ABSTRACT

This application report describes how to create a low cost and low power IR remote control featuring the new MSP430F2xx family of ultra-low power microcontrollers. The transmitter design described in this report is completely interrupt driven and consumes 0.1\(\mu\)A while waiting for the user’s button-press. The software provided implements the RC5 protocol on the MSP430F21x1, but can easily be modified to implement any other IR standard on any MSP430.

1 Introduction

The low cost and low power MSP430-based TV IR remote control described in this application report contains a minimum of external components. The design uses two Timer_A3 capture/compare blocks and 5 digital I/O ports of the MSP430F21x1 with less than 700 bytes of code. An external IR LED, transistor, capacitor, 3V CR2032 Lithium coin cell battery, 3 diodes, 3 resistors, and 6 switches complete the system. With this implementation, the MSP430 remains in LPM4 most of the time where the chip consumes 0.1 \(\mu\)A.

2 IR Remote Control Theory

A TV infrared remote control must receive user commands through button-presses and output the appropriate IR signal through the air to an IR receiver. To allow the receiver to distinguish between the remote’s IR signal and all the other sources of infrared light, IR remote controls modulate their signals, usually between 30–60 kHz. In this application report, 40 kHz is used. A mark is defined as the presence of a 40 kHz modulated IR signal and a space is the lack of an IR signal. The specific IR protocol defines how the series of marks and spaces translate to a user command.

3 RC5 Protocol

The RC5 protocol is a type of Manchester encoded data packet. Manchester data is unique in that a data is signified by a transition in the middle of the bit. A one is transmitted as a space-to-mark transition and a zero as a mark-to-space transition. The RC5 IR packet consists of 14 bits: two start bits (S1, S0), one control bit (C), five address bits (A4 to A0), and a six bit command code (C5 to C0). The entire 14-bit packet is received MSB first, starting with two start bits.

Figure 1 shows the RC5 packet transmitted by the MSP430 through the IR LED. The start bits are always transmitted as ones. The control bit toggles whenever a new key is received. The five address bits represent 32 different potential addresses of the equipment for which the packet is intended. The six command bits represent 64 commands that can be transmitted. The bit period for RC5 is 1.78 ms long, with half of that period high and the other half low. The duration for the complete 14-bit packet is approximately 25 ms.
### 4 Clock Selection

Figure 1 shows the timing required for an RC5 packet transmission. During a transmission, the 0.89ms half bit time needs to be counted, and while transmitting a mark a 40 kHz PWM signal must be generated. The MSP430F2xx family features an internal digitally controlled oscillator (DCO) that is stable without an external crystal, allowing faster wake-up times from LPM4 (less than 1 µs) and lower overall system cost.

The CALDCO registers of the MSP430F2xx devices contain DCO calibration data for several operating frequencies. The application described here uses the calibration data corresponding to a 1 MHz DCO operating frequency. CALDCO_1MHZ and CALBC1_1MHZ contain the appropriate values for DCOCTL and BCSCTL1 respectively.

To achieve the 40 kHz PWM output, Timer_A3 is used in Up Mode sourced by the DCO. A value of 24 in CCR0 sets the period to 40 kHz. CCR1 determines the duty cycle. A lower duty cycle will extend battery life, but the duty cycle must be long enough for the LED to adjust to it and the receiver to recognize it. A value of 7 in CCR1 produces a 29% duty cycle.

When a mark is being transmitted Timer_A3 is configured to produce the 40 kHz PWM output as described above and the TACCRO interrupt is enabled. In order to move to the next half bit after 0.89 ms, the number of TACCRO interrupts must be counted. When a space is being transmitted TACCRO is given a value of resulting in an interrupt after 0.89 ms. The number of TACCRO interrupts counted for a mark and the value in TACCRO for a space is dependent on the software overhead in between finishing a mark/space and determining what the next half bit should be. The code supplied uses values to generate 0.89 ms marks and spaces.
5 Demonstration Circuit

The design trade-offs for the application include cost, size, battery life, and transmission distance. The schematic for the MSP430 TV IR remote control is shown in Figure 2. The design uses a low cost CR2032 3V Lithium coin cell battery. Because the application requires short bursts of relatively high current and a Lithium coin cell battery cannot source high levels of current, capacitor C1 is used to source the IR LED. This capacitor is charged through resistor R3 and discharged through resistor R2 when the LED is turned on.

Figure 2. MSP430 TV IR Remote Control Schematic
The choice of values for C1, R2 and R3 is very important. R2 determines how much current will be drawn through the LED, which determines the range of the remote control. R3 determines how fast capacitor C1 is charged. The value must be small enough to charge capacitor C1 in a reasonable amount of time, but large enough to not overstress the battery. Depending on the values of R2 and R3, the capacitor must be large enough to retain most of its charge through a complete data packet.

In this remote control demo application, the MSP430F2xx family eliminates the need for many external components. Because the internal DCO is stable on its own, there is no need for an external crystal. Also, the MSP430F2xx family devices have software-selectable internal pull-up and pull-down port pin resistors, saving board space and cost.

6 Current Consumption Analysis

The CPU is active for less than 1,500 clock cycles each transmission. While running at 1 MHz this takes less than 1.5 ms. During this time the MSP430 consumes approximately 170 μA. The rest of the time during a transmission, approximately 114 ms (including delay to determine if button remains pressed), the MSP430 operates in LPM0 consuming approximately 55 μA. While the MSP430 is waiting for the user to press a button it is consuming only 0.1 μA (LPM4).

7 The Software

The software main loop flow is shown in Figure 3, and the transmission flow is shown in Figure 4. Functionally identical C and assembly source code are available on the MSP430 website

When the MSP430 is started, the initialization routine is run to setup the MSP430 and peripherals appropriately. Then the device enters LPM4. When it receives an interrupt from Port 1.0 or 1.1, the MSP430 wakes up, debounces the button press, and determines which key has been pressed as described in the application report titled Implementing an Ultralow-Power Keypad Interface With the MSP430 (SLAA139).

After the MSP430 determines which button has been pressed, it loads the proper command bits then adds the start, toggle and address bits. The marks and spaces are transmitted as described in the Clock Selection section. While the mark or space is being transmitted, the MSP430 is operating in LPM0.

When all bits have been sent, the Timer A is reconfigured to produce an interrupt in 89 ms. When the interrupt occurs the MSP430 determines whether a button is still being pressed. If it is still pressed, the toggle bit is toggled and the command is transmitted again. If it is no longer pressed, the program returns to the main loop where the MSP430 is placed in LPM4.
Reset

Initialization And Setup

Enter LPM4

S/W Debounce

Scan Keypad

N

Key Pressed?

Y

Determine Which Key is Pressed

Setup For Key Release

Transmit

P1.0, P1.1 Interrupt From Key Press

Clear Flag(s), Clear LPM4 Disable Further P1.x Interrupts

Figure 3. Software Main Loop Flow
8 References
1. Decode TV IR Remote Control Signals Using Timer_A3 (SLAA134)
2. Implementing an Ultralow-Power Keypad Interface With the MSP430 (SLAA139)
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