

# AN1759

## Add a Non-Volatile Clock to the MC68HC705J1A

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### Introduction

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Many embedded systems require the measurement of time. This can be accomplished internally by some MCUs that have on-chip real-time clocks. Even so, for date, month, and leap year measurement, this task can take substantial amounts of bandwidth and code space.

The DS1307 64x8 serial real-time clock provides calendar and time keeping functions along with system-enhancing non-volatile RAM. With a 2-wire interface, timekeeping can be managed easily.

Some applications of using the DS1307 are:

- Logging of chronological events
- Tracking power down time of a system
- Providing alarm functions

The non-volatile RAM (random-access memory) also gives the user additional applications such as:

- Power down information storage for consumer electronics like TVs, VCRs, and hand-held portables
- Identification number storage for remote addressing or security
- Storage of telecommunication information like phone number recall and speed dialing

This application note describes the interface between the MC68HC705J1A (J1A) and the DS1307. Circuitry and example code are given to demonstrate the interface between the two parts.

### Features

The DS1307 provides these features:

- Real-time clock counts seconds, minutes, hours, day of the week, date, month, and year.
- Leap year compensation valid up to 2100
- 56 bytes of non-volatile RAM for data storage
- 2-wire serial interface
- Programmable square wave output with frequencies of 1 Hz, 4.096 kHz, 8.192 kHz, and 32.768 kHz
- Automatic power switching to battery when main power fails
- In battery backup mode, less than 500 nA consumed at 25 °C
- 8-pin DIP or SOIC package
- Optional industrial temperature range of -40 °C to +85 °C

### Description

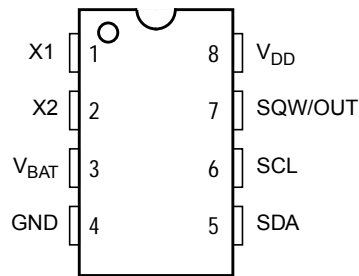
The DS1307 is a low-power binary coded decimal (BCD) clock calendar that provides seconds, minutes, hours, day, date, month, and year. In addition, it has 56 bytes of non-volatile RAM. End-of-the-month adjustments are automatic for months with less than 31 days. The device also corrects for leap years. The clock can operate in either 12-hour or 24-hour mode. In 12-hour mode, an a.m./p.m indicator is used.

The DS1307 has built-in power management circuitry to detect power failures on the  $V_{DD}$  pin and when detected will switch power over to the battery back-up pin,  $V_{BAT}$ . Access to the device is terminated when  $V_{DD}$  falls below  $1.25 \times V_{BAT}$ . Further accesses to the device are not allowed. On power up, the device switches power from  $V_{BAT}$  to  $V_{DD}$  when the  $V_{DD}$  pin is 0.2 volts above  $V_{BAT}$ . Once  $V_{DD}$  is higher than  $1.25 \times V_{BAT}$ , normal operations can continue.

Address and data are communicated via the 2-wire bus. The DS1307 operates as a slave at all times and is accessed by first transmitting the DS1307's identification code on the bus.

## DS1307 Hardware Interface

### Pinout and Pin Descriptions



**Figure 1. DS1307 Pinout**

#### $V_{DD}$ and GND

These pins serve as the main power source for the device. When +5 volts is applied to this pin, the device is fully accessible and data can be read or written. If the power on the  $V_{DD}$  pin falls below  $1.25 \times V_{BAT}$ , the device switches its power supply to  $V_{BAT}$ . At this point, reading and writing to the device is prohibited. The timekeeping function and non-volatile RAM are unaffected.

#### $V_{BAT}$

This pin is the power input for any standard 3-volt lithium battery or other 3-volt source. For proper operation, this voltage must be held between 2.5 and 3.5 volts. A lithium battery with at least a 35-mA hours rating will back up the DS1307 for more than 10 years in the absence of power.

*X1 and X2*

These pins are used to connect a 32.768-kHz crystal to the device. No other capacitors or resistors are needed for this crystal circuit. The internal oscillator circuitry is designed for a crystal with load capacitance of 12.5 pF. For the test circuit described in this application note, an Epson C-001R crystal was used. The Digi-key part number for this device is SE3201-ND.

