

ATAK4015744

Smart RF Wireless Control System

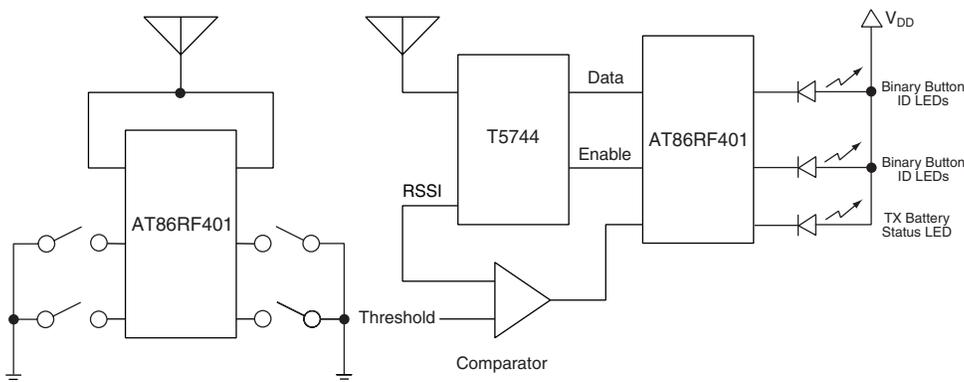
Application Note

This application note is designed to demonstrate a complete one-way RF wireless control system. It is specifically intended to showcase the AT86RF401 transmitter and the T5744 receiver.

Functional Description

The ATAK4015744U/E (U for 315 MHz, E for 433.92 MHz) Evaluation Kit demonstrates a one-way RF system comprised of an AT86RF401U/E transmitter and a T5744 receiver. The kit ships with software that allows the transmitter to send a unique 8-bit code corresponding to one of four buttons on the transmitter PCB. The code contains the button identity as well as battery status of the transmitter. On the receive side, the T5744 demodulates the RF signal into a digital signal and presents it to the AT86RF401, which contains an integrated AVR[®] microcontroller. Once the signal is processed, a binary representation of the button pressed and the battery status are displayed on the three LEDs. The RF system uses on-off keyed (OOK) carrier modulation and pulse width modulation (PWM) to encode the digital information. See Figure 1 for a system block diagram.

