM (KB)	24	24	24	24	24	24
FLASH (KB)	20	-	-	-	20	-
User ROM (KB)	-	20	-	-	-	20
RX +TX	✓	✓	✓			
RX only	-	-	-	✓	✓	✓
Services (profiles)	5	5	5	5	5	5

The Atmel ATA583X/ATA578X block diagram in [Figure 1-1 on page 3](#) illustrates the two RF input paths; one RF output path and the integrated RX/TX switch all of which require external connections. These RF ports and their associated functions will be the primary focus of this application note;

- RFIN\_LB (pin 1) - Low band (310-318MHz and 418-477 MHz) receiver input pin
- RFIN\_HB (pin 2) - High band (868-956MHz) receiver input pin
- SPDT\_RX (pin 3) - RX/TX switch output to receive paths
- SPDT\_ANT (pin 4) - RX/TX switch common path connected to the antenna
- SPDT\_TX (pin 6) - RX/TX switch output to transmit path (not available in Atmel ATA578X)

The internal single pole double throw (SPDT) RF switch is provided to isolate transmit and receive paths however its usage is optional. If used it must be interconnected externally to the appropriate receive and transmit ports on the chip. This switch also performs an optional function called “damping” that helps the chip operate in high signal level conditions. When the RF input port senses a very strong input signal at the tuned frequency, the RX/TX switch adds 15dB of attenuation to the RF signal path. This prevents the input port from being overloaded and the part is able to continue receiving in this case. However, the use of this switch also introduces a fixed signal loss of ~0.75dB that does subtract from the parts sensitivity and transmit power. Using the switch is optional and if chosen to be bypassed this fixed signal loss can be avoided. If bypassed it is up to the user to isolate transmit and receive signal paths and to manage operation in high signal level conditions.

Figure 1-1. Atmel ATA583X/ATA578X Block Diagram



## 2. Typical RF Performance Requirements

Some of the key radio parameters to be considered in this application note are detailed in this section. In many applications these parameters are traded off, e.g., sensitivity versus dynamic range and so the system is optimized for one or two parameters.

### 2.1 RF Transmit Power

Transmit power is the power level of the output RF signal. The Atmel® ATA583X device has an output power specified at pin 7 (RF\_OUT) of the IC package. The addition of components to this signal path reduces the power available for transmitting signals. These components typically include the internal TX/RX (SPDT) switch and SAW filters. The range of the RF link is dependent on the RF output power so the less power lost to external components the greater the range. The device has a programmable output power level with a range from  $-12\text{dBm}$  to  $+14.5\text{dBm}$ .

Note that placement of SAW filters in the transmit path requires a careful approach to the design particularly when used with high output power levels. If the filter output is not matched perfectly then phase-shifted reflected signals (due to the group delay introduced by SAW filter) are present that will interfere with the desired signal and cause instabilities.

### 2.2 RF Receive Sensitivity

Receive sensitivity is the lowest RF power level of a signal that can be successfully be received. The Atmel ATA583X device has its receive sensitivity specified at the RF input ports pin 1 (RFIN\_LB) and pin 2 (RFIN\_HB) of the IC package. The addition of any components to this signal path reduces the minimum sensitivity level. These components typically include the internal TX/RX (SPDT) switch and SAW filters. The device has a sensitivity level range of  $-108\text{dBm}$  to  $-123\text{dBm}$  depending on which IF bandwidth, data rate and modulation types are selected. An active external low noise amplifier (LNA) can optionally be added to the RF receive path that will improve the sensitivity.

### 2.3 RF Blocking Performance

Blocking is defined as the degradation of receiver sensitivity in the presence of stronger (blocking) signals at frequencies outside the tuned frequency of the receiver. This parameter is critical to receiver performance in the presence of other RF radiating devices such as cell phones, garage door openers and pagers. To successfully operate in dense RF environments a SAW filter is typically used.

### 2.4 RF Dynamic Range - In Band Signal

RF dynamic range is the range of power levels, at the tuned frequency, over which the receiver can operate. The dynamic range of the receiver is important because it must be able to successfully operate with strong signals well as weak ones. This is critical as a receiver must be able to perform when very strong signals are present such as when the transmitter is physically close to the receiver. To successfully operate in high signal level conditions the device has an internal damping function (part of the SPDT switch) that adds  $15\text{dB}$  of attenuation to the RF front end in strong signal conditions.