*SQW/OUT*

When enabled, this pin outputs one of four selectable frequencies:

- 1 Hz
- 4.096 kHz
- 8.192 kHz
- 32.768 kHz

The 1-Hz signal can be used to feed an external interrupt pin on an MCU. This allows the MCU to use minimal bandwidth when servicing the timekeeping function of a system.

When disabled, the pin acts as a normal output pin. It is controlled via the DS1307 control register.

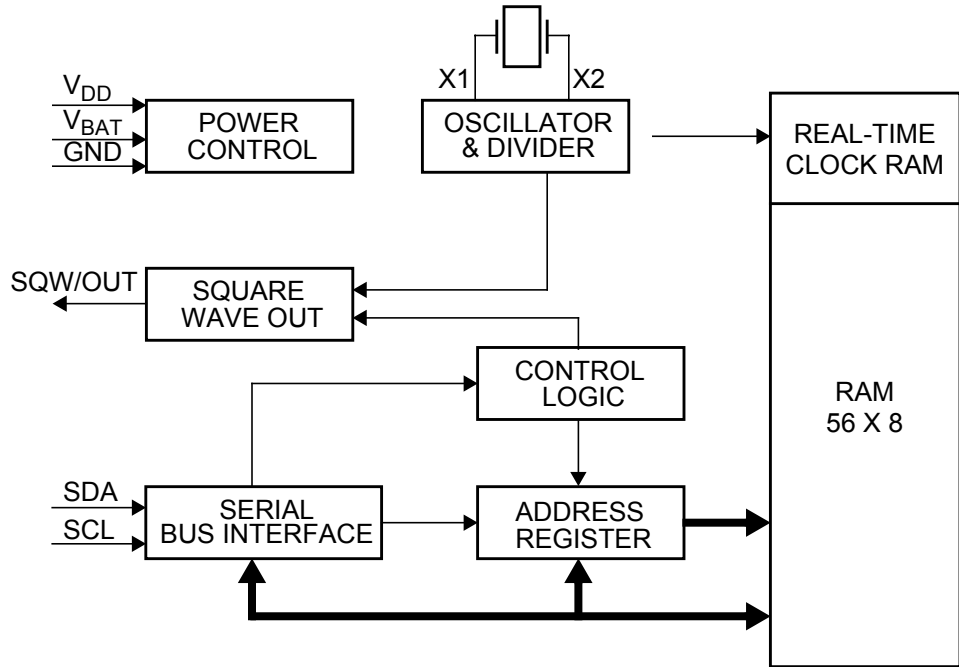
*SCL*

The SCL pin is the clock input for the DS1307 2-wire serial interface.

*SDA*

The SDA pin is an I/O pin used to transmit and receive data off the 2-wire serial interface. SDA is an open-drain pin that requires an external pullup resistor.

**Block Diagram**



**Figure 2. DS1307 Block Diagram**

**Serial Interface**

The DS1307 supports the bidirectional, 2-wire protocol. The protocol has these characteristics:

- Any device sending out data is defined as a transmitter.
- Any device receiving data is defined as a receiver.
- The device controlling the transfer is called the master.
- The device being controlled is called the slave.
- The master initiates all transactions.
- The master always provides the clock for both transmit and receive operations.
- The DS1307 is always considered the slave.
- The clock signal is called SCL.
- The data signal is called SDA.
- All data is sent most significant bit (MSB) first.