Figure 1. Block Diagram



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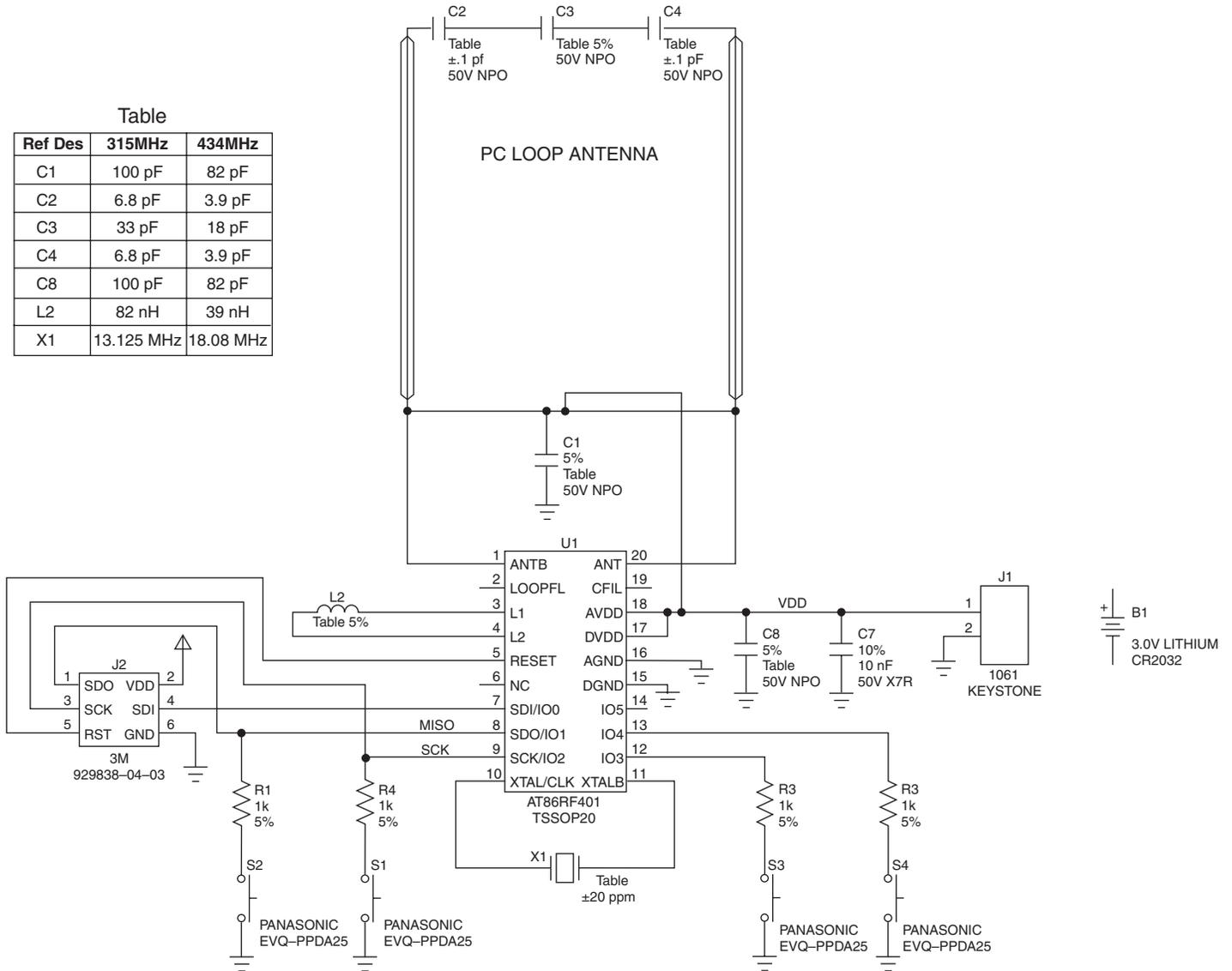


System Hardware

Transmitter

The transmitter consists of a PCB containing an AT86RF401, push buttons, battery holder, printed trace antenna, programming header, and some discrete components. Figure 2 shows a schematic representation of the transmitter.

Figure 2. Schematic Representation of AT86RF401 Transmitter



VCO Inductor

Several items affect the placement of L2, the VCO tune inductor, and must be considered when designing with the AT86RF401. The inductor should be placed with its long axis parallel to the leads on the TSSOP package. This helps prevent the transmitted RF signal radiated by the PCB trace antenna from coupling back into the VCO/PLL. The AT86RF401 contains an internal switched capacitor array that is placed parallel to the external VCO inductor. This array is able to fine-tune the VCO for optimal performance. Normally, this inductor should be placed as close to the AT86RF401 as possible. By modifying the trace length connecting the inductor to the IC, one can obtain a nonstandard inductor value and center the VCO tuning range for maximum flexibility.

Antenna Design

Designing a differential loop antenna should be approached with symmetry in mind. Each leg of the loop should match the impedance of the IC's antenna output and share the same geometry as the opposite side. This will insure balanced operation, symmetrical radiation patterns, and maximum power efficiency. The AT86RF401 requires that the antenna be biased to V_{DD} . It is recommended that the tap to V_{DD} be centered between the two antenna pins and include a bypass capacitor to ground. The loop antenna will require a capacitor to obtain optimal power efficiency. By utilizing several capacitors placed in series, it is easier to obtain the proper value for peak performance. For more detailed information, refer to the application note *AT86RF401 RF Wireless MicroTransmitter: PCB Trace Antenna Design Considerations and Implementation Guidelines*.

