Decode TV IR Remote Control Signals Using Timer_A3

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ABSTRACT

This application report describes the use of Timer_A3 to decode RC5 and SIRC TV IR remote control signals. The decoder described in this report is interrupt-driven and operates as a background function using specific features the Timer_A3. Only a small portion of the MSP430 CPU’s nonreal-time resources is used. Specific hardware bit-latching capabilities of the Timer_A3 module are used for real-time decoding of the IR data signal, independent and asynchronous to the CPU. CPU activity and power consumption are kept to an absolute minimum level. The Timer_A3 decoder implementation also allows other tasks to occur simultaneously if required. The solutions provided are written specifically for MSP430x11x(1) and MSP430x12x derivatives, but can be adapted to any other MSP430 incorporating Timer_A3.

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Introduction

Adding TV remote-control decoding capability to an MSP430 application is a low-cost method of enabling IR wireless communication. IR decoding capability can be added to an MSP430x11x(1) application using one Timer_A3 capture/compare register, less than 200 bytes of code, and an external sensor. See the demonstration circuit in Figure 1. For demonstration purposes, the decoded IR information packets are transmitted serially to a PC and a LED illuminates on P1.0 if a channel + code is received.

Figure 1. IR Decoder Demonstration Circuit
Both RC5 and SIRC protocols transmit packets of information serially using a 40-kHz modulated IR carrier. A logical 1 indicates the presence of 40-kHz modulated IR, and a 0 indicates its absence. The 40-kHz modulation is used to filter out natural forms of IR present from sources such as sunlight or office florescent lights. While 40 kHz is the most common modulation frequency, some systems use other frequencies in the 32-kHz to 64-kHz range. In order to decode RC5 or SIRC signals, the 40-kHz modulation must first be removed to expose the actual data bits in the serial packet. A simple three-pin VISHAY TSOP1840SS3V 3-V integrated sensor is used in this report to amplify, filter, and demodulate the IR signal, providing a clean logic-level output with only the serial data present. With no 40-kHz IR modulation present, the sensor output is high; when 40-kHz IR is present, the output is low. Thus, the sensor also has the effect of inverting the transmitted data in addition to removing the modulation. The IR-sensor output is connected directly to MSP430x11x(1) input pin P1.2. P1.2 is configured by software as a capture/compare function for Timer_A3 capture/compare register 1 (CCR1) using the port 1 option-select (P1SEL) register. Using the capture/compare features of Timer_A3 enables much easier decoding of the IR data. CCR1 does the IR data receive and transmit bit latching in hardware, independent of CPU and other system activity. The IR decoding is done as a background task using minimum CPU resources. To communicate the received IR data, a UART is implemented using CCR0. The UART transmit function is configured on P1.1.

Clock Selection

Both RC5 and SIRC packet timings are relatively slow (>1 ms/bit) compared to the operation of the MSP430. The demonstration circuit uses a common 32,768-Hz watch crystal as the source for the auxiliary clock (ACLK), which is also selected as the Timer_A3 clock source. With this clock source, Timer_A3 has a resolution of 30.5 µs—more than enough accuracy to resolve either RC5 or SIRC protocols with no bit errors. The on-chip digitally-controlled oscillator (DCO) is used at the default frequency of approximately 1 MHz for the CPU master clock (MCLK). As the 32,768 Hz watch crystal sources the clock for Timer_A3 and IR decoder function, CPU speed is not critical. The CPU only needs to operate sufficiently fast to manage the tasks required. Using the slower ACLK for the IR decoder and the faster DCO for the CPU, both ultralow-power standby and fast-burst code execution are enabled. The MSP430 CPU must not be clocked from the slow watch crystal to eliminate the occurrence of long interrupt latency and higher power consumption. The CPU must be clocked fast, but in short interrupt-driven intervals, to conserve power and allow rapid noncompromised program execution.