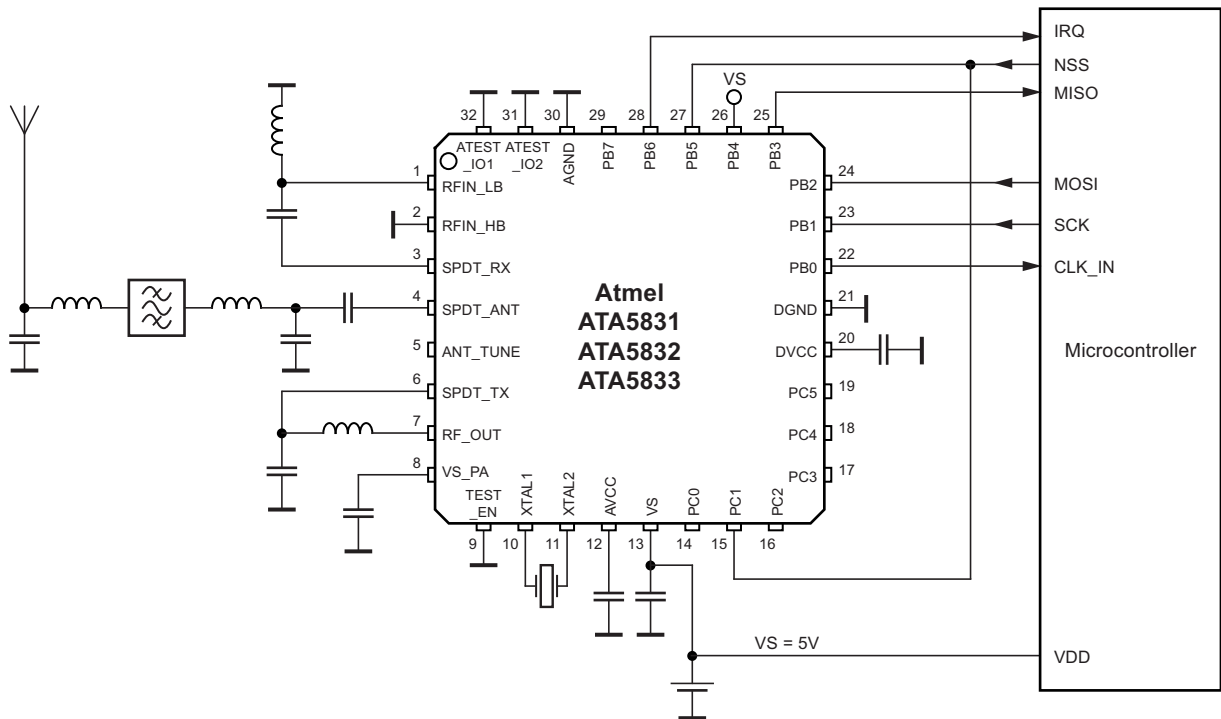
### 3. Atmel ATA583X/ATA578X RF Configuration Options

The Atmel® ATA583X/578X part can be configured in numerous ways. This section will highlight several of these those possible options highlighting the pros and cons of each. No one configuration is right for all requirements so each case must be evaluated on an individual basis. The configuration flexibility of this family of parts is one of its key advantages allowing the end user to optimize performance according to the requirements for the design.

#### 3.1 Atmel ATA583X Transceiver Typical Application with SAW Filter

In this example a single band transceiver is illustrated. A SAW filter is used at the antenna input to limit out of band frequencies enabling operation in dense RF environments. This is perhaps the most common use case and represents a good compromise for all aspects of transmit and receive RF performance. See comment on use of SAW filters in the transmit path in [Section 2.1 “RF Transmit Power” on page 4](#). Use of SAW filters in this configuration requires optimum matching between SAW filter and antenna and is not recommended for power settings greater than 5dBm.

