STK511

AVR-based Uni-directional Radio Starter Kit

User Guide

4842B–AVR–10/09

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Section 1

Overview

1.1 Features

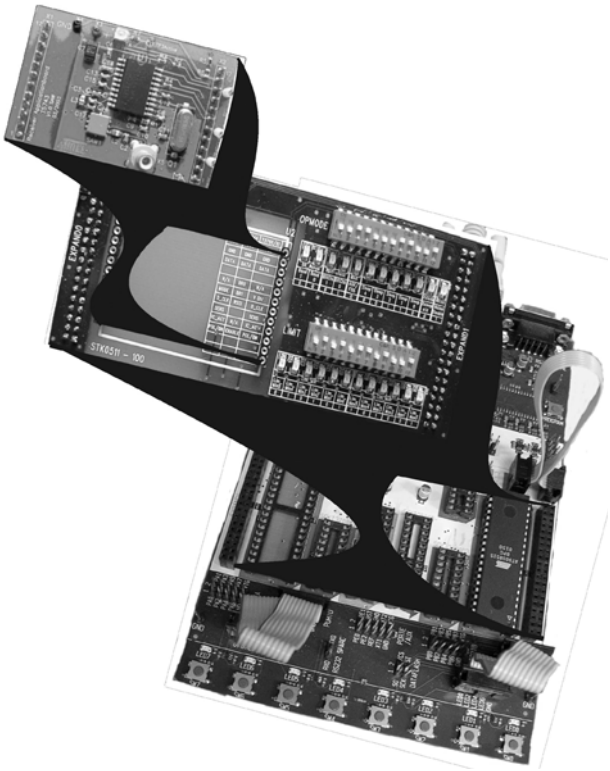
- Plug-in Connectors Accept ATA5743/44/60/61 RF Receiver Application Board
- DIP Switches Define Configuration Register Settings
- LED Indicators Provide Programming Status of Configuration Register
- Data Selector Switch Enables Fast Transition Between Operating Modes
- Configuration Programming Button Simplifies Programming
- Fully Compatible STK®500 Interface Connectors

1.2 Introduction

This document explains the operation of the STK511 – an AVR®-based UHF Radio Evaluation Kit. The STK511 Starter Kit was developed as a tool for evaluating Atmel's receivers (ATA5743, ATA5744, ATA5760 and ATA5761) and transmitters (T5750, T5753 and T5754). Although most Atmel receivers require programming of configuration registers via a bi-directional, one-wire interface, this kit provides register programming in an easy to use way for the customer to quickly evaluate an AVR-based UHF Radio system. Included in this kit is software to evaluate both ASK and FSK modulated radio systems across the RF spectrum of 315 MHz to 915 MHz and complete reference designs for receivers and transmitters. While above mentioned ICs are supported by this kit, pre-configured kits are only available for 868 MHz (using ATA5760 and T5750) and 915 MHz (with ATA5761 and T5750).

In addition to providing a quick, one-step, programming tool for configuring Atmel RF receivers, the Receiver Interface Board of the STK511 Starter Kit doubles as an expansion card for the STK500. This allows the user to develop software for receiver applications using any of the AVR microcontrollers supported by the STK500. The STK511 Starter Kit, when combined with the STK500, enables extremely quick prototype development for customers interested in Atmel's UHF radio design solutions.

Figure 1-1. STK511 Starter Kit



Included in the Kit:

- STK511 Receiver Interface Board
- RF Receiver Application Board (one of the following)
  - ATA5760 (868 MHz)
  - ATA5761 (915 MHz)
- RF Transmitter Application Board
  - Tiny13 + T5750 (868/915 MHz)
- CD containing sample software
- One CR2032 battery
- External whip antenna (RX only, TX antenna is PCB trace)

Optional items not included in the kit:

- Atmel AVR STK500 Starter Kit and Development System

Section 2

Getting Started

The STK®511 Starter Kit comes complete with all the hardware needed to demonstrate a working RF system. Included are the STK511Interface Board, RF Receiver Application Board, and RF Transmitter Application Board.

2.1 Setting up the Hardware

The Receiver Application Board should be oriented with its signal pins toward the DIP switches and LEDs on the STK511 Receiver Interface Board. This places the power and ground test points on the top of the receiver board adjacent to the DATA selector switch. Insert the receiver board into the provided connectors.

If the STK511 Receiver Interface Board is used as an expansion card for the STK500, align the EXPAND0 and EXPAND1 connectors with the corresponding EXPAND0 and EXPAND1 headers on the STK500 and press together. Be cautious of pinching any ribbon cable ends on the STK500 board when inserting the STK511 Receiver Interface Board into the connectors.

Once the Receiver Application Board has been inserted into both twelve-pin connectors, power must be supplied in one of two ways:

A) the power and ground pins on the Receiver Application Board can be connected to a +5V supply, or

B) the supply can be sourced through the STK500 connectors EXPAND0 and EXPAND1.

If the STK500 is used to source power, the VTARGET jumper (located on the STK500) must be connected and VTARGET set to 5V in the STK500 board settings located under the appropriate tab in AVR Studio®, Atmel's software development tool.

2.2 Configuring the Receiver

Atmel RF Receivers designated ATA5743, ATA5760 and ATA5761 contain two configuration registers (Atmel RF receiver designated ATA5744 does not). These registers control the digital processing of the incoming RF signal, as well as define the receivers' polling interval. The register values are stored in volatile memory and are lost when power is removed; therefore, they must be re-programmed every time power is applied. Programming is achieved with a one-wire protocol using the receivers' DATA line. This line is bi-directional and is also used for providing the demodulated data to the user. More detail on this can be found in the individual receivers' datasheets.

With this in mind, the user must decide how to configure the receiver for the intended application. To illustrate this process, the following example will show how to change the receiver to ASK from its default mode of FSK.

1. Once the hardware is setup, verify that the DATA selector switch is in the STK511 position.
2. Apply power, locate the DIP switch corresponding to the OPMODE register, and set the 5th DIP switch to the *ON* position. The LED enclosed in the silkscreen legend labeled *Mod* should light up, indicating a *1* (corresponding to ASK mode) was selected.
3. Press the *Configure* button to program the OPMODE and LIMIT registers with the selected configuration.

Now, the receiver is ready to receive an ASK (or in most cases, On-Off Keyed - OOK) signal. The demodulated signal appears on the DATA line of the Receiver Application Board. This signal can be routed to the on-board microcontroller or to the STK500, depending on the position of the DATA selector switch and values of jumpers R25-R32 (See “Receive Signal Routing” on page 4-6. for additional information).

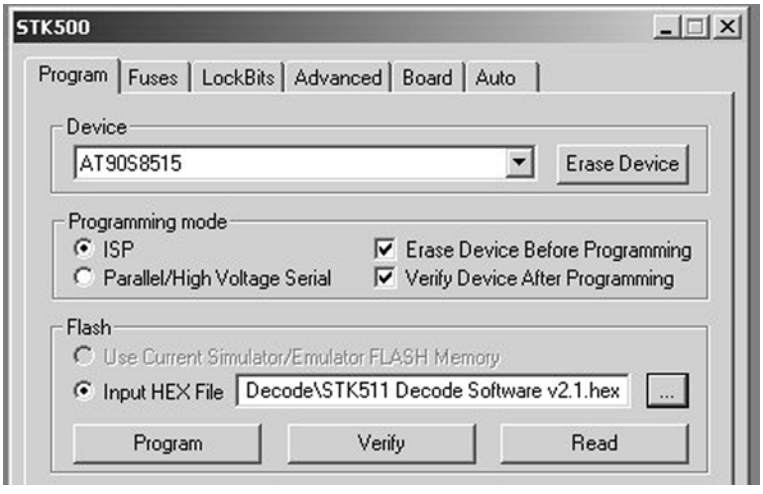
2.3 Running the Demo

The Transmitter Application Board contained in the evaluation kit is shipped preprogrammed with a light intensity sensor program. It can be used with the STK500/511 Assembly to display ambient light intensity using LEDs on the STK500. To run this demo it must first be properly configured.