Demonstration Circuit

The demonstration circuit is powered directly by a PC serial port with regulation from a 3.3-V TPS76033 low-dropout voltage regulator. One low-power LED is used in the circuit on P1.0 to indicate if a channel + command has been received. A serial port interface on P1.1 is implemented using a TI SN74AHC1G04 inverter. If a fully compliant RS232 interface is required, integrated circuits such as TI's low-power 3-V MAX3221 can be used. Reset is pulled high and a 32,768 Hz watch crystal is used for clock generation. No phase-shift capacitors are required if a watch crystal is used, as these are integrated in the MSP430 clock buffer.
Decoding Software

Two software examples are included. Example 11x1_rc5.s43 decodes the RC5 protocol, and 11x1_sirc.s43 decodes SIRC. The Mainloop of both examples is short and operates identically. Only the background IR decoder software is unique.

Mainloop call #IR_Ready ; Ready IR decoder
    bis.w #LPM3,SR ; Enter LPM3, stop, save power
    call #TXIR_2_PC ; TX received command
    call #LED_Disp ; Test for Channel +
    jmp Mainloop ;

The IR decoder function is enabled in Mainloop by calling the IR_Ready subroutine. Next, software in the Mainloop sets bits in the CPU status register (SR) to put the system into low-power mode 3 (LPM3). In LPM3, the CPU and DCO are off, but Timer_A3 is still counting from the ACLK with CCR1 interrupt logic fully active. Even though the system is in LPM3, the Timer_A3 driven decoder will run interrupt-driven in the background. The architecture of the MSP430 automatically enables the CPU and DCO when any enabled interrupt is requested. The DCO starts and becomes stable in less than 6 \( \mu \)s. Short burst events can be processed efficiently. Additionally, when an enabled interrupt occurs, the system automatically saves the original SR on the stack and clears the SR low-power bits inside of the interrupt service routine. After the interrupt service routine has been processed, the reti (return from interrupt) instruction pops the original SR off the stack. The system returns to the previous state prior to the interrupt service routine—unless the SR on the stack is modified inside of the interrupt service routine.

In this report, after a complete IR packet has been received using the background CCR1 interrupt service routine, software returns the CPU to active in Mainloop by clearing the LPM3 bits from the SR saved on the stack. This is a convenient way of managing the Mainloop with true event-driven programming. The received IR data packet is converted to four ASCII characters and transmitted to a PC using 2400 baud 8N1 UART protocol by calling the TXIR_2_PC subroutine. The four ASCII characters are preceded by a carriage return and line-feed character. The active Mainloop completes by calling the LED_Disp subroutine. The LED_Disp subroutine will set P1.0 to power the LED if the IR data packet is a channel + command. The Mainloop repeats, waiting in LPM3 for the next IR data packet.

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 1 is received by the MSP430 (after inversion by the IR sensor) as a high-to-low transition, and a 0 as a low-to-high 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 2 shows the RC5 packet as received by the MSP430 after demodulation and inversion from the IR sensor. The start bits are always transmitted as 1. 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.
Two CPU registers are used in the 11x1_RC5.s43 example. IRData (R6) receives the RC5 IR packet, and IRBit (R7) is used as a temporary counter to track the IR data bits as they are received. The choice of R6 and R7 is arbitrary—any two CPU registers or RAM bytes can be used. Two variables are defined: Bit_50 is 1/2 of an RC5 1.78-ms bit length in Timer_A3 clocks (same as ACLK), and Bit_75 is 1/4 of a bit length. As a 32,768-Hz watch crystal is used in this report to generate the ACLK, Bit_50 and Bit_75 are as follows:

```
Bit_50   equ     29                      ; 890 µs @ 32768 ACLK
Bit_75   equ     44                      ; 1348 µs @ 32768 ACLK
```