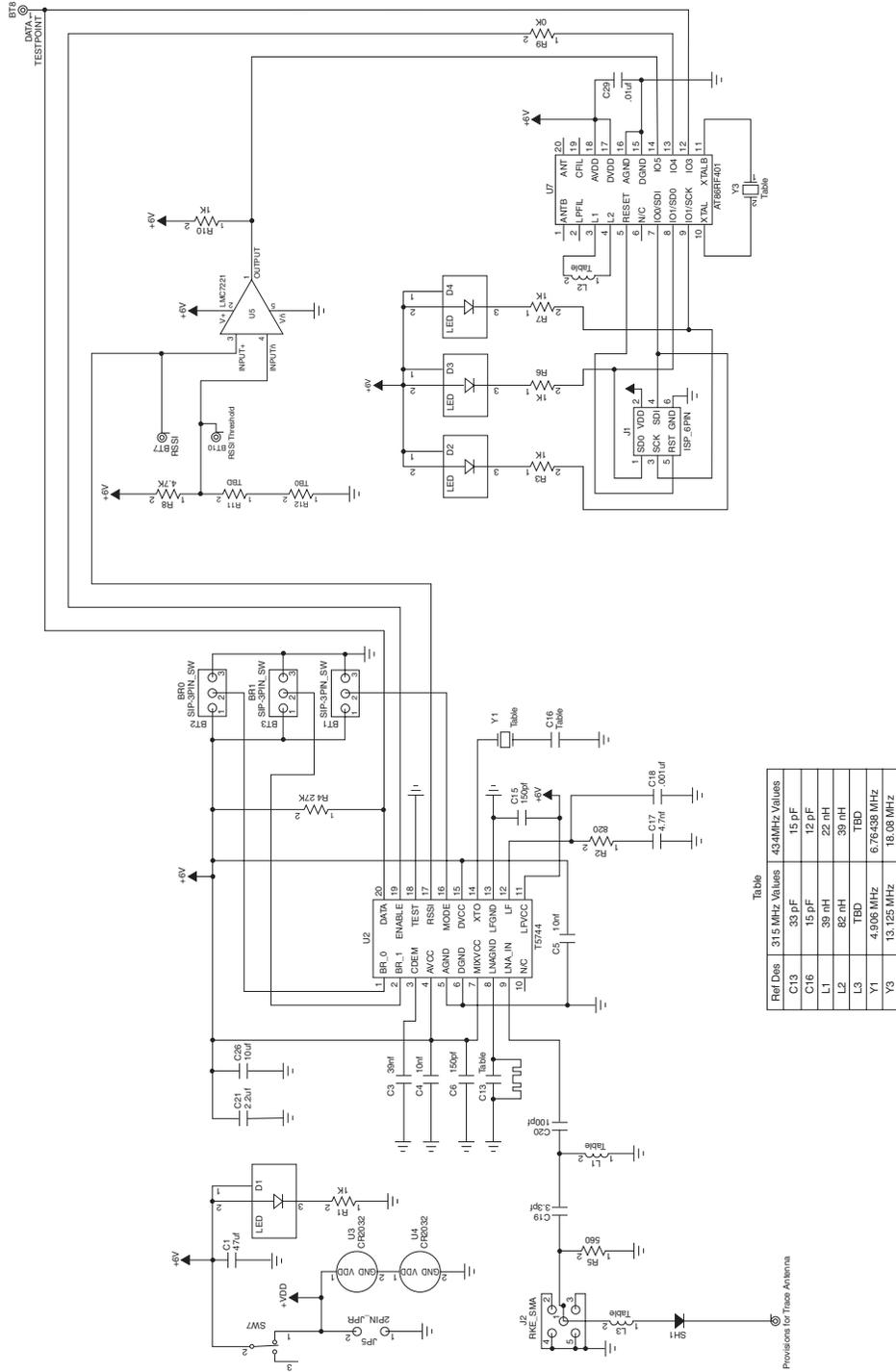
Programming

In-system programming (ISP) is possible via the serial peripheral interface (SPI), making code development and code changes easy to implement. The ISP is implemented with a six-wire ribbon cable and connects the host PC to the AT86RF401. The ISP header traces should be routed with care being taken to minimize loop areas being created. These loop areas, specifically the V_{DD} and Ground trace loop, can act as an antenna, couple RF energy back into the VCO, and could pull the output frequency off center.