2.3.1 STK500 Configuration

1. Insert an AT90S8515 microcontroller into the red 40-pin socket (SCKT3000D3) on the STK500 board.
2. Verify that the 6-pin ribbon cable is connected between the SPROG3 and the ISP6PIN headers and is oriented correctly.
3. Connect the 10-pin ribbon cable from the LEDS header to the PORTC header.
4. Apply power (12 V) to the supplied connector and turn on the STK500 power switch.
5. Connect the serial cable between RS232 CTRL and the host PC.
6. In AVR Studio, select *Tools/STK500* from the menu.
7. Select the *Board tab* and verify that the VTARGET voltage is set to 5 V.
8. On the *Program tab*, select *AT90S8515* from the *Device* pull-down menu.
9. Load the STK511 RX Decode.hex file, included on the Sample Software CD, into the field labeled *Flash Input Hex File* and press the *Program* button (see Figure 2-1 on page 2-2).

Figure 2-1. Receiver Decode Software



2.3.2 STK511 Receiver Interface Board Configuration

1. Verify that the Receiver Application Board has been inserted into the appropriate sockets on the STK511 Receiver Interface Board.
2. Connect the STK511 Receiver Interface Board to the STK500 by aligning EXPAND0 and EXPAND1 connectors and pressing together.
3. Switch the Data Selector switch to the STK511 position.
4. Verify power is supplied to the STK500 board.

The Transmitter Application Board as shipped will be set to run with the default receiver configuration register settings. The DIP switches on the STK511 Receiver Interface Board should be set according to the following values:

DIP switch #1……#12

OPMODE register: 000100011001

LIMIT register: 010101101001

Note: The default values are also shown on the bottom line of the silkscreen on the STK511 board.

5. Once the DIP switches have been properly set, press the *Configure* button to write these values into the receiver's registers.
6. Switch the Data Selector switch to the STK500 position and the receiver is now ready to pass data from the transmitter to the STK500 for decoding.

2.3.3 Using the Transmitter

To conserve battery life, the transmitter is shipped in a low current *sleep* mode. Pressing one of the two buttons will *awaken* the transmitter from its *sleep* mode and initiate periodic data transmissions corresponding to the level of ambient light. Simultaneously pressing both buttons will toggle the modulation between ASK and FSK modes. If both LEDs blink during transmission then FSK is selected. If only one LED blinks while transmitting then ASK modulation is selected. The periodic RF transmission rate can be selected to occur quickly or slowly. Pressing one of the buttons results in a transmission rate of once every ¼ second while pressing the other button results in a transmission once every 8 seconds. The transmissions occur after the button is released. The transmitter enters a "sleep" mode after 30 seconds of activity.

It is possible to reprogram the transmitter via the supplied 6-pin header. For more information on how this is done, See "Hardware Description" on page 5-1..

2.4 Evaluating the Demo

Once the system is set up, operation is straightforward. The transmitter will send light intensity information data periodically. This will be displayed as a bar graph using the LEDs on the STK500. For real-time updates, set the transmission rate to ¼ second intervals on the transmitter. Slowly cover up the transmitter to view the LED bar graph change in response to changes in light intensity. Conversely, exposing the transmitter to a light source will cause the LED bar graph to illuminate more LEDs.

It is also possible to view the data being sent by connecting an oscilloscope to the test point on the Receiver Application Board labeled *DATA*. This test point can also be used to view the programming commands when the *Configure* button is pressed.

Section 3

STK511 Receiver Board

3.1 Hardware Description

3.1.1 Overview

The Atmel UHF receivers ATA5743, ATA5760, and ATA5761 are considered *intelligent* receivers. They demodulate and process the incoming ASK or FSK RF signal before providing a digital output to the user. These receivers are well suited for low cost, low data rate transmissions. For more detail about the receiver IC, refer to its respective datasheet. This section will focus on the design and features of the Receiver Application Board.

3.1.2 IC_Active LED

The IC_Active signal on the Receiver Application Board provides status of receiver IC activity. If it is *low*, then the receiver is in sleep mode. When the receiver is in the active mode, the IC_Active line is driven *high*. The LED on the Receiver Application Board gives a visual indication of the value of this signal by turning on when IC_Active is *high*. When selected, polling will cause the IC_Active signal to pulse. This may cause the LED to illuminate less brightly. This is normal and provides the user with an intuitive indication of how often the receiver IC is in the active mode.

3.1.3 CDEM Capacitor

The CDEM capacitor, on the Receiver Application Board, works in conjunction with the Baud Range to set the data bandpass filter corner frequencies. The Baud Range is set in the receiver configuration registers and establishes the upper corner frequency, while the CDEM capacitor establishes the lower corner frequency of the data bandpass filter. A sufficiently large capacitor value must be used to allow the lowest frequency of the data to pass through. However, too large a capacitance results in poor settling times and can skew or truncate incoming RF data. For suggested capacitance values for different Baud Rates, refer to the individual receiver datasheets.

3.1.4 Mode Selection

Unique to the Atmel ATA5743 only is the MODE input. This input changes the IC's internal basic clock cycle and can affect the polling duty cycle and Bit Check timing limits. If the receiver board was built for 315 MHz operation, the MODE input was connected to ground. If the board was built for 434 MHz, operation, the MODE input was connected to + supply. The proper connection of the MODE input is achieved using resistor network R5/R6. 315 MHz operation corresponds to R5 unpopulated and R6 a 0 Ω resistor. 434 MHz operation corresponds to R5 populated with a 0Ω resistor and R6 left unpopulated.

Note: Changes to the MODE input also requires changes to the crystal oscillator, loop filter, LNA, and antenna matching components. It is strongly recommended that the datasheet be referenced before attempting to make changes to the operating frequency.

3.1.5 XTAL Oscillator

The internal local oscillator (LO) for the receiver is determined by a scaled representation of the crystal frequency. The scale factor is different for each receiver. The ATA5743 receiver uses the crystal frequency times sixty-four to achieve the LO frequency. The ATA5760 and ATA5761 both use the crystal times 128 for the LO. This scaling factor must be taken into consideration when determining the crystal frequency. The following illustrates how the crystal oscillator frequency can be calculated.

To determine the proper crystal frequency, subtract the intermediate frequency (IF) from the carrier frequency and then divide by the scaling factor for that IC. The IF for the receivers supported by this kit is about 1 MHz. Using the ATA5743 at a carrier frequency of 315 MHz, the crystal frequency is calculated below.

XTAL (f) = (315 MHz – 1 MHz)/64
= 314 MHz/64
= 4.90625 MHz

The crystal manufacturer should specify the load capacitance for the crystal. It is recommended that the center frequency of the crystal be verified to ensure optimal operation of the receiver. This can be done by carefully measuring the RESET_MARKER frequency. This occurs on the DATA pin upon first application of power and has a frequency of $1/(4096 \times T_{CLK})$, where T_{CLK} is the basic clock cycle. Refer to the device datasheet for more details pertaining to T_{CLK}.

3.1.6 Signal Testpoints

Several testpoints were included on the Receiver Application Board to provide access to key signals. Signals accessible through testpoints are labeled Data, DCLK (DataCLK), and Polling (Enable).

The Data testpoint provides access to the main interface to the receiver IC. This is a bi-directional line that passes data to and from the receiver. It is an open collector output on the receiver so an external pull-up resistor is included on the Receiver Application Board.

DCLK (DataCLK) provides access to the Data Clock output from the receiver. This signal only appears under certain conditions but can greatly reduce the software effort needed to decoding the transmission. For the Data Clock to appear, the received RF signal must be encoded using Manchester or Bi-phase format. These forms of encoding are unique in that the duty cycle is always 50% regardless of the bit value transmitted. In this encoding scheme, sending sequential bits of the same value results in a square wave with some edge-to-edge time T. When the value of the bits sent is different from the previous one, the edge-to-edge time becomes 2T. The receiver looks for this transition from T to 2T and is able to synchronize with the incoming transmission. Consequently, the receiver places Data Clock pulses on the D_CLK line that correspond with valid demodulated data.

The Polling (Enable) testpoint is an input signal to the receiver and allows the user to quickly place the receiver in the active mode (receiver continuously active). Asserting this signal *low* will cause the receiver to enter the active receive mode. Incoming signals will be processed according to the configuration set in the registers. A logic *high*, places the receiver in the polling mode with sleep times set by the value in the OPMODE register.

3.1.7 Antenna Matching

On the Receiver Application Board, provisions have been made to match the receiver IC to an antenna. This match may include a SAW filter in some cases. This SAW filter is not required but can be used to achieve more image suppression. As shipped, the Receiver Application Board is matched to 50 Ω at the SMA. It is intended for use with an off-the-shelf external whip antenna. An antenna with an impedance different from this will require additional matching.