The subroutine IR_Ready enables CCR1 to capture the Timer_A3 counter register (TAR) and request an interrupt on the falling edge of the IR sensor output, as configured on P1.2. TAR is captured on the falling edge and automatically stored in CCR1 and a TA1_ISR interrupt is requested. Inside of the TA1_ISR, software determines if the interrupt was triggered from a capture or compare. As a capture was the source of the first interrupt, BIT_75 (¼ of a bit length) is added directly to CCR1, which stored the exact time the IR sensor output edge fell in the middle of the first bit. Because the stored CCR1 capture occurred in the middle of the first bit, adding ¼ of a bit length will effectively offset CCR1 to the middle of the first half of the next bit. CCR1 is now reconfigured by software to compare mode. The next CCR1 interrupt is now timed for the middle of the first half of the second start bit. As configured, when the CCR1 compare occurs, the logic level present at P1.2 will be latched into the register’s synchronous capture compare input (SCCI) latch. SCCI provides the very important feature of enabling CCR1 hardware to capture and store the logic level on P1.2 with the exact timing generated from Timer_A3, irrespective of other system or CPU activities. In this application, the CPU is actually off while the IR decoder is enabled. Even with the CPU off, the logic level of P1.2 will be captured and stored in SCCI exactly when the CCR1 compare occurs. Software does not directly read P1.2; instead it reads the latched data in SCCI after the event. Software will recover received data from SCCI bit by bit, shifting the data into the storage register IRData.
After each bit has been recovered, CCR1 is reconfigured to capture on both rising and falling edges. The next capture will occur and self-synchronize on the next bit’s midpoint transition. To insure the data packet is decoding properly, the CCR2 interrupt is also enabled and loaded with a value of 1/2 the bit length of the compare stored in CCR1. The next bit transition received should occur in approximately 1/4 of a bit length if the packet is decoding properly. Inside of a normally occurring CCR1_ISR CCR1 edge capture, CCR2 interrupt is cleared by software. If CCR1_ISR does not capture a normally occurring edge and clears the CCR2 interrupt, CCR2_ISR will reset the decoder assuming an overrun error. In normal operation, the balance of the bits are recovered and received into IRData.

SIRC Protocol

The SIRC protocol uses a data packet with an encoding scheme of variable bit length. The length of a bit determines its logical value. The start bit is 2.4 ms of modulated IR, a 600-µs 0, and a 1.2-ms 1. All data bits, excluding the start bit, also include a 600-µs sync pulse, or lack of IR presence. The total length of a received 0, including the sync pulse, is therefore 1200 µs, and the total length of a 1 is 1800 µs. A complete SIRC packet consists of the start bit and 12 data bits. The 12 data bits are comprised of a seven-bit command code (C6 to C0) and a five-bit device code (D4 to D0). The SIRC protocol sends data LSB first. C0 is the first bit received following the start bit.

Figure 3 shows the SIRC data packet as received by the MSP430 after demodulation and inversion from the IR decoder.

Example 11x1_SRC.s43

Three CPU registers are used in the 11x1_SRC.s43 example: IRData (R6) receives the IR data, IRBit (R7) is used to track bits as they are received, and IRlength (R8) is used to store the length of the data bits as they are received. Three variables are defined: IR_Mid is ½ of an SIRC bit length in Timer_A3 clocks, IR_Start is approximately 2.3 ms in Timer_A3 clocks (the minimum length of a valid start bit), and IR_Start2 is approximately 2.5 ms in Timer_A3 clocks (the maximum length of a valid start bit).
IR_Mid equ 49 ; 1500 μs @ 32768 Hz ACLK
IR_Start equ 75 ; 2300 μs @ 32768 Hz ACLK
IR_Start2 equ 82 ; 2500 μs @ 32768 Hz ACLK

The subroutine IR_Ready enables CCR1 to capture on a falling edge from the IR sensor connected to P1.2. The MSP430 system is then placed in LPM3 with only ACLK and Timer_A3 active. On the first falling edge, indicating the beginning of the start bit, a CCR1 capture occurs capturing TAR into CCR1 and requesting interrupt TA1_ISR. The count in TAR is automatically captured and stored in CCR1 by hardware, no software is required. CCR1 is stored by software in IRLength after the capture. After the first falling edge, CCR1 capture edge is switched to a rising edge that will capture at the end of the start bit. The length of a data bit is calculated by subtracting the current TAR capture stored in CCR1 from the previous saved in IRLength. If the start bit length received is not between 2.3 ms and 2.5 ms, the decoder software will reset assuming that an error has occurred. A valid start bit should be approximately 2.4 ms. Inside the TA1_ISR, the IRBit is used to count down the 12 data bits as they are received. Each data bit is calculated by comparing its bit length to IR_Mid. The length of IR_Mid is 1500 μs, which is ½ the difference between a 1 and a 0. A bit length greater than IR_Mid is decoded as a 1, a length less than IR_Mid is decoded as a 0. Hardware capturing of Timer_A3 insures that software interrupt latency does not effect the accuracy of the captured timer value and the calculated bit length. Software does not directly read Timer_A3, but instead, the latched timer value in CCR1. The system stack is also used to temporarily save the current CCR1 value to be subtracted from the previous in IRLength.

```
IR_ST_Test push.w &CCR1 ; Save CCR1 count to stack
sub.w   IRLength,0(SP) ; Time length last capture
IR_Bit cmp.w #IR_Mid,0(SP) ; C=1 if IR RXed bit = 1
IR_Shift rrc.w IRData ; Carry ->IRData
```