Figure 3-1. Atmel ATA583X Transceiver Application with SAW Filter



#### PROS

- Minimized component count
- Good blocking performance with SAW filter
- Enhanced dynamic range utilizing SPDT damping function
- Common TX/RX antenna
- Transmitted harmonic limited by SAW filter

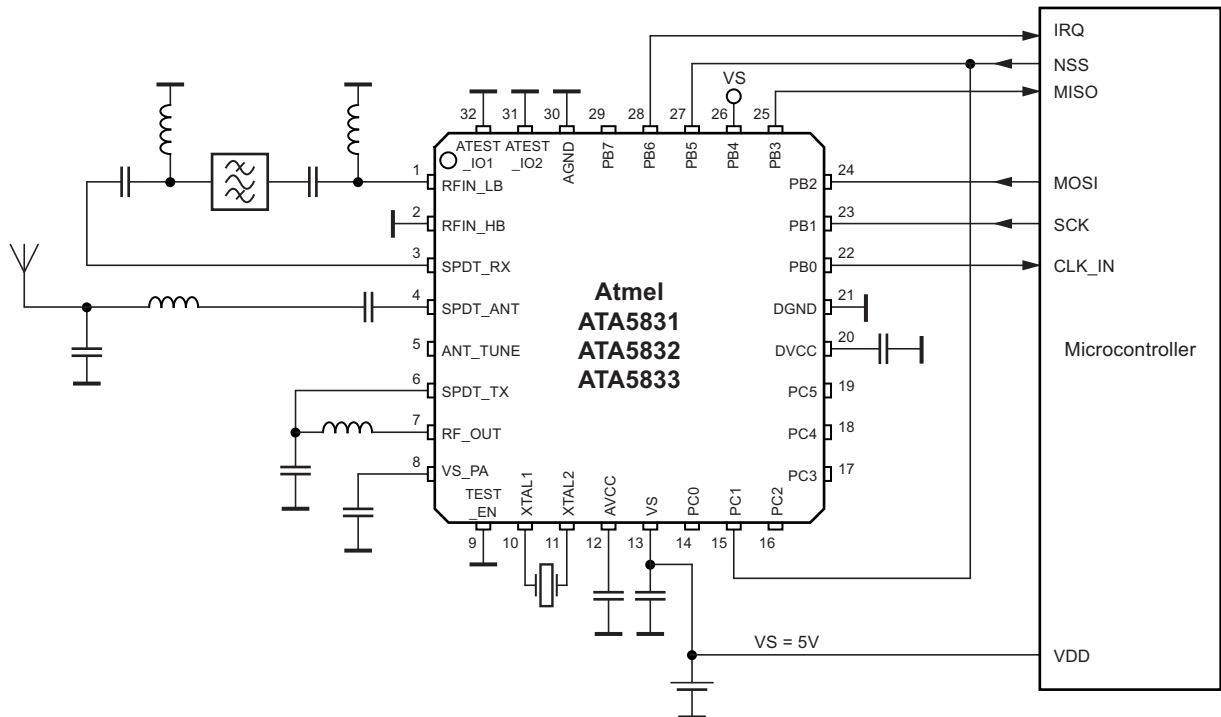
#### CONS

- SAW filter loss (~2dB) effects both transmit and receive paths
- Transmit power can exceed SAW max limits (typically +10dBm)
- RF transmit mismatch to the SAW filter can result in reflected RF voltages exceeding chip limits when transmitting at high power levels. Per the concerns of using a SAW filter in the transmit path outlined in [Section 2.1 “RF Transmit Power” on page 4](#) care needs to be taken to isolate phase shifted reflected signals from the desired signal. This includes board-level coupling and IC-level coupling with the latter being subject to degradation if RF voltage levels exceed IC limits.

### 3.2 Atmel ATA583X Transceiver Optimized for Transmit Power

In this example a single frequency transceiver is illustrated. The SAW filter is relocated to the receive side of the TX/RX switch. This eliminates the SAW signal loss for the transmitter increasing output power however the transmitted output spectral content is no longer filtered by the SAW. Note that the TX/RX switch can be saturated by wide band interference (at any frequency) and that tight EMC or blocking specifications may not be met with this circuit configuration. The isolation provided by the SPDT switch function is limited to ~60dB.