3.2 Software Description

3.2.1 Overview

Decoding of the incoming digital signal from the receiver is performed by the AT90S8515 microcontroller onboard the STK500 in socket SCKT3000D3. The demodulated RF signal present on the receiver DATA line is routed to bit 4 of PortB. Also the D_CLK (Data Clock) line, provided by the RF receiver, is routed to bit 2 of PortB. For this demo, the RF signal is in Manchester format.

It is possible to decode the data by measuring edge-to-edge timing of this line, but many Atmel receivers simplify this task by recovering the clock from the DATA signal. This clock can be found on the D_CLK line and will only appear when a predefined number of logic *1s* (set in the OPMODE register under Bit Check) are followed by a logic *0*. This logic *0* is considered the start bit and from this point forward the D_CLK line will provide a low going pulse for each data bit. The decoding microcontroller *watches* for these data clock pulses and records the state of the DATA line at each occurrence. The logic state of the DATA line following each clock pulse signifies the bit value.

Three 8-bit registers are reserved for buffering the incoming data. As the demodulated signal is received and decoded, as described above, it is loaded into these registers. Once this is complete, the three received bytes are compared to each other. For the received data to be considered valid at least two of the three received bytes must match. This redundancy improves system integrity.

A valid message results in the display of data on the LEDs of the STK500 board.

3.2.2 Sample Software

Below is a sample of the Demo Receive Software that decodes the incoming demodulated signal:

```
/*********************************************
Function : CheckRX
Date     : 6/22/2004
Author   : Toby Prescott
Company  : Atmel
Comments: Decode logic for incoming demodulated signal
*********************************************/
void CheckRX(void)
{
      // Initialize variables
      int timeOut = 0, timeOutVal = 1000, i, j;
      int flag1 = 0, flag2 = 0;

      // Look for D_CLK to begin pulse. This is for the start bit
      while(!flag1 && timeOut < timeOutVal)
      {
           // Check D_CLK. Exit when low
           if(PINB.2 == 0){flag1 = 1;}
           // Increment timeout
           else if(PINB.2 == 1){timeOut++;}
      }
```

```
            timeOut = 0;
            // Look for D_CLK to end pulse.
            if(flag1)
            {
                while(!flag2 && timeOut < timeOutVal)
            {
                // Check D_CLK. Exit when high
                if(PINB.2 == 1){flag2 = 1;}
                // Increment timeout
                else if(PINB.2 == 0){timeOut++;}
            }
        }
        // If D_CLK pulse was found continue to decode the incoming data
        if(flag2)
        {
            // Loop until all three bytes have been read in
            for(j = 0; j < 3; j++)
            {
                // Loop until eight bits of each byte have been read in.
                for(i = 8; i > 0; i--)
                {
                    flag1 = 0; // Clear the flag
                    timeOut = 0;// Clear timeout count
                    // Look for D_CLK to begin pulse.
                    while(!flag1 && timeOut < timeOutVal)
                    {
                        // Check D_CLK. Exit when low
                        if(PINB.2 == 0)
                        {
                            flag1 = 1;
                            //PORTD = 0x00;//For debug
                        }
                        // Increment timeout
                        else if(PINB.2 ==1){timeOut++;}
                    }
                    flag2 = 0;// Clear the flag
                    timeOut = 0;// Clear timeout count

                    // Look for D_CLK to end pulse.
                    if(flag1)
                    {
                        while(!flag2 && timeOut < timeOutVal)
```

```
                {
                    // Check D_CLK. Exit when high
                    if(PINB.2 == 1)
                    {
                            flag2 = 1;
                            //PORTD = 0xFF; //For Debug
                    }
                    // Increment timeout
                    else if(PINB.2 == 0){timeOut++;}
                }
            }
            // Check level of DATA line. Load value into register
            if(PINB.4 == 1  && flag2)
            {
                // If DATA line high load a 0
                // This will reverse the data and
                // Turn on the LED when a 1 was sent
                ReceiveData[j] &=(~(1<<(i-1)));
            }
            // Check level of DATA line. Load value into register
            if(PINB.4 == 0  && flag2)
            {
                // If DATA line low load a 1
                // This will reverse the data and
                // Turn off the LED when a 0 was sent
                ReceiveData[j] |=(1<<(i-1));
            }
        }

    }
    // Check for two of the three bytes received to match before displaying
    if(ReceiveData[0] == ReceiveData[1] || ReceiveData[0] ==
    ReceiveData[2])
    {
        DisplayData = ReceiveData[0];// Load data to be displayed
        delay_ms(40);             // Wait
        DisplayLED();             // Write to LEDs

    }
    // Check for two of the three bytes received to match before displaying
    else if(ReceiveData[1] == ReceiveData[2])
    {
```

```
            DisplayData = ReceiveData[1];   // Load data to be displayed
            delay_ms(40);                // Wait
            DisplayLED();                   // Write to LEDs
        }
        delay_ms(40);// Wait
        ResetRX();                    // Set the Receiver back to polling
      }
  }
```

Section 4

STK511 Receiver Interface Board

4.1 Hardware Description

Figure 4-1. STK511 Configuration Options

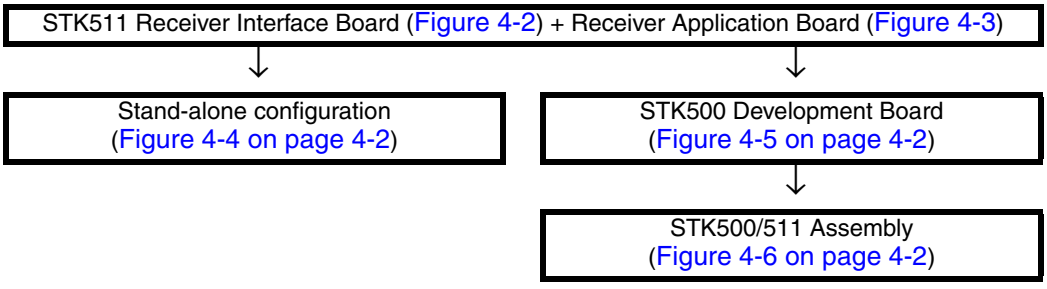


Figure 4-2. STK511 Receiver Interface Board

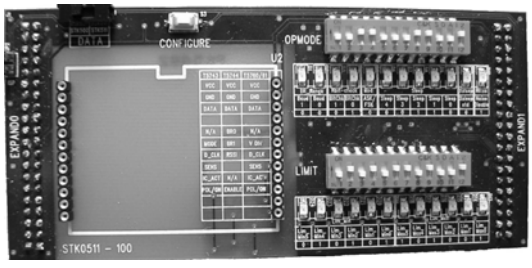


Figure 4-3. Receiver Application Board

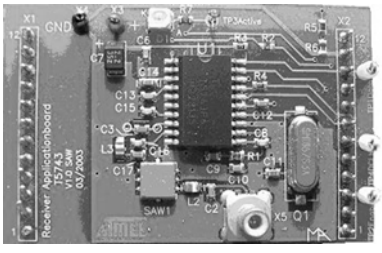


Figure 4-4. Stand-alone

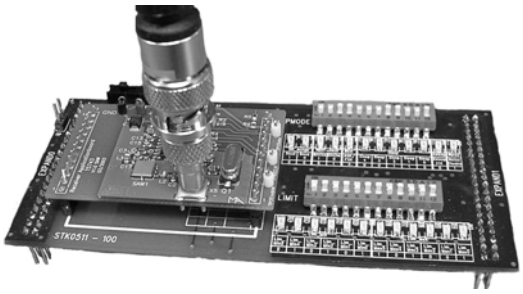


Figure 4-5. STK500 Development Board

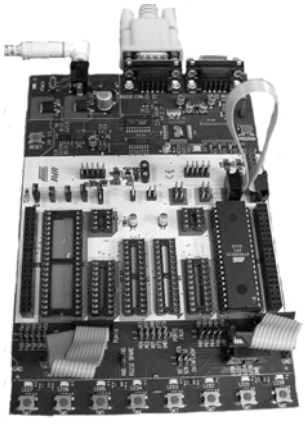
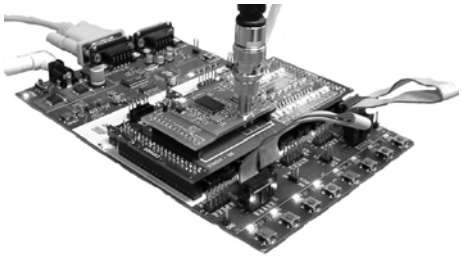


Figure 4-6. STK500/511 Assembly



4.1.1 Standalone Configuration

The STK511 Receiver Interface Board can be used in a standalone configuration along with one of Atmel's Receiver Application Boards (see Figure 4-4). When the Receiver Application Board is combined with the Receiver Interface Board and connected to an external 5 volt power supply, it's configuration registers can be programmed and the resulting demodulation performance can be evaluated. This configuration enables fast, real-time changes to the receiver settings while evaluating its RF performance. For example the receiver can be changed from Baud Range 0 (1 to 1.8 kHz) to Baud Range 1 (1.8 to 3.2 kHz) by toggling a DIP switch and pressing a button. A more detailed description of how this is done can be found in the section "Configuring the Receiver" on page 2-1.