With CCR1 hardware capturing the Timer_A3 value exactly when edges occur on P1.2, other real-time activities can occur simultaneously with the IR decoder. The IR decoder software runs interrupt-driven in the background. Data are shifted into IRData bit-by-bit under software control after each bit has been received.

**UART Software**

The UART function is implemented with CCR0 and uses two CPU registers: RXTXData (R4) and BitCnt (R5). A complete description of the UART function is provided in a separate application report, please see the References section of this report.

**PC Monitor**

A standard PC terminal program can be used to receive the serial data packets transmitted from the demonstration circuit. The 16-bit IRData are right justified and sent as four ASCII characters. The terminal program must be set at 2400 baud 8N1.

**References**

1. *MSP430x11x1 Mixed Signal Microcontroller* datasheet, Texas Instruments literature number SLAS241
2. *MSP430x1xx Family Users Guide*, Texas Instruments literature number SLAU049
3. *Implementing a UART Function with Timer_A3*, Texas Instruments literature number SLAA078
4. *Photo Module for PCM Remote Control System*, VISHAY literature number 82052
Appendix A  11x1_SIRC.s43.txt

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#include "msp430x11x1.h"

******************************************************************************
* MSP-FET430X110 Demo - Decode SIRC IR Remote Control / TX to PC @ 2400 *
******************************************************************************

Description: Decode 12-bit SIRC format IR packet using Timer_A.
Timer_A CCR1 is used to decode IR packet, capture mode to measure IR bit
length. Received packet is TXed to PC using Timer_A CCR0 as a UART
function. Packet sent as four ASCII bytes, preceded by a CR and LF
character. P1.0 is set if channel+ is RXed, reset if not. IR data are
received LSB first. Start, 12-bits of data.
D4-D3-D2-D1-C6-C5-C4-C3-C2-C1-C0-Start

Demonstrate with IR monitor - TX IRData as CR, LF, 4 ASCII Bytes

MSP430F1121
-------------
/|\ | XIN|--
| | 32kHz
--|RST XOUT|--
| |
IR Receiver->|P1.2/CCR1 |P1.0|-- LED0
| P1.1|-- 2400 8N1
|