**Figure 3-2. Atmel ATA583X Transceiver Optimized for Output Power**



#### PROS

- Transmit power increased with no SAW filter loss
- Good receiver blocking at lower signal levels with SAW filter in receive path
- Common TX/RX antenna

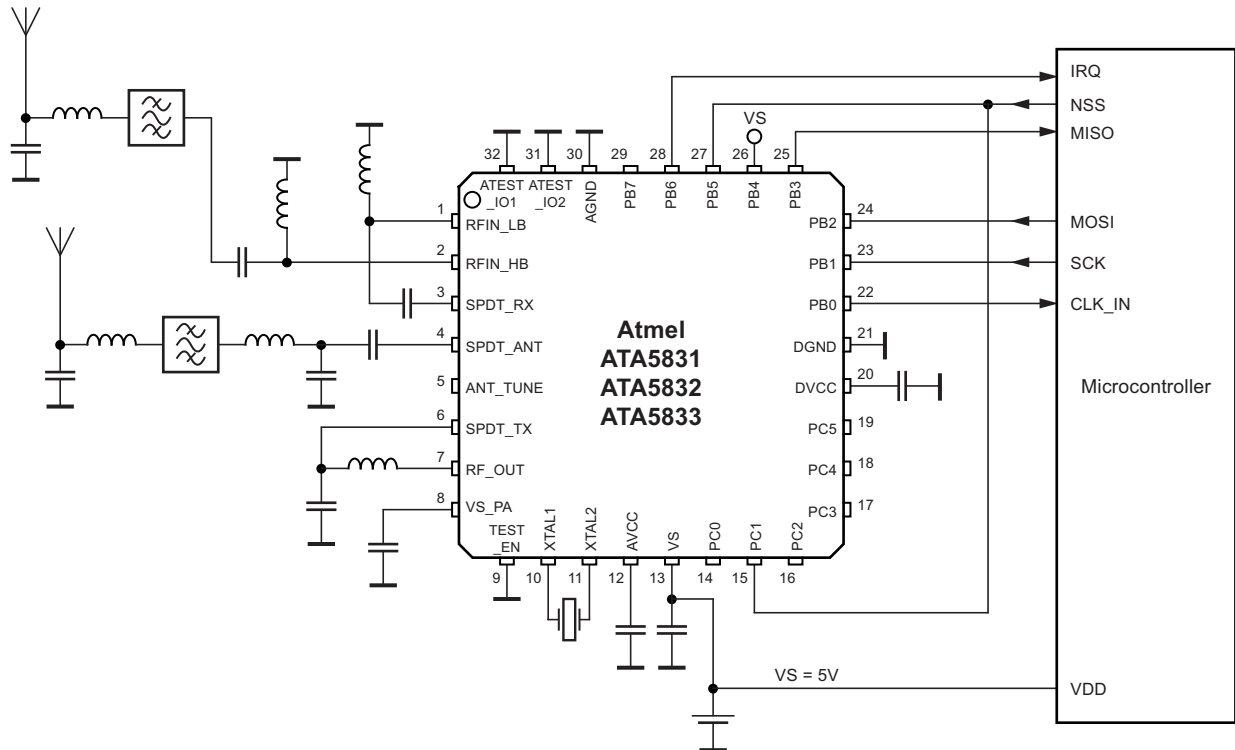
#### CONS

- SAW filter loss (~2dB) effects receive path
- Susceptible to out of band receiver jamming (SPDT saturation)
- Transmitter harmonic content no longer limited by SAW

### 3.3 Atmel ATA583X Transceiver Typical Dual Band (One TRX and One RX) Application with SAW Filters

In this example a dual band application is illustrated. One band functions as a transceiver while the other band is receive only.

**Figure 3-3. Atmel ATA583X Transceiver Dual Band Application**



#### PROS

- Two band operation
- TX/RX
- RX on separate band
- Minimized component count
- Good blocking performance - both RX paths with SAW filters
- Enhanced dynamic range utilizing SPDT damping function transceiver band only
- Common TX/RX antenna
- Transmitted harmonic limited by SAW filter