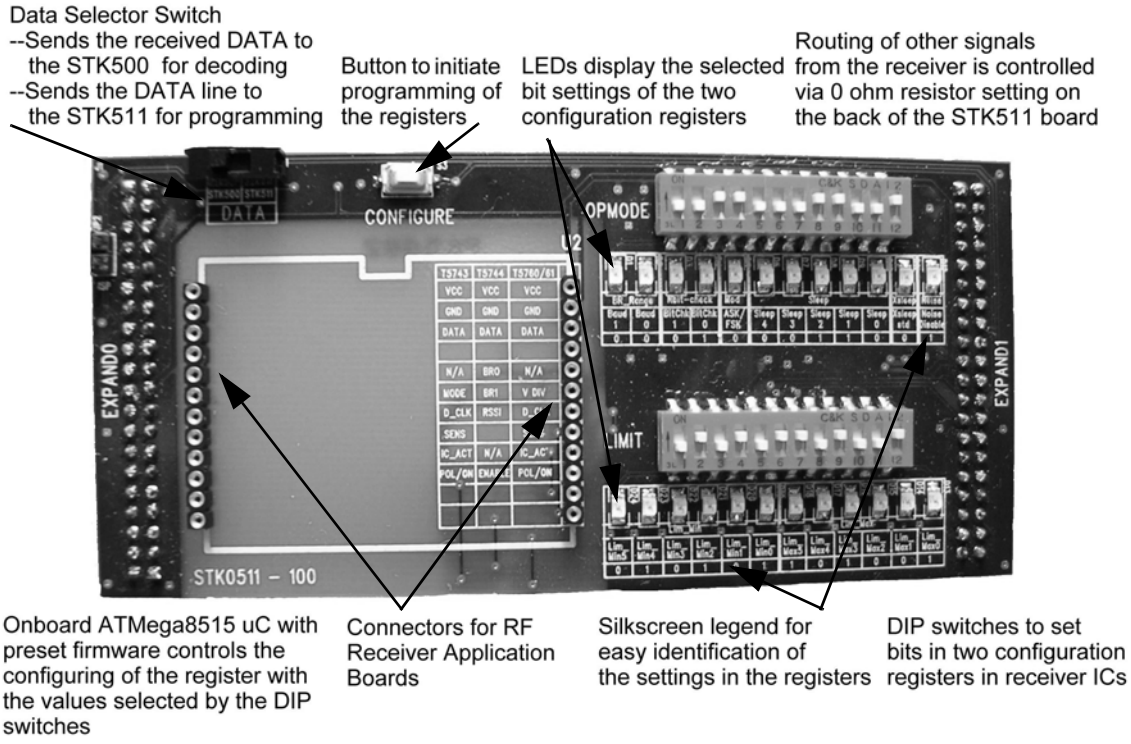
4.1.2 STK500/511 Assembly Configuration

When using the STK511 Receiver Interface Board as an expansion card for the STK500, (see Figure 4-6 on page 4-2) the customer has the added capability of porting receiver signals directly into the STK500 development system. The receiver's configuration registers still remain available for manual changes, but it is now possible to develop software to decode the data demodulated by the receiver. The STK500 board supports most of the AVR® microcontrollers that Atmel offers. This development environment allows the user to create prototypes and functional demonstrations and eliminates the need to fabricate custom printed circuit boards.

4.2 STK511 RF Receiver Interface Board

The following section describes the physical aspects of the STK511 Receiver Interface Board. Figure 4-7 shows the hardware placement and gives a short description of key components.

Figure 4-7. STK511 Receiver Interface Board Hardware Placement



4.2.1 Receiver Connectors

As stated previously, the STK511 Receiver Interface Board was designed to interface with Atmel's RF Receiver Application Boards. There are two rows of connectors (labeled U2) on the STK511 Receiver Interface Board that accept the Receiver Application Boards. These twelve pin connectors allow the receiver board to communicate with the STK511 Receiver Interface Board firmware, as well as route signals to the sockets provided on the STK500 AVR Development board. The pin-outs of the different Receiver Application Boards are listed in a silkscreen table on the STK511 Receiver Interface Board. This provides quick identification of important signal pins on the receiver board. Because the STK500 is compatible with so many Atmel microcontrollers, it is possible to create a fully functional prototype receiver using the user's desired microcontroller.

The following table shows how the signals from the receiver connectors (U2) are routed to the microcontroller I/O ports. As shipped, the STK511 Receiver Interface Board routes the Receiver Application Board signals, necessary for stand-alone operation, to the on-board microcontroller. The remaining signals are routed to the STK500 through the expansion connectors. See section "Receive Signal Routing" on page 4-6 for additional information.

Receiver Signal to I/O Port Mapping

U2 Connector	Receiver Application Board			Microcontroller I/O Port
Pin #	ATA5743	ATA5760/1	ATA5744	
12	VCC	VCC	VCC	---
11	GND	GND	GND	---
10	DATA	DATA	DATA	PB4
9	---	---	---	---
8	---	---	BR0	PB1
7	MODE	V DIV	BR1	PB3
6	D_CLK	D_CLK	RSSI	PB2
5	SENS	SENS	---	---
4	IC_Active	IC_ACTIVE	---	PB1
3	POL/ON	POL/ON	ENABLE	PB0
2	---	---	---	---
1	---	---	---	---

4.2.2 Configuration Register DIP Switches

Upon receiving power, the receiver's OPMODE and LIMIT registers contain default settings. Any values other than the default require programming. The OPMODE register controls Baud Rate range, Bit Check quantity, Modulation type, Sleep polling time, and Noise Suppression. The LIMIT register controls the maximum and minimum valid time between edges. See the receiver datasheet for more information on the registers.

The DIP switches on the STK511 Receiver Interface Board allow individual bits in these registers to be modified. As an added convenience, the STK511 Receiver Interface Board contains a silkscreen legend that specifies each bit function for both registers as well as their corresponding default value.

The configuration register DIP switches connect to the following I/O ports of the ATmega8515 AVR microcontroller which is integral to the STK511 Receiver Interface Board. The bits not listed in the table below are set to constants in the firmware.

Table 4-1. DIP Switch to I/O Port Mapping

OPMODE Register														
Bit1	Bit2	Bit3	Bit4	Bit5	Bit6	Bit7	Bit8	Bit9	Bit10	Bit11	Bit12	Bit13	Bit14	Bit15
---	---	PD0	PD1	PD2	PD3	PD4	PD5	PD6	PD7	PC0	PC1	PC2	PC3	---
LIMIT Register														
Bit1	Bit2	Bit3	Bit4	Bit5	Bit6	Bit7	Bit8	Bit9	Bit10	Bit11	Bit12	Bit13	Bit14	Bit15
---	---	PA0	PA1	PA2	PA3	PA4	PA5	PA6	PA7	PC4	PC5	PC6	PC7	---

4.2.3 Configuration Register LED Indicators

Each configuration register bit has a corresponding LED on the STK511 Receiver Interface Board and is grouped according to specific functions. If an LED is *ON* the corresponding bit is set to logic *1*. The LEDs are enclosed by the silkscreen legend and become part of the table for easy reference.

4.2.4 DATA Selector Switch

The DATA selector switch controls the routing of the bi-directional DATA line coming from the Receiver Application Board. The switch either routes the DATA line to the STK511 Receiver Interface Board's on-board microcontroller or to the Atmel AVR microcontroller on the STK500 board. The silkscreen legend designates the selected mode based on switch position. To enable the Receiver Application Board, a low pulse must be applied to the DATA line whenever power is applied (see receiver datasheet “Clearing the Reset Marker” for more detail). The STK511 Receiver Interface Board provides this signal as part of the firmware initialization routine. Therefore, when powering up the STK511 Starter Kit and configuring the registers in the receiver, the DATA Selector Switch must be set to the STK511 position.