Bit pattern as seen at MSP430
Start = 2.4ms low ~ 79 @ 32kHz ACLK
1 = 1.2ms low
2 = 0.6ms low
sync = 0.6ms high
; sync sync sync sync
;    ---+    +++    +++    +++    +++++    +++++
;          |      |      |      |      |      |
; +---\---+    ---+    ------+    ---+    +-------+
;     ^ 0  ^ 1     ^ 0  ^ Start ^
;
; CPU registers used
#define RXTXData R4
#define BitCnt R5
#define IRData R6
#define IRBit R7
#define IRlength R8
;
; Conditions for 2400 Baud SW UART, ACLK = 32768
Bitime_5 equ 06 ; .5 bit length + small adj.
Bitime equ 014 ; 427us bit length ~ 2341 baud
;
IR_Mid equ 49 ; 1500us @ 32768Hz ACLK
IR_Start equ 75 ; 2300us @ 32768Hz ACLK
IR_Start2 equ 82 ; 2500us @ 32768Hz ACLK
;
LED0 equ 001h ; LED0 on P1.0
TXD equ 002h ; TXD on P1.1
IRIN equ 004h ; IR input on P1.2
Ch_up equ 16 ;
Ch_dwn equ 17 ;
LF equ 0ah ; ASCII Line Feed
CR equ 0dh ; ASCII Carriage Return
;
; M. Buccini
; Texas Instruments, Inc
; July 2001
;*****************************************************************************
;---------------------------------------------------------------
ORG 0F000h ; Program Start
;---------------------------------------------------------------
RESET  mov.w #0300h,SP ; Initialize ’x12x stackpointer
call #Init_Sys ; Initialize System Peripherals
Mainloop  call  #IR_Ready  ; Ready IR decoder
    bis.w  #LPM0,SR  ; Enter LPMx, stop, save power
call  #TXIR_2_PC  ; TX received command
call  #LED_Disp  ; Test for Channel +/-
jmp  Mainloop
;
;
;----------------------------------------------------------
Init_Sys;  Initialize System Peripherals
;
;
;----------------------------------------------------------
StopWDT  mov.w  #WDTPW+WDTHOLD,&WDTCTL  ; Stop Watchdog Timer
SetupTA  mov.w  #TASSEL0+MC1,&TACTL     ; ACLK, continuous
SetupC0  mov.w  #OUT,&CCTL0             ; TXD Idle as Mark
SetupP1  bis.b  #IRIN+TXD,&P1SEL        ; P1.2 CCR1, P1.1 CCR0
        bis.b  #LED0+TXD,&P1DIR        ; P1.0, TXD outputs
        bic.b  #LED0,&P1OUT            ; P1.0, low, LED off
eint
    ret  ; Return from subroutine
;
;
;----------------------------------------------------------
IR_Ready;  Subroutine prepares to receive 12-bit SIRC into IRData buffer
;
;
;----------------------------------------------------------
clr.w  IRData
    clr.w  IRlength
mov.b  #14,IRBit  ; Two start edges and 12 data bits
SetupC1  mov.w  #CM1+SCS+CAP+CCIE,&CCTL1    ; CAP CCI1A, falling edge, int
    ret  ; Return from subroutine
;
;
;----------------------------------------------------------
TXIR_2_PC;  Subroutine to send CR, LF and IRData as four ASCII bytes to PC
    R15 used as working register and not saved
;
;
;----------------------------------------------------------
mov  #CR,RXTXData  ; CR to UART buffer
call  #TX_Byte    ; CR --> PC/user
mov  #LF,RXTXData  ; LF to UART buffer
call  #TX_Byte    ; CR --> PC/user
;
TX_Word_ASCII;  TX Word from IRData as four ASCII bytes
swpb  IRData  ; IRData = 3412
call  #TX_Byte_ASCII
swpb  IRData  ; IRData = 1234
; TX_Byte_ASCII; TX Byte from IRData in two ASCII bytes
mov.b  IRData,R15              ; transmit ..x. of value
call   #NUM_ASCIR
mov.b  IRData,R15              ; transmit ...x of value
jmp    NUM_ASCIA

NUM_ASCIR  rrc.b  R15                     ; 1. and 3. pass
         rrc.b  R15
         rrc.b  R15
         rrc.b  R15

NUM_ASCIA  and.b  #0fh,R15                ; 2. and 4. pass
         add.b  #030h,R15
         cmp.b  #03ah,R15
         jlo    NUM_End
         add.b  #039,R15

NUM_End    mov.b  R15,RXTXData            ; load transmit buffer, FALL

;------------------------------------------------------------------------------

TX_Byte;    Subroutine to TX Byte from RXTXData Buffer using CCR0 UART
;------------------------------------------------------------------------------

mov.w   &TAR,&CCR0              ; Current state of TA Counter
add.w   #Bitime,&CCR0           ; Some time till first bit
bis.w   #0100h, RXTXData        ; Add mark stop bit to RXTXData
rla.w   RXTXData                ; Add space start bit
mov.w   #10,BitCnt              ; Load Bit Counter, 8 data + SP
mov.w   #OUTMOD0+CCIE,&CCTL0    ; TXD = mark = idle
TX_Wait    tst.w   BitCnt                  ; Wait for TX completion
          jnz     TX_Wait
          ret