Receiver

The receiver consists of a PCB with two ICs (T5744 and AT86RF401), battery holders, printed trace antenna, programming header, and some discrete components. Provisions exist for making use of the receive signal strength indicator (RSSI) capability in the T5744, but this capability is not utilized in this evaluation kit. Three LEDs are connected to the AT86RF401 and provide acknowledgment that a properly demodulated signal was received. Figure 3 shows a schematic representation of the receiver.

Figure 3. Schematic Representation of ATAK4015744 Receiver



- Power Supply** The power for the receiver is supplied by two lithium coin cells. The batteries are isolated when not in use by way of a single-pole, single-throw switch. A green LED indicates when the receiver power supply is on. A tantalum capacitor provides bulk bypass capacitance for the system.
- Programming** Because the AT86RF401 is being used to decode the demodulated signal, the ISP considerations are the same as in the transmitter section. If a different microcontroller is used, ISP will depend on the requirements for that microcontroller.
- Baud Rate Selection** The T5744 has a selectable band-pass filter that provides basic signal processing on the demodulated output by limiting the speed of edge transitions. It also provides suppression of spikes on the data output. Two jumpers (BR0 and BR1) control the baud rate range. See the T5744 data sheet for BR_Range settings (www.atmel.com). The transmitted baud rate must fall within the limits set by BR0 and BR1 for the receiver to function properly. As shipped, the kit is configured to the highest baud rate, e.g., with an upper cutoff frequency of approximately 20 kHz.
- Frequency Selection** The T5744 can function at either 315 or 433.92 MHz by merely changing a few components. The XTAL and MODE pin jumpers determine the operating frequency. Additionally, it is recommended that the capacitor on the LNAGND pin be changed to allow optimal performance at each frequency. See the T5744 data sheet for suggested values.
- Antenna Design** The T5744 uses a single input antenna design. The receiver board contains provisions for a matching network to the PCB trace antenna or to a simple $\lambda/4$ wire whip antenna. The network is matched to a 50-ohm load. Note that the trace antenna is not matched to 50 ohms and is only intended to demonstrate short-range functionality. A more optimal match (and consequently a greater range) is possible by disconnecting the PCB trace antenna and connecting a $\lambda/4$ antenna at J2.
- RSSI Comparator** Optional provisions have been provided for using the RSSI. By comparing the RSSI voltage to a fixed reference and sending the result to the microcontroller, one can be sure that a strong RF signal is present before decoding the data.



System Software

Transmitter

The transmitter sample code is found on the ATAK4015744 Evaluation Software CD. The evaluation kit comes with this software programmed into the transmitter. More information on programming using the AT86RF401 is contained in the data sheet (www.atmel.com).

Sleep Mode

The AT86RF401 can be placed in a low-current sleep mode for longer battery life. The current draw is less than 0.5 μA while in this mode. The AT86RF401 is programmed so that a button input will bring it out of sleep mode. This was done by configuring the I/Os to be button-input driven. When a button is pressed, the I/O pin transitions from high to low, causing the internal microcontroller to come out of sleep mode and continue executing code.

Low Battery Detect

The AT86RF401 has a register-programmable low battery detector. The programmer can set a voltage threshold in software and detect whether the battery level is above or below that voltage. This indication of battery level is monitored by software each time a button is pressed. The battery status is included in the encoded message transmitted to the receiver. The software included in this evaluation kit sets the voltage threshold to approximately 2.1 volts. If the transmitter battery is lower than this voltage, the receiver will activate the low battery LED.