Note: This is probably the single most important piece of information regarding the successful operation of this Evaluation Kit. Having this switch in the wrong position can cause a lot of unexplained problems. Always verify that this switch is set to desired position.

4.2.5 *Configure* Push Button

The configuration selected by the DIP switches is not programmed into the receiver until the *Configure* button is pressed. When pressed, the on-board microcontroller programs these values into the appropriate registers of the receiver. Each register is written twice to allow verification that the proper data was set. The button is connected to PB6 of the on-board microcontroller I/O port.

Note: The Data selector switch must first be set to the STK511 position for the settings to be written into the receiver.

4.2.6 On-board Microcontroller

The STK511 Receiver Interface Board’s on-board microcontroller is the ATmega8515 8-bit AVR. It is shipped with all of the firmware for supporting the functions of the STK511 Starter Kit. Programming the flash memory of this microcontroller can be achieved through the STK500.

In order to reprogram the on-board microcontroller through the STK500 complete the following steps:

1. All devices must be removed from the programming sockets on the STK500.
2. Short the ISP Jumper (JP2) on the STK511 Receiver Interface Board.
3. The SPROG3 header on the STK500 must be connected to the ISP6PIN header.
4. The STK511 Receiver Interface Board must be connected through the expansion connectors (EXPAND0 and EXPAND1).

The ISP pins are connected to the following I/O pins on the microcontroller.

Table 4-2. STK511 Receiver Interface Board On-board Programming Pinout

ISP Pin	I/O Pin Microcontroller
PB7	SCK
PB6	MOSI
PB5	MISO
RST	RST

4.2.7 Receive Signal Routing

Two signals from the Receiver Application Board are routed to the STK511 Receiver Interface Board on-board microcontroller, to allow for operation as a stand-alone system, while the rest are routed to the STK500. Provisions have been made for re-routing all the signals from the receiver to either the STK511 Receiver Interface Board or the STK500 boards. For the advanced user, this flexibility could be used to realize a complete stand-alone receiver system. The routing is controlled by selective population of 0-Ω resistors on the back of the STK511 Receiver Interface Board. The following table lists the routing choices. Components shown in bold designate how the STK511 Receiver Interface Board is configured as shipped. To change the signal routing, remove/add the appropriate resistors.

Table 4-3. Receiver Signal Routing

U2				Routing to On-board Microcontroller	Routing to STK500 Board
Pin #	**ATA5743**	**ATA5760/1**	**ATA5744**		
12	VCC	VCC	VCC		
11	GND	GND	GND		
10	DATA	DATA	DATA	DATA Selector Switch	
9					
8	N/A	N/A	BR0	R32 - NC	R31 - 0 Ω
7	MODE	V DIV	BR1	R28 - 0 Ω	R27 - NC
6	D_CLK	D_CLK	RSSI	R26 - NC	R25 - 0 Ω
5	SENS	SENS			
4	IC_Active	IC_ACTIVE	N/A	R32 - NC	R31 - 0 Ω
3	POL/ON	POL/ON	ENABLE	R29 - 0 Ω	R30 - NC
2					
1					

4.3 Software Description

4.3.1 Overview

The firmware supplied with the STK511 Receiver Interface Board performs the following functions:

- Clears the Reset Marker upon power up
- Reads the values set by the configuration register DIP switches
- Programs the OPMODE and LIMIT registers via the bi-directional DATA line
- Holds the receiver in a polling mode via the POL/ON line

Many Atmel receivers generate a *Reset Marker* signal, consisting of a 128 kHz square wave, upon power up. This must be cleared before normal operation can occur. Applying a 10 ms low pulse to the DATA line clears the *Reset Marker*. This function is part of the initialization routine of the STK511 Receiver Interface Board firmware. However, the DATA selector switch must be set to STK511 mode during power up for this to occur.

When the *Configure* button is pressed, several things occur. First, the actual settings of the DIP Switches are checked by reading ports A, C, and D. The settings are then programmed into the receiver according to the Atmel bi-directional, one-wire interface protocol. The serial programming sequence is repeated twice for each of the registers. Verification of the programmed data is accomplished by checking for the presence of an acknowledge pulse. An acknowledge pulse occurs when the data written into the register is the same as the data already in the register. Lastly the receiver is held in polling mode with a sleep time defined by the register setting.

4.3.2 Sample Software

Below is a sample of the STK511 Receiver Interface Board Firmware that shows how to write to the LIMIT register.

```
//-----------------------------------------------------------------------------
// Procedure: WriteLIMITReg
// Function:  Write register-value from EEProm to RX
// Author:    Toby Prescott
// Date:      03.12.2004
// State:     -
//-----------------------------------------------------------------------------
unsigned char WriteLIMITReg(void)
{
     //--- Local Variabledeclaration:
     unsigned char cBitPos; // Pointer to the current bit
     unsigned char cTempByte;
     unsigned int iQuit = 0;
     char eeprom *e_eeprom_ptr;

       //--- Write the LIMIT register into the receiver:
       while(!iQuit)
       {
          e_eeprom_ptr = &e[2];
          // Point to the fourth byte of memory (LSB of LIMIT)

          //--- Send the programming start pulse (t1) to the Receiver:
          ClearBit(PORTB,RX_DATA);  // PortB.4 Low
          SetBit(DDRB,RX_DATA);     // PortB.4 Output (=Low)

       delay_ms(TimeT1);

       ClearBit(DDRB,RX_DATA);   // PortB.4 Input (=Open)
       //  SetBit(PORTB,RX_DATA); // PortB.4 Pullup

       delay_us(50);             // Short Delay
```

```
        cTempByte = *e_eeprom_ptr++;// Load LSB of LIMIT reg and decrement
                                    pointer

        for(cBitPos = 8; cBitPos > 0; cBitPos--)
        {
            //-- Sync:
            while(TestBit(PINB,RX_DATA// Wait to Synchronization pulse begin
                                  (neg edge)
            {
                // Timeout nach > 800 µs !!!
            }

            delay_us(50);        // Short Delay

            while(!(TestBit(PINB,RX_DATA)// Wait to Synchronization pulse end
                                    (pos edge)
            {
                // Timeout nach > 300 µs !!!
            }
            delay_us(50);        // Short Delay

            //-- Program:
            if(!(TestBit(cTempByte,cBitPos-1 // If the current bit is low,
made
                                      an low-impulse:
            {
                delay_us(TimeT4); //Delay until programmingpulse
                                   ( t4+((t5-t7)/2) )
                SetBit(DDRB,RX_DATA); // Begin the programming pulse
                                   (PortB.4
                                  // Output=Low)
                delay_us(TimeT7); // WaitUs 200 µs for (t7)
                ClearBit(DDRB,RX_DATA); // End the Programming pulse
                                     (PortB.4
                                  // Input=Open)
            }
            delay_us(50);         // Short Delay
        }

        cTempByte = *e_eeprom_ptr++;  // Load MSB of LIMIT reg and
                                      decrement pointer

        for(cBitPos = 8; cBitPos > 1; cBitPos--)
```

```
        {
            //-- Sync:
            while(TestBit(PINB,RX_DATA)) // Wait to Synchronization pulse
                                          begin (neg edge)
            {
               // Timeout nach > 800 µs !!!
            }

            delay_us(50);             // Short Delay

            while(!(TestBit(PINB,RX_DATA))) // Wait to Synchronization pulse
end
                                         (pos edge)
            {
               // Timeout nach > 300 µs !!!
            }

            delay_us(50);             // Short Delay

            //-- Program:
            if(!(TestBit(cTempByte,cBitPos-1// If the current bit is low,
                                          made an low-impulse:
            {
               delay_us(TimeT4);      // Delay until programmingpulse (
                                         t4+((t5-t7)/2) )
               SetBit(DDRB,RX_DATA);  // Begin the programming pulse
                                         (PortB.4
                                      // Output=Low)
               delay_us(TimeT7);      // WaitUs 200 µs for (t7)
               ClearBit(DDRB,RX_DATA); // End the Programming pulse
                                         (PortB.4
                                      // Input=Open)
            }
            delay_us(50); // Short Delay
        }
               iQuit = 1;
            }
          delay_us(2000);             // Wait until the Rx is finished

//--- No Errors occurs:
return ERR_Ok;

} // End of WriteLIMITReg )
```

Section 5

STK511 Transmitter Board

5.1 Hardware Description

5.1.1 Overview

Supplied with this kit is a single-frequency UHF RF transmitter, operating on 315, 433.92, 868.3, or 915 MHz. It employs the Atmel T575x series of UHF transmitter ICs and the Atmel AVR® ATtiny13 8-bit microcontroller IC.