;------------------------------------------------------------------------------

TA0_ISR    ; RXTXData Buffer holds UART Data
;------------------------------------------------------------------------------

add.w   #Bitime,&CCR0           ; Time to Next Bit
UART_TX    bic.w   #OUTMOD2,&CCTL0         ; TX Mark
         rra.w   RXTXData                ; LSB is shifted to carry
         jc      TX_Test
         ret

TX_Space    bis.w   #OUTMOD2,&CCTL0         ; TX Space
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TX_Test dec.w BitCnt ; All bits sent (or received)?
  jnz TX_Next ; Next bit?
  bic.w #CCIE,&CCTL0 ; All Bits TX/RX, Disable Int.
TX_Next reti ;

;------------------------------------------------------------------------------------------------------------------
TAX_ISR; Common ISR - CCR1-4 and overflow
;------------------------------------------------------------------------------------------------------------------
  add.w &TAIV,PC ; Add Timer_A offset vector
  reti ; CCR0 - no source
  jmp TA1_ISR ; CCR1
;  jmp TA2_ISR ; CCR2
;  reti ; CCR3 - not used
;  reti ; CCR4 - not used
;TA_over reti ; TA overflow - not used

TA1_ISR mov.w #CM0+SCS+CAP+CCIE,&CCTL1 ; CAP CCI1A,rising edge,int
IR_ST_Test push.w &CCR1 ; Temp save to stack CCR1 count
  sub.w IRlength,0(SP) ; Time length last capture
  cmp.b #14,IRBit ; First falling edge?
  jeq IR_Next ; Jump
;  cmp.w #IR_Start2,0(SP) ; Start bit > 2.5ms
;  jge IR_error ; Jump
;  cmp.w #IR_Start,0(SP) ; Start bit minimum ~ 2.3ms
;  jge IR_Next ; Jump
IR_error incd.w SP ; Clean up stack
  call #IR_Ready ; ERROR - restart RX sequence
  reti ; Return from interrupt

IR_Bit cmp.w #IR_Mid,0(SP) ; C=1 if IR RXed bit = 1
IR_Shift rrc.w IRData ; Carry ->IRData
IR_Next mov.w &CCR1,IRlength ; Save captured edge
  incd.w SP ; Clean up stack
  dec.b IRBit ;
  jnz IR_Cont ; Jump-> not last bit
IR_Comp clr.w &CCTL1 ; Disable CCR1
  rrc.w IRData ; 12-bit IRData right justified
  rrc.w IRData ;

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Decode TV IR Remote Control Signals Using TimerA3

```
rrc.w IRData ;
rrc.w IRData ;
and.w #0FFFh,IRData ; Isolate 12-bit packet
mov.w #GIE,0(SP) ; Decode Byte = Active in Mainloop

IR_Cont    reti ;

;------------------------------------------
LED_Disp; LED0 (P1.0) set if IRData = Channel+ code (16)
;------------------------------------------
and.w #07Fh,IRData ; Isolate 7-bit command code
LED_off    bic.b #01h,&P1OUT ; LED0 off
LED0_tst   cmp.w #Ch_up,IRData ; Test for Channel+ (32)
jne     LED_exit ;
    bis.b #01h,&P1OUT ; LED0 on
LED_exit    ret ; Return from subroutine

;------------------------------------------
; Interrupt Vectors Used
;------------------------------------------
ORG 0FFFEh ; MSP430 RESET Vector
DW RESET ;
ORG 0FF2h ; Timer_A0 Vector
DW TA0_ISR ;
ORG 0FF0h ; Timer_AX Vector
DW TAX_ISR ;
END
```
Appendix B  11x1_RC5.s43.txt

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;
#include "msp430x14x.h"