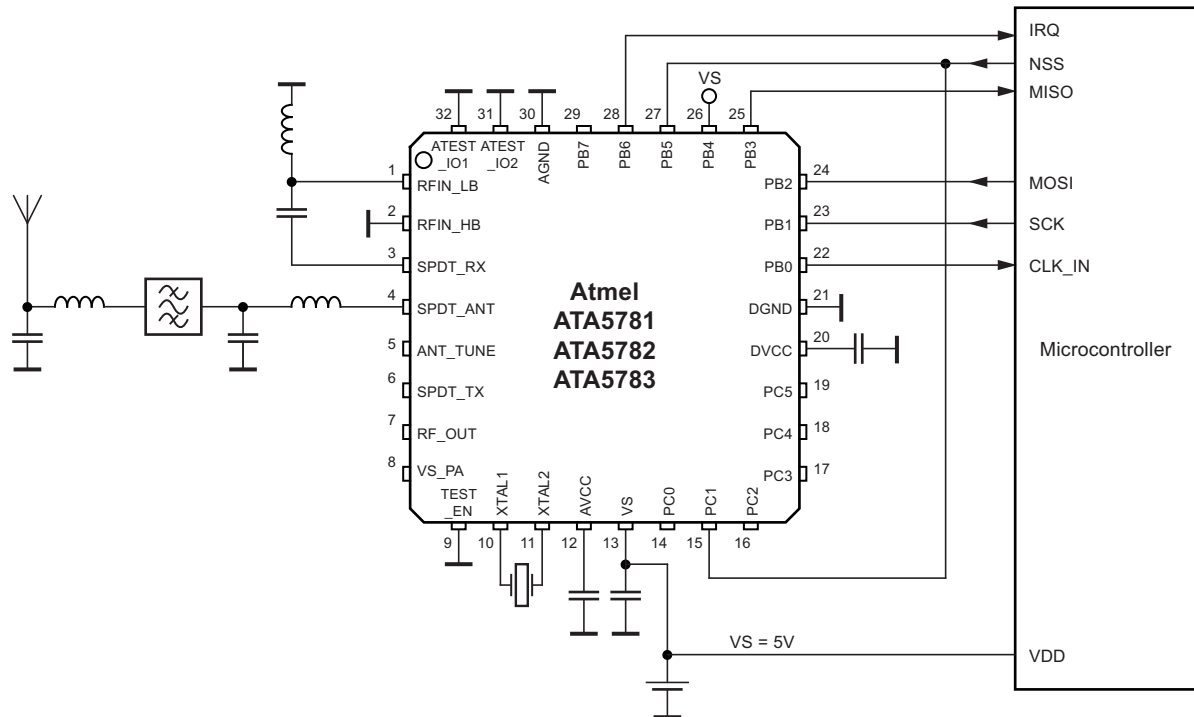
#### CONS

- SAW filter loss (~2dB) effects transmit and both receive paths
- Transmit power can exceed SAW max limits (typically +10dBm)
- RF mismatch to the SAW filter can result in reflected RF voltages exceeding chip limits when transmitting at high power levels
- Two antennas required and optionally an external SPDT to effectively isolate both receive paths

### 3.4 Atmel ATA578X Typical Receiver Application with SAW

In this example a single frequency receiver is illustrated. A SAW filter is used at the antenna input to limit out of band frequencies enabling operation in dense RF environments. This is perhaps the most common use case and represents a good compromise for all aspects of receive RF performance.

Figure 3-4. Atmel ATA578X Typical Receiver Application



#### PROS

- Minimized component count
- Saw filter improves RX out of band blocking performance
- Enhanced dynamic range utilizing SPDT damping function