The transmitter is housed in a 2-button key fob with openings in the fob that expose two LED activity-indicators, a CdS photocell, and a 6-pin header for microcontroller programming (see Figure 5-1).

Figure 5-1. STK511 Transmitter

5.1.2 Physical Features

Button Inputs: The STK511 transmitter features two push-button inputs. As described in the Software section, the functionality of these buttons is user-programmable. The transmitter software accompanying this kit demonstrates both single-button and simultaneous two-button presses.

Indicator LEDs: Two LEDs, located above the buttons, confirm button-press action and indicate the software-controlled activity of the T575x transmitter IC.

CdS Photocell: To demonstrate the capability of the 10-bit A/D converter (ADC) resident in the ATtiny13, this photocell presents to the ADC input an analog voltage inversely proportional to the intensity of the incident light.

Six-pin ISP Header: The transmitter's ATtiny13 microcontroller can be programmed through the convenient 6-pin ISP header with the cable supplied in the STK500. Figure 5-2 defines the individual pins' functions. This also allows the user to customize the functionality of the transmitter without having to disassemble the transmitter in order to gain access to the microcontroller (see Figure 5-3).

Figure 5-2. 6-pin ISP Header Pinout (Viewed from the Top of the Fob)

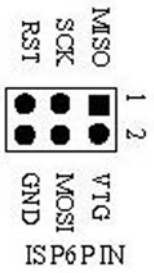


Figure 5-3. Transmitter Programming Assembly

Using Atmel's AVR Studio® software program and the STK500, for example, the demo software provided on the accompanying CD can be easily loaded. The assembly-language code is well commented and should enable the user to modify such things as the Manchester-encoded transmission data rate and duty cycle, or the update interval for light-sensor.

5.1.3 Functional Features

Modulation Modes: The STK511 transmitter can be configured to modulate its RF carrier using either ASK or FSK. Selection of either modulation scheme is defined by the software in the microcontroller, which frees the user from having to change components on the PCB.

Data is modulated using Manchester-encoding at a 1 kHz data rate. At power up, the software is initialized to support FSK. However, the modulation mode can be toggled between ASK and FSK by simultaneously pressing and releasing both buttons on the transmitter. FSK is indicated when both LEDs flash during data transmission while only one LED flashes during ASK.

ASK modulation occurs when the AVR enables the T5750/3/4 IC and sends a serial data stream to the IC's control input. In contrast, an FSK-modulated signal is generated when the AVR sends the serial data stream to the crystal oscillator's pair of load capacitors. The lower, shifted RF FSK frequency is obtained by asserting an AVR I/O low which connects an additional load capacitance to the crystal oscillator. When that same AVR control-port pin is set as a high-impedance input, the upper RF FSK frequency (which is the same as the carrier frequency during ASK modulation) is generated.

WatchDog Timer: Another built-in feature of the ATtiny13 microcontroller, utilized in the STK511 transmitter, is the WatchDog Timer (WDT). At time-out, the WDT can generate either a system-reset signal or an interrupt, which can be handled by software Interrupt Service Routine. For example, in the *Sensor* program (one of the demo programs on the accompanying CD), the WDT is programmed to generate an interrupt that awakens the transmitter at one of two specified intervals (selectable by the user) in order to measure light intensity on the CdS photocell. The WDT time-out interval can be defined within a range of 0.016 seconds to 8 seconds by setting bits in a control register.

Multi-function Ports: The ATtiny13 has excellent I/O capabilities, despite its 8-pin packaging, due to multiple functionality of each I/O pin (excluding V_{CC} and GND). Because of this flexibility, ISP programming, external (pin-change) interrupts, analog signal input, external clock input, and many other features are possible.

Low-current Sleep Mode: Three levels of sleep are possible with the ATtiny13, each offering a different combination of in-sleep/wake-up capabilities and current-saving options. One configuration, as demonstrated in the accompanying demo software, permits the ATtiny13 to draw less than 1 µA of current while asleep.

Internal RC Oscillator: The ATtiny13 contains a fuse-selectable, calibrated internal RC oscillator, which provides a 4.8 MHz or 9.6 MHz clock. No external components are required. The accuracy of the oscillator is ±10% of the nominal frequency. Atmel Application Note AVR053 outlines a method to re-calibrate the oscillator to an accuracy approaching ±1%.

External Clock Input: In addition to an internal RC oscillator clock source, the ATtiny13 can accept an external clock signal. The T575x transmitter ICs can provide this buffered clock if a 0-Ω resistor is installed at the R1 location on the transmitter application board. The frequency of this T575x-supplied clock is $f_{XTAL}/4$.

5.1.4 Circuit Description

Button-inputs S1 and S2: Two button inputs allow the user to control the function of the transmitter. These button inputs are connected between ports PB1/PB2 of the ATtiny13 and the +3 V supply. Initially, these ports are set as input, a hi-Z tristate condition. The voltage level on these ports is held low by the two 220k resistors, R7 and R8, to ground. This is necessary because the voltage at the T575x PA_ENABLE port must be < 0.25 V to remain low, or else RF energy could be inadvertently radiated. Resistors R2 and R6 limit the current into these two ports. When a button is pushed, the +3 V supply (through the R6/R7 or R2/R8 voltage divider) is presented to the corresponding port (PB1 or PB2, respectively). This change in level on the port pin is sensed by the microcontroller and a pin-change interrupt is generated. Firmware then directs the microcontroller to the appropriate Interrupt Service Routine vector.

Indicator LEDs: Activity on switches S1 and S2, as well as the port states of PB1 and PB2 (such as transmitter activation, or ASK/FSK modulation), is indicated on these LEDs. R4 and R9 are source-current-limiting resistors.

A/D Converter: The ATtiny13 has a built-in 10-bit A/D converter. The STK511 transmitter demonstrates the capability of this ADC with a CdS cell incorporated as a light-intensity sensor. This cell has a dark resistance of ~200 kΩ and an illuminated resistance < 100 Ω. In the circuit, resistor R3 sets the bias from port PB4 (when set to *output high*) on the CdS cell. R3 is also a part of a voltage divider with R5 that determines the input voltage range to the ADC port (PB3). In addition, the parallel resistance of R5 and the CdS cell is calculated to provide a range of ~0 V up to 1.1 V to the ADC input (1.1 V is the internal voltage reference value for the ADC).

Antenna: The STK511 transmitter incorporates a PC-board-trace loop antenna. The antenna is driven by the single-ended output of the T575x through port ANT1. Bias voltage for the T575x's power amplifier is fed to ANT1 through a printed-trace inductor of 50 mH-100 mH, L2. At the output of the T575x, C2, C10, and L2 form a matching network, which can be set-up as a C, L, LC, or π configuration. C4 and C5 are additional matching capacitors, which compensate for the inductance of the loop. The optimum load (ie, antenna) impedance for the T5750/3/4 can be found in the respective IC's documentation.

Keying Circuit: RF transmission from the T575x is controlled by signals on its two ports ENABLE and PA_ENABLE. These signals originate from the ATtiny13's ports PB4 and PB1, respectively.

With this straightforward, two-line control, ASK modulation (or in most cases OOK), is easily implemented in the microcontroller software. When the T575x's ENABLE port is taken high by port PB4, the transmitter is activated. Then, RF energy is transmitted when port PB1 pulls PA_ENABLE high. Requiring that two ports on the T575x be pulled high in order to emit RF energy helps prevent accidental transmissions.

Manchester-encoded OOK transmission is achieved, for example, by taking the T575x's PA_ENABLE high during one-half of the bit interval, then allowing it to go low during the other half of the bit interval (or, vice-versa).

Crystal Oscillator: The crystal, X1, along with capacitors C6 and C7, determines the transmit frequency of the STK511 transmitter. C7 is the manufacturer-specified load capacitor for the crystal used. It places the transmitter at the main frequency of operation (e.g., 315 MHz, 433.92 MHz, etc.), for ASK/FSK modulation, f0. With microcontroller port PB0, C6 is switched in-and-out of a parallel combination with C7 to generate an FSK-modulated signal. When configured as an *input*, PB0 is in a hi-Z tri-state condition and C6 is not part of the crystal's capacitive load. C6 is provided a path to ground, placing it in parallel with C7, when PB0 is changed to an *output low*. This additional load capacitance shifts the frequency of the crystal oscillator circuit lower, providing the second frequency of FSK modulation, f1. Adjusting the value of C6 can easily set the amount of shift, f0 - f1. For this particular transmitter, the shift is on the order of 40 kHz.