/****************************************************************************
; MSP-FET430X110 Demo - Decode RC5 IR Remote Control / TX to PC @ 2400
;
; Description: Decode 12-bit bi-phase RC5 format IR packet using Timer_A.
; Timer_A CCR1 is used to decode IR packet, capture mode to detect mid-bit
; edge and compare mode to latch data bit. CCR2 is used for decoder
; over-run detection. Received packet is TXed to PC using Timer_A CCR0 as
; a UART function. Packet sent as four ACII bytes, preceded by a CR and LF
; character. P1.0 is set if channel+ is RXed, reset if not.
; IR data are received MSB first. 2 Start, C and 11-bits of data.
; S1-S2-C-A4-A3-A2-A1-A0-C5-C4-C3-C2-C1-C0
;
; Demonstrate with IR monitor - TX IRData as CR, LF, 4 ASCII Bytes
;
; MSP430F1121
;--------------------
; /|\                   XIN|--
; | |                    | 32kHz
; --|RST                 XOUT|--
; | |                        |
; IR Receiver->|P1.2/CCR1  P1.0|---> LED
; |                     P1.1|---> 2400 8N1
;
; Bit pattern as seen at MSP430
;
; 1.78ms
; ++++ ++++ ++++ ++++ ++++

Decode TV IR Remote Control Signals Using TimerA3
Decode TV IR Remote Control Signals Using TimerA3

; CPU registers used
#define RXTXData R4
#define BitCnt R5
#define IRData R6
#define IRBit R7

; Conditions for 2400 Baud SW UART, ACLK = 32768
Bitime_5 equ 06 ; .5 bit length + small adj.
Bitime equ 014 ; 427us bit length ~ 2341 baud

LED0 equ 001h ; LED0 on P1.0
TXD equ 002h ; TXD on P1.1
IRIN equ 004h ; IR input on P1.2
Bit_50 equ 29 ; 890 us @ 32768 ACLK
Bit_75 equ 44 ; 1348 us @ 32768 ACLK
Ch_up equ 32 ;
Ch_dwn equ 33 ;
LF equ 0ah ; ASCII Line Feed
CR equ 0dh ; ASCII Carriage Return

; M. Buccini
; Texas Instruments, Inc
; July 2001

;*****************************************************************************
; ORG 0F000h ; Program Start
;*****************************************************************************
RESERVED mov.w #0300h,SP ; Initialize 'x112x stackpointer
call #Init_Sys ; Initialize System Peripherals
;
Mainloop call #IR_Ready ; Ready IR decoder
bis.w #LPM3,SR ; Enter LPMx, stop, save power
call #TXIR_2_PC ; TX received command
call #LED_Dispatch ; Test for Channel +/-
jmp Mainloop
;

;
Init_Sys; Initialize System Peripherals

;------------------------------------------------------------------------
StopWDT  mov.w  #WDTPW+WDTHOLD,&WDTCTL  ; Stop Watchdog Timer
SetupTA  mov.w  #TASSSEL0+MC1,&TACTL     ; ACLK, continuous
SetupC0  mov.w  #OUT],&CCTL0             ; TXD Idle as Mark
SetupP1  bis.b  #IRIN+TXD,&P1SEL        ; P1.2 CCR1, P1.1 CCR0
       bis.b  #LED0+TXD,&P1DIR        ; P1.0, TXD outputs
       bic.b  #LED0,&P1OUT            ; P1.0, low, LED off
eint                            
ret                             ; Return from subroutine

;------------------------------------------------------------------------
IR_Ready; Subroutine to prepare to receive 12-bit RC5 into IRData
;------------------------------------------------------------------------
clr.w   IRData                  
mov.w   #014,IRBit              ; 12 data + 1 start + completion
SetupCl mov.w  #CM1+SCS+CAP+CCE,&CCTL1    ; CAP CCR1A, falling edge, int
ret                            

;------------------------------------------------------------------------
TXIR_2_PC;  Subroutine to send CR, LF and IRData as four ASCII bytes to PC
;         R15 used as working register and not saved
;------------------------------------------------------------------------
mov    #CR,RXTXData            ; CR to UART buffer
call   #TX_Byte                ; CR --> PC/user
mov    #LF,RXTXData            ; LF to UART buffer
call   #TX_Byte                ; CR --> PC/user

TX_Word_ASCII; TX Word from IRData as four ASCII bytes
    swpb   IRData                  ; IRData = 3412
    call   #TX_Byte_ASCII          ;
    swpb   IRData                  ; IRData = 1234

TX_BYTE_ASCII; TX Byte from IRData as two ASCII bytes
    mov.b  IRData,R15              ; transmit ..x. of value
    call   #NUM_ASCIR              
    mov.b  IRData,R15              ; transmit ...x of value
    jmp    NUM_ASCIA               