PWM Encoding

This one-way RF system uses PWM to encode the data being transmitted. The kit utilizes a 1/3:2/3 bit encoding scheme but can be modified via software. This means that a "1" is represented by the first two-thirds of the bit period containing RF signal and the last one-third of the period containing no RF. A "0" is the opposite: the first one-third has an RF signal and the last two-thirds does not. The message is composed of two bytes of preamble (0xFFFE) followed by a byte of data (the upper nibble contains battery status and the lower nibble contains button ID). The data byte is repeated three times. If the battery status is "0", then the battery is above the low battery threshold; otherwise, it is below the threshold. The button ID is defined as follows: Button 0 is 0001, Button 1 is 0011, Button 2 is 0111, and Button 3 is 1111. This gives each button a unique identity that cannot be mistaken by a bit shift error.

Bit Timer Function

The bit timer function performs the actual keying of the transmitter, enabling precise timing for the modulation of the RF power amplifier. Two timer values were determined to correlate with the 2/3:1/3 time periods. When transmitting a "1", the RF output is turned on and the two-thirds time value is loaded into the bit timer. When the time expires, the RF is turned off and the one-third time value is loaded. When this time has elapsed, the next bit to be transmitted is determined. For a more detailed description of the bit timer function, see the AT86RF401 data sheet.

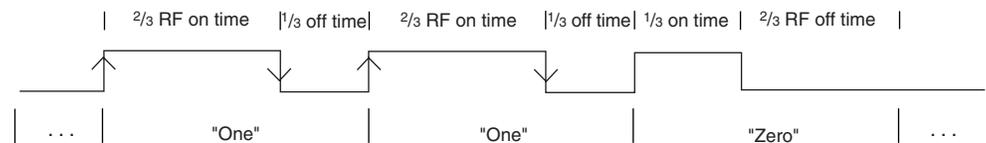
Receiver

The receiver sample code is found on the ATAK4015744 Evaluation Software CD. The evaluation kit comes with this software programmed into the receiver. The microcontroller used is the same as the transmitter, which simplifies software development.

Decode Using Bit Timer

The receiver is configured to remain on all the time. Consequently, the serial data output of the T5744 toggles in response to noise. The microcontroller portion of the AT86RF401 must check every edge to determine if the signal is valid. This is done by using the bit timer. When the bit timer is in receive mode, a counter counts up from zero until an edge on I/O 3 interrupts the counter. To decode the incoming data stream from the T5744, the timer is set to zero and begins counting until an edge occurs. Using PWM encoding, the bit can be determined to be a "1" or "0" by measuring the time from a rising edge to a falling edge. See Figure 4 for clarification. Since the timer is reset every time an edge occurs, dealing with only falling edge events will give the time from rising to falling edge. Once the bit value is determined (a long duration between rising and falling edges corresponds to a "1"; a short duration corresponds to a "0"), that value is shifted into a register, which is compared to the least significant byte of the preamble. When the preamble has been received, a flag is set and the next eight bits are shifted into the register. The battery status bit is checked, and the register is compared with the expected byte for each of the four button identities. If no match is found, the code clears and begins looking for the preamble again.

Figure 4. PWM Detection



Drive LEDs

If the correct code for a button identity is found, the AT86RF401 displays the binary representation of the button on two LEDs. Button 0 has both LEDs turned off. Button 1 has the first off and the second on. Button 2 has the first on and the second off. Finally, Button 3 has both LEDs turned on. At the same time, if the code for a low battery was sent, the low battery LED is turned on.

Optional RSSI

Compare provisions are available in the software to check the output of the RSSI comparator circuit after each edge occurs on I/O 3, allowing the microcontroller to ignore edges that occur without the presence of a strong RF signal. This can be used to identify and reject "noise" on the serial data output of the T5744. The disadvantage to using RSSI in this fashion is that the range of the receiver is compromised.



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