If desired, switching C6 into and out-of parallel with C7 can also be done with an external JFET at U3. The SST211 is a low-capacitance, enhancement-mode JFET that works well in this application.

For Manchester-encoded FSK transmission, the T575x's PA_ENABLE is held high during both the halves of the bit interval. C6 is switched in-and-out appropriately for each bit-interval half to create the frequency-shifted modulation.

5.2 Software Description

5.2.1 Overview

There are two sample programs included on the accompanying CD that demonstrate the transmitter's functional capabilities. One called *STK511 TX UpDown*, increments and decrements a counter and transmits the count value. The other, called *STK511 TX Sensor*, utilizes the integral CdS photocell as a light-intensity sensor and sends an 8 bit digital value corresponding to the voltage measured across the light sensor.

Button functionality specific to each program is included in the descriptions that follow.

1. *STK511 TX UpDown* senses right/left button presses and increments/decrements (respectively) a counter in the ATtiny13. The count value is transmitted to the companion receiver upon button release. With the receiver mated through the STK511 to the STK500, the count value is displayed (in hexadecimal format) on the 8 LEDs of the STK500. When not transmitting the results of an increment/decrement command, the transmitter is in a low-current-consumption sleep mode.
2. *STK511 TX Sensor* demonstrates the capabilities of the A/D converter in the ATtiny13, using the CdS photocell as a light-intensity sensor. The resistance of the photocell's output (which is inversely proportional to the amount of light incident on the sensor) is converted to an input voltage signal to the A/D converter. The resulting A/D conversion quantization is binned into one of eight value-ranges, which is transmitted to the companion receiver mated to the STK511. The relative intensity of the detected light is displayed in bar graph form on the 8 LEDs of the STK500 -- from right to left, more lighted LED indicate higher light levels incident on the photocell. The two buttons on the transmitter initiate periodic RF transmission of the binned A/D data, as well as determine the transmit interval. Pressing the right button sets the transmit interval at 0.25 seconds; the left, at 8 seconds. Sensor readings are sent for approximately 30 seconds, after which the transmitter enters a low-current-consumption sleep mode. Periodic transmissions resume when either button is pressed.

5.2.2 Sample Software

```
; - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
; routine: Main
; calls: Setup, Snooze
; called by:
; function: main pgm
; - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
Main:
        RCALL   Snooze      ; Sleep
        CPI     WDTcounter,0x00; TP - Check for 30 sec timeout here
        BRNE    KeepAlive   ; TP - If not 30 sec loop but keep sleeping in
                              between TX

        LDI     R16,0x50    ; TP - If 30 sec passed turn off the WD Timer
        OUT     WDTCR,R16
        LDI     R16,0x00    ; TP - Sleep until button press starts WD Timer
        OUT     WDTCR,R16
```

```
KeepAlive:
        RJMP    Main

; - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
; routine: ISRPinChg
; calls: Debounce, S1S2Pressed, WDTStart
; called by: <uC interrupt firmware>
; function: services a single button-press; and, checks for simultaneous
; button press (for changing modulation modes)
; - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
ISRPinChg:
        PUSH    R19         ; TP - All functions must have push and pop
                              statements!

        IN      r31, SREG   ; save Status Register

        CLI                 ; TP - Disable interrupts
        WDR                 ; TP - Clear watchdog timer


        RCALL   Debounce    ; TP - Add delay for debounce
        IN      r16, PINB   ; see which button was pushed

        CPI     R16,0x06    ; TP - IF BOTH
        BREQ    ISRPinBoth

        CPI     R16,0x02    ; TP - IF only S2
        BREQ    ISRPinS2

        CPI     R16,0x04    ; TP - IF only S1
        BREQ    ISRPinS1

        RJMP    ISRPinChgEnd; TP - Exit if glitch

ISRPinBoth:
        CPI     MODE,FSK    ; TP - For both buttons pressed, check current
                              state
        BREQ    SETmodeASK  ; TP - If currently FSK, set mode to ASK
        LDI     mode,FSK    ; TP - If not FSK, set mode to FSK
        RJMP    ISRPinLoop  ; TP - Exit button ISR when buttons released

SETmodeASK:
```

```
        LDI     mode,ASK     ; TP - Set mode to ASk
        RJMP    ISRPinLoop   ; TP - Exit button ISR

ISRPinS1:
        LDI     R16,0x50     ; TP - If S1 pressed first set up WDT to 1/4 sec
        OUT     WDTCR,R16
        LDI     R16,0x44     ; TP - This will start the timer when sei
        OUT     WDTCR,R16    ; TP - Then set number of interrupts in 30 sec

        LDI     WDTcounter, 0x78 ; 0x78=120 - sleep after 0.25x120=30 secs
        RJMP    ISRPinLoop   ; TP - Exit button ISR when button released

ISRPinS2:
        LDI     R16,0x50        ; TP - If S2 pressed first set up WDT to 8
                                  sec
        OUT     WDTCR,R16
        LDI     R16,0x61        ; TP - This will start the timer when sei
        OUT     WDTCR,R16       ; TP - Then set number of interrupts in 30
                                  sec

        LDI     WDTcounter, 0x04; 0x04 - sleep after 8x4=32 secs
        RJMP    ISRPinLoop      ; TP - Exit button ISR when button released

ISRPinLoop:
        WDR                     ; TP - Clear watchdog timer
        IN      R16,PINB        ; TP - Check for button release
        ANDI    R16,0x06        ; TP - If either button still pressed, loop
        BRNE    ISRPinLoop      ; TP - When both buttons released exit ISR
        RCALL   Debounce        ; TP - Add delay for debounce

ISRPinChgEnd:

        LDI     r16, 0x20
        OUT     GIFR, r16       ; clear Pin Chg Interrupt Flag
                                ; just caused by releasing switch
        SEI                     ; TP - Enable interrupts
        OUT     SREG, r31       ; restore Status Register

        POP     R16             ; TP - All functions must have push and pop
                                  statements!
        RETI
```

```
; - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
; subroutine:  ISRWatchDog
; calls:  SensorADC
; called by: <uC watchdog interrupt firmware>
; function:  calls A-D Converter routine (which reads signal from light
;              sensor) at the appropriate interval-rate, based on which
;              button was pressed
; - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

ISRWatchDog:
        PUSH    R16             ; TP - All functions must have push and pop
                                  statements!

        IN      R31,SREG        ; TP - Save status register
        CLI                     ; TP - Disable interrupts

        RCALL   SensorADC       ; TP - Read the sensor data
        RCALL   Xmt             ; TP - Send the data
        DEC     WDTcounter      ; TP - Decrement number of WDT interrupts

        LDI     r16, 0x00       ; TP - Reset I/O states
        OUT    PORTB, r16       ; set ports to low
        OUT    DDRB, r16        ; set ports to inputs

ISRWatchDogEnd:
        LDI    R16,0x20         ; TP - Clear interrupt flags
        OUT    GIFR,R16
        LDI    R16,0xF7
        OUT    MCUSR,R16

        WDR                     ; TP - Clear watchdog timer
        SEI                     ; TP - Enable interrupts
        OUT    SREG,R31         ; TP - Restore status register

        POP    R16              ; TP - All functions must have push and pop
                                  statements!
        RETI
```

Section 6

Regulatory Requirements

6.1 General

This kit is intended to showcase the broad flexibility of Atmel's RF radio chip-set by offering multiple transmission modes that span frequencies across the RF spectrum from 315 MHz to 915 MHz. Consequently, local regulatory limitations will apply that restrict certain combinations of transmission modes and RF spectrum. These regulations generally place restrictions on carrier frequency, transmission duty cycle, harmonic content, and method of measurement. The following paragraphs attempt to provide general guidelines with respect to these operating parameters. The user is strongly urged to review and understand all applicable local regulations pertaining to the implementation of the target application during the early phases of the design process.

6.2 Output Field Strength/Power

FCC limits transmitted RF energy to an average level, specified in terms of field strength, measured at a distance of 3 meters from the transmitter. The averaging interval defined by the FCC is 100 ms. Through careful selection of a transmission protocol, it is possible to utilize a transmitter that generates up to 20 dB above the FCC limit, provided the RF transmission is only active for 10 ms during any 100 ms interval. For duty cycles greater than 10%, the duty cycle correction factor (also referred to as relaxation factor) can be calculated as follows:

Correction Factor = 20log[max RF *on time* in ms/100 ms]

While use of this duty cycle correction factor is most often applied to OOK/ASK applications, it can also be applied to FSK modulation and harmonic frequencies.