NUM_ASCIR  
  rrc.b R15                     ; 1. and 3. pass
  rrc.b R15
  rrc.b R15
  rrc.b R15

NUM_ASCIA  
  and.b #0fh,R15                ; 2. and 4. pass
  add.b #030h,R15
  cmp.b #03ah,R15
  jlo    NUM_End
  add.b #039,R15

NUM_End   
  mov.b R15,RXTXData            ; load transmit buffer, FALL

TX_Byte;  Subroutine to TX Byte from RXTXData Buffer using CCR0 UART

  mov.w   &TAR,&CCR0              ; Current state of TA Counter
  add.w   #Bitime,&CCR0           ; Some time till first bit
  bis.w   #0100h, RXTXData        ; Add mark stop bit to RXTXData
  rla.w   RXTXData                ; Add space start bit
  mov.w   #10,BitCnt              ; Load Bit Counter, 8 data + SP
  mov.w   #OUTMOD0+CCIE,&CCTL0    ; TXD = mark = idle
  TX_Wait  
  tst.w   BitCnt                  ; Wait for TX completion
  jnz     TX_Wait
  ret

TX_Space   
  bis.w   #OUTMOD2,&CCTL0         ; TX Space

TX_Test    
  dec.w   BitCnt                  ; All bits sent (or received)?
  jnz     TX_Next
  bic.w   #CCIE,&CCTL0            ; All Bits TX/RX, Disable Int.
  TX_Next  
  reti

TAX_ISR;  Common ISR - CCR1-4 and overflow
add.w &TAIV,PC ; Add Timer_A offset vector
reti ; CCR0 - no source
jmp TA1_ISR ; CCR1
jmp TA2_ISR ; CCR2
;
reti ; CCR3
;
reti ; CCR4
;TA_over reti ; Return from overflow ISR
;
TA1_ISR bit.w #CAP,&CCTL1 ;
jc RX_edge ; Jump -> Edge captured
;
RX_Bit dec.w IRBit ;
jz RX_Comp ; Test of end of packet
RX_Cont bit.w #SCCI,&CCTL1 ; Carry = Data bit in SCCI
rlc.w IRData ; Carry -> IRData
mov.w #CM1+CM0+CAP+CCIE+SCS,&CCTL1 ; CAP CC1A, both edges, int
push.w &CCR1 ; Max time till next edge
add.w #Bit_50,0(SP) ;
pop.w &CCR2 ;
mov.w #CCIE,&CCTL2 ; Enable timeout interrupt
reti ;
;
RX_Comp clr.w &CCTL1 ; Disable CCR1
and.w #0FFFh,IRData ; Isolate 12-bit packet
mov.w #GIE,0(SP) ; Decode = Active in Mainloop
reti ;
;
RX_edge clr.w &CCTL2 ; Disable CCR2 timeout
mov.w #CCIE,&CCTL1 ; Compare mode w/ int.
add.w #Bit_75,&CCR1 ; Time to middle of data bit
reti ;
;
TA2_ISR clr.w &CCTL2 ; Disable CCR2 timeout
call #IR_Ready ; ERROR - restart RX sequence
reti ; Return from interrupt
;
------------------------------------------------------------------------------------------------------------------------

LED_Disp; LED0 (P1.0) set if IRData = Channel+ code (32)
------------------------------------------------------------------------------------------------------------------------
and.w  #03Fh,IRData ; Isolate 6-bit command code
LED_off  bic.b  #01h,&P1OUT ; LED0 off
LED0_tst  cmp.w  #Ch_up,IRData ; Test for Channel+ (32)
jne  LED_exit ;
bis.b  #01h,&P1OUT ; LED0 on
LED_exit  ret ; Return from subroutine

;-----------------------------------------------
; Interrupt Vectors Used
;-----------------------------------------------

ORG  0FFFEh ; MSP430 RESET Vector
DW  RESET ;
ORG  0FFF2h ; Timer_A0 Vector
DW  TA0_ISR ;
ORG  0FFF0h ; Timer_AX Vector
DW  TAX_ISR ;
END
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