#### CONS

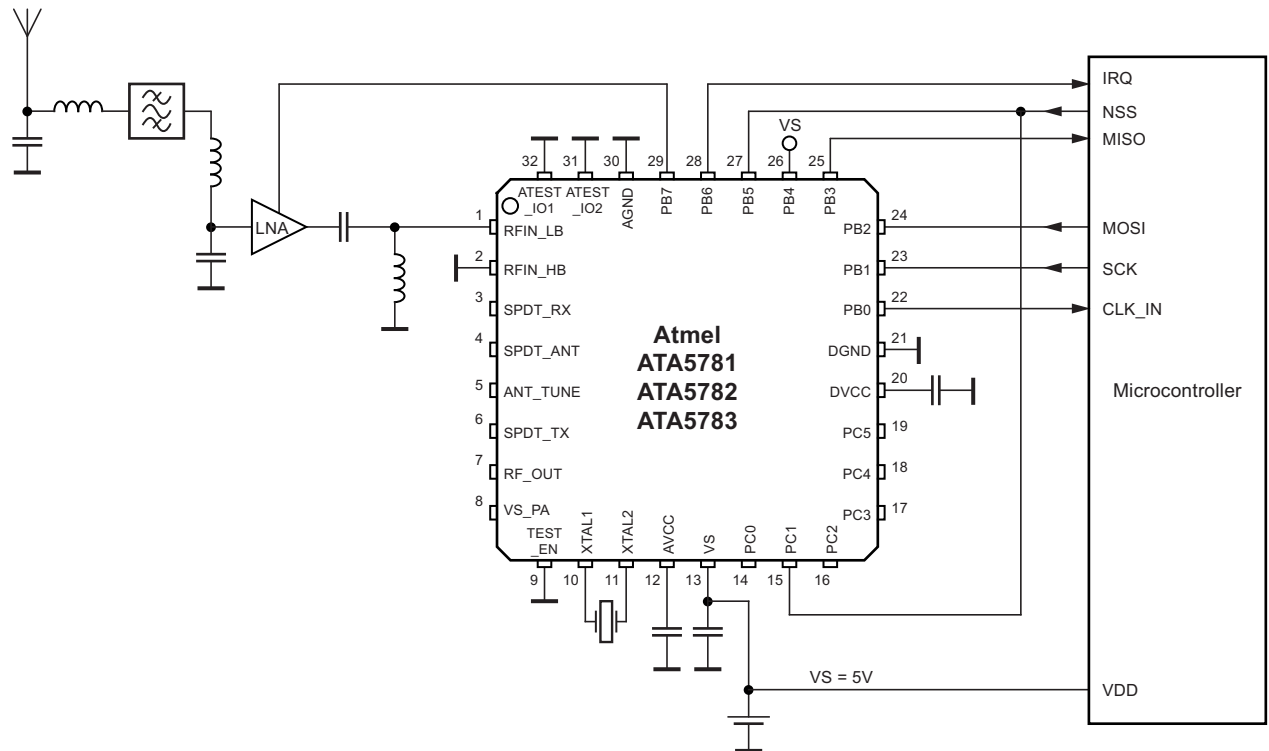
- SAW filter loss (~2dB)



### 3.5 Atmel ATA578X Receiver Optimized for Receiver Sensitivity

In this example a single frequency receiver is illustrated. The RF input is routed directly to the input port on the chip bypassing the SPDT switch. This avoids the loss in the switch but sacrifices the damping function provided by the switch. A SAW filter is used at the antenna input to limit out of band frequencies enabling operation in dense RF environments.

**Figure 3-5. Atmel ATA578X Receiver Optimized for Sensitivity**



#### PROS

- Good receiver blocking performance with SAW filter
- SPDT switch bypassed for best sensitivity