For 315 and 434 MHz, the limit is 6,042 and 11,000 µV/m respectively. Harmonic and other spurious emissions must be 20 dB below the fundamental. For operation at 915 MHz, the limit increases to 50 mV/m for the fundamental and 0.5 mV/m for harmonics (50 dBc for spurious emissions). However, field strength is no longer based on an average, which precludes the use of the duty cycle correction factor as described above. In all cases, care must be taken to insure that harmonics and spurious emissions avoid the field strength limits that exist in the many restricted bands defined by the FCC.

For European applications, RF energy is regulated based on peak effective radiated power. Unlike the FCC, duty cycle correction is not allowed. Peak power is limited to 10 dBm at 434 MHz and 14 dBm at 868 MHz. The European limits enable much more RF output energy than the FCC limits allow. However, harmonics and spurious emissions restrictions are more stringent than those in the FCC's rules. They must be kept below -54 dBm when they fall in the following bands 47 MHz to 74 MHz, 87.5 MHz to 118 MHz, 174 MHz to 230 MHz, and 470 MHz to 862 MHz and below -36 dBm for all other frequencies < 1 GHz. The limit relaxes further to below -30 dBm for frequencies > 1 GHz.

6.3 Operating Frequency

The Federal Communications Committee (FCC) governs the use of RF spectrum in the United States. The European Telecommunications Standards Institute (ETSI) covers this in Europe. The FCC allows the type of RF transmissions generated by this kit at 315, 434, and 915 MHz but not at 868 MHz. ETSI limits the use of this kit to both 434 and 868 MHz.

6.4 Operating Duty Cycle

In addition to the RF spectral energy constraints described above, the FCC imposes additional restrictions on A) the type of data that can be sent and B) the transmission duty cycle. Only control signals such as those used with alarm systems, door openers, remote switches, etc. are allowed. Radio control of toys, continuous transmissions such as voice or video, and data transmissions are not permitted. The following conditions apply to RF transmission duty cycles:

- RF must end < 5 seconds after release of manual transmission
- RF must end < 5 seconds after start of an automatic transmission
- Periodic transmissions aren't allowed unless they are used to determine security or safety system integrity and the RF transmission does not exceed one transmission, of not more than one second per hour, per transmitter.

In Europe, the average duty cycle must be limited to < 10% at 434 MHz and < 1% at 868 MHz for the power levels typical of the transmitter in this kit. Average duty cycle is defined as the ratio, expressed in %, of the maximum transmitter RF *on time* relative to a 1-hour period.

6.5 Additional information

Information with regard to United States RF regulations can be found in:

- FCC Rules and Regulations, Chapter 47, Part 15

Information with regard to European RF regulations can be found in:

- EN 300 220-1 Electromagnetic Compatibility and Radio Spectrum Matters
- ERC Recommendation 70-03 E Relating to the use of Short Range Devices

Section 7

Troubleshooting Guide

Table 7-1. Troubleshooting Solutions

Problem	Reason	Solution
LED on Receiver Application Board not active	Power is not applied or is less than 5V	Verify that 5V is supplied to the Receiver Application Board via on-board pins or through the Receiver Interface Board connection to the STK®500 (VTG jumper).
	DATA Selector switch was not set to the STK511 position when power was applied	Set DATA Selector switch to STK511 and re-apply 5V supply
	Receiver in permanent sleep mode because *Sleep* mode of all *1s* selected in OPMODE register	Select different polling rate and re-program OPMODE register
	Receiver Application Board rotated 180° when mounted on the Receiver Interface Board	Verify that Receiver Application Board signal testpoints are placed toward the DIP switches.
LED(s) on Receiver Interface Board not active	Power not applied	Verify that Power is supplied to the Receiver Interface Board through either the Receiver Application Board or the STK500 Board (VTG jumper).
	Corresponding DIP Switch bit(s) not set	Set the corresponding bit(s) to *ON* on the DIP Switch for that register
	Bias resistor(s) damaged	Replace the corresponding bias resistor(s) on the back of the Receiver Interface Board with 1 kΩ
	Incorrect firmware loaded into the Receiver Interface Board where I/O port of the on-board microcontroller programmed to logic high	Reload the Receiver Interface Board Firmware as described in section "Software Description" on page 3-3

Table 7-1. Troubleshooting Solutions (Continued)

Problem	Reason	Solution
Registers in the receiver do not appear to be programming	Power supplied is too low	Verify that the power being supplied is 5V
	DATA Selector switch was not set to the STK511 position when *Configure* button pressed	Set DATA Selector switch to STK511 and re-press button
	Receiver Interface Board firmware has become corrupted	Reload the Receiver Interface Board Firmware as described in section "Software Description" on page 3-3
	Registers may be programming correctly with no visible signs of change	Monitor the Data Testpoint with an oscilloscope to check for presence of the acknowledge bit
	Some external source may be holding the Data line *low*	
	Receiver Application Board rotated 180° when mounted on the Receiver Interface Board	Verify that Receiver Application Board signal testpoints are toward the DIP switches.
Unable to load Receiver Interface Board firmware	Receiver Interface Board not correctly connected to STK500	Verify EXPAND0 and EXPAND1 are properly oriented
	ISP ribbon cable not connected properly	Ensure ribbon cable connected between ISP6PIN header and SPROG3 header
		Check orientation of pin 1 on headers
	Incorrect device selected	Select ATmega8515 from the *Device* menu. Verify that the signature byte matches in the *Advanced* tab
	Device present in STK500 sockets	Remove all devices from the programming sockets of the STK500
	ISP jumper not shorted on Receiver Interface Board	Connect shunt
	Power and serial cable not connected to STK500	Verify setup of the STK500 hardware
Transmitter not responding to button press	Battery dead	Open Transmitter Application Board case and replace coin cell battery
	Demo Software corrupted	Reload the desired software according to section "Software Description" on page 4-6
	Switch contact not made	Ensure proper contact of the button to the Transmitter Application Board
No activity on Transmitter Application Board LED(s)	Low Battery voltage	Replace coin cell battery
	Transmitter is in sleep mode	Press button to wake from sleep mode
	Demo Software corrupted	Reload the desired software according to section "Software Description" on page 4-6

Table 7-1. Troubleshooting Solutions (Continued)

Problem	Reason	Solution
Transmitter Application Board LED(s) constantly lit	Demo Software corrupted	Reload the desired software according to section "Software Description" on page 4-6
Unable to program Transmitter Application board through ISP header	Incorrect orientation of the ribbon cable connecting the ISP header to the STK500	Verify the orientation of both sides of the ribbon cable
	Power not supplied to transmitter on-board microcontroller	Supply 3 volts to the transmitter microcontroller through the coin cell battery or via the STK500
	Wrong device selected in the STK500 software	Select ATtiny13 from the *Device* menu. Verify that the signature byte matches in the *Advanced* tab
	Power and serial cable not connected to STK500	Verify setup of the STK500 hardware
Demo not working (STK500 LED(s) not responding to transmitted signal)	Incorrect orientations of the Receiver Application Board or Receiver Interface Board	Verify the hardware is assembled correctly as shown in chapter 1
	Power not properly supplied to all boards	See troubleshooting section for each board.
	Data Selector switch not set to STK500 position	Set the switch to the proper position and re-run the demo
	Microcontroller socket on STK500 not populated	The demo uses an AT90S8515 microcontroller in the STK500 to decode the received signal
	Corrupted software in the STK500 microcontroller	Reload the Receiver Decode software as shown in Figure 2-1 on page 2-2
	10-pin ribbon cable not connected properly	Verify that the 10-pin ribbon cable is properly connected to the LEDS header from the PORTC header on the STK500
	Incompatible modulation used on the transmitter and receiver	Verify that transmitter and receiver are both set for the same modulation type (ASK versus FSK)
	CdS Photocell covered	The LED(s) on the STK500 are only active when the CdS Photocell is subjected to a light source and one of the buttons has been pressed
	Receiver set to permanent sleep	Check for Sleep bits in the OPMODE register set for all *1*
	Receiver limits incorrect	Verify correct register settings as given in chapter 1
	Receiver antenna not connected	Connect external whip antenna to Receiver Application Board

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