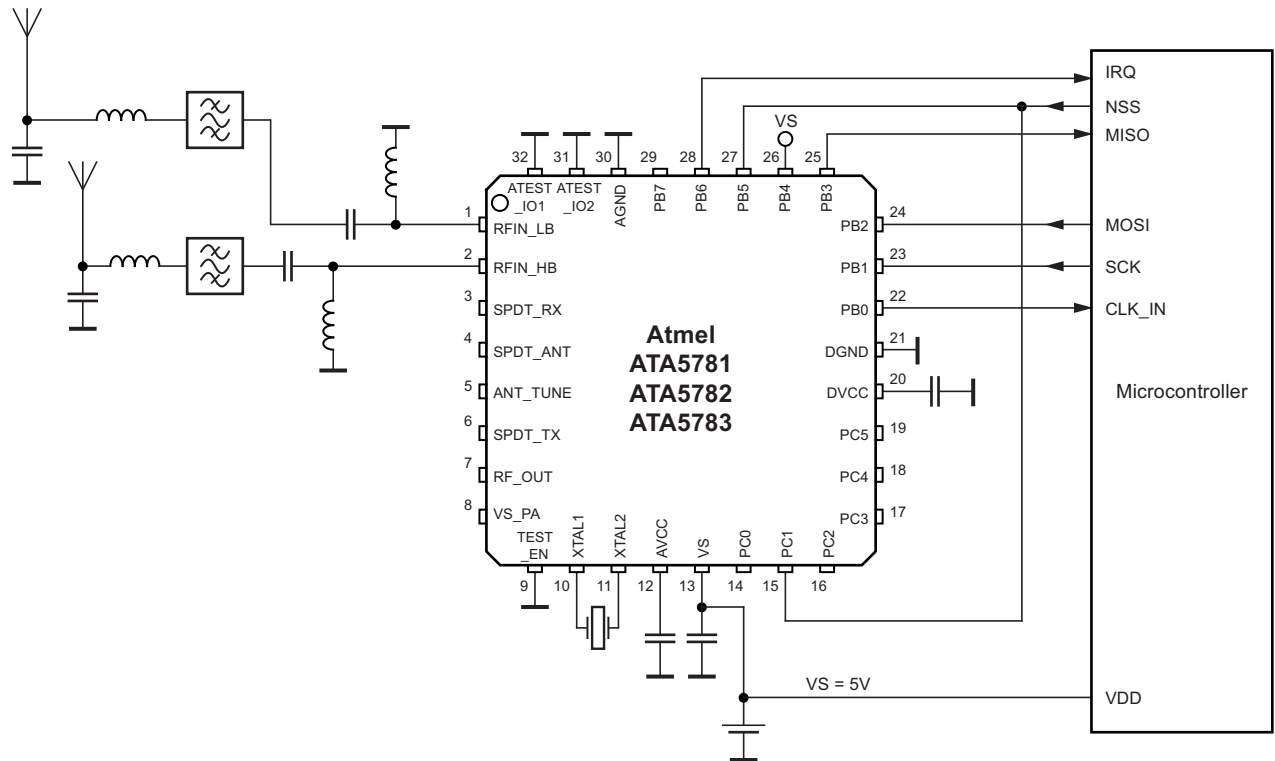
#### CONS

- SAW filter loss (~2dB)
- Compromised dynamic range with SPDT damping function not used

### 3.6 Atmel ATA578X Dual Band Receiver Optimized for Sensitivity

In this example a dual band application is illustrated. One band functions as a transceiver while the other band is receive only. The RF inputs are routed directly to the input ports on the chip bypassing the SPDT switch. This avoids the loss in the switch but sacrifices the damping function provided by the switch. A SAW filter is used at both antenna inputs to limit out of band frequencies enabling operation in dense RF environments.

**Figure 3-6. Atmel ATA578X Dual Band Receiver SPDT Bypassed**



#### PROS

- Saw filter improves RX out of band blocking performance
- SPDT switch bypassed for best sensitivity
- Dual band receiver

#### CONS

- Degraded high level desired signal operation (SPDT switch damping function bypassed)
- SAW filter loss (~2dB)
- Requires two antennas

## 4. External Component Details

This section provides an overview of components commonly applied externally to a RF receiver and discussed in the preceding paragraphs.

### 4.1 Surface Acoustic Wave (SAW) Filters

SAW filters are used in wireless car access receivers to function as RF pre-selection filters. Usually placed immediately after the antenna in the RF circuit path the goal is to preselect or filter out all frequencies not used by the system. This serves to “block” those undesired frequency components that might interfere with operation of the radio receiver. It is particularly important to block signals from intentional RF radiators such cell phones (RF output power up to +30dBm) and garage door openers operating near the receiver. If there is no filtering of these incoming RF signals the internal LNA or damping switch can be saturated by these out of band transmitters and rendered incapable of operation. Automotive SAW filters are available with a pass bandwidth from 200KHz to 2MHz and with an insertion loss of 2-4dB. While the insertion loss reduces the overall system sensitivity the ability to operate in a dense RF environment is usually more desirable than maximum radio sensitivity.

### 4.2 Low Noise Amplifier (LNA)

A LNA is an electronic amplifier placed before the RF input port on a radio receiver. It is used to enhance the sensitivity of the receive enabling a longer reception range. Note that the sensitivity of a receiver is determined primarily by the system noise figure which establishes the noise floor of the system. While an external LNA provides additional gain for the incoming signal it more significantly establishes a good noise figure for the incoming signal.

The desired characteristics of an LNA are first a low noise figure and then some amplification or gain. It is a common misconception that the sensitivity of a receiver is increased by the gain of the LNA, i.e., LNA gain = 12dB so sensitivity of the system improves by 12dB. An LNA typically does improve sensitivity but it is primarily due to noise figure improvement. A well executed external LNA device typically improves the sensitivity of an Atmel® ATA583X/578X system by 3-5dB. A good LNA has a low noise figure of ~1.5dB and a gain of ~5-20dB. Be aware that adding an LNA the device also establishes several other critical receiver specifications such as intermodulation and compression points. These specifications are critical to operation in high signal level environments and need to be traded off versus the resultant increase in sensitivity. Special care should be exercised when adding an LNA since it is typically operates over a wide frequency range and so is susceptible to interference over the whole range of operation.

## 5. Revision History

Please note that the following page numbers referred to in this section refer to the specific revision mentioned, not to this document.

Revision No.	History
9309B-RKE-04/15	• Put document in the latest template