**Figure 3** shows the 2-wire bus interface between a master and slave.

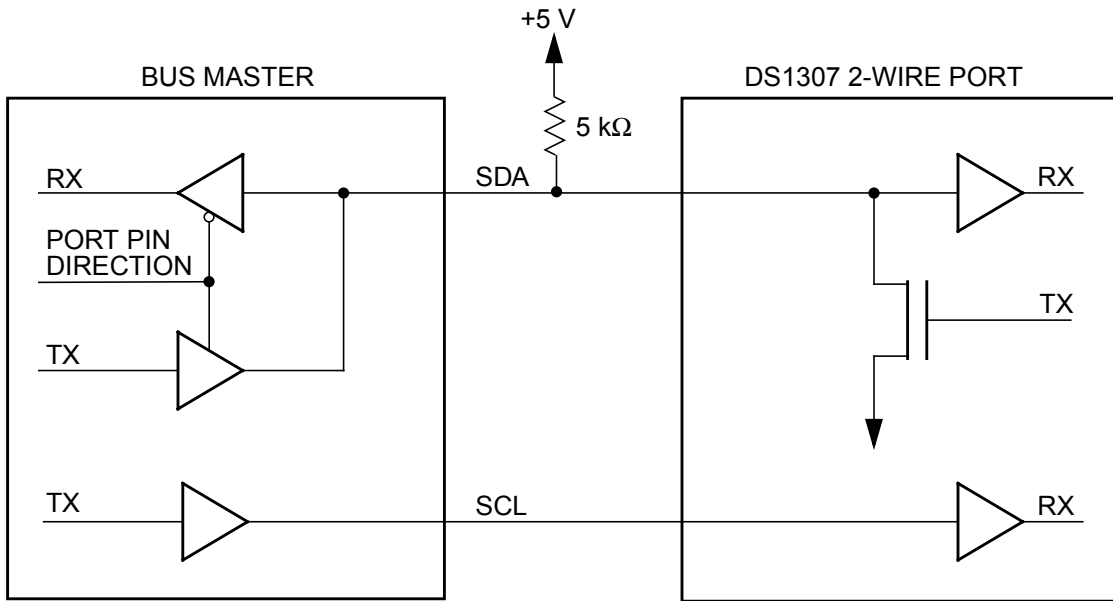


Figure 3. 2-Wire Serial Bus Interface

*Bus Idle*

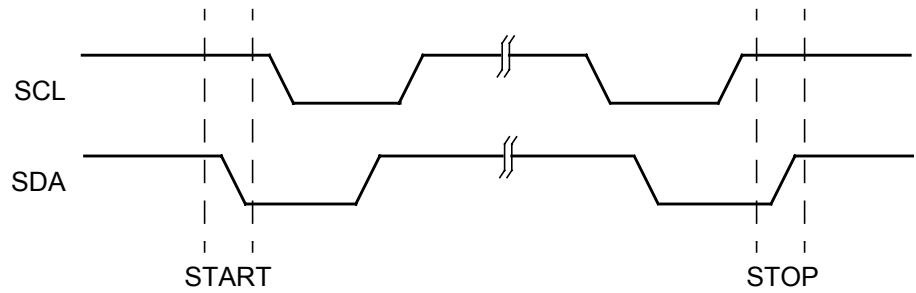
In idle mode, both the SDA and SCL are held high.

*Start Transfer*

All transfers begin with the start transfer condition. This is done by bringing the SDA pin from HIGH to LOW while the SCL pin is HIGH. The DS1307 is monitoring the bus for this signal and will not start any transactions until this condition is met. See [Figure 4](#).

*Stop Transfer*

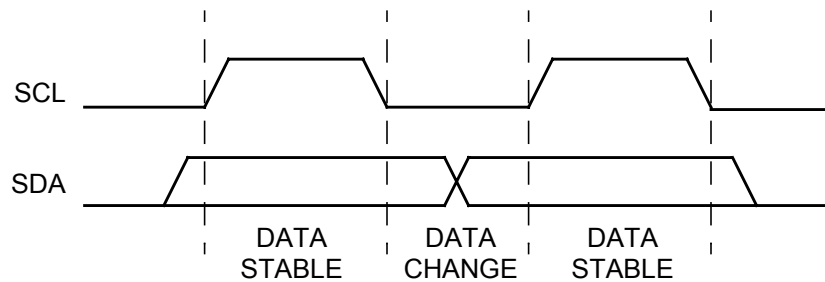
All transfers must be terminated with the stop transfer condition. This is done by bringing the SDA pin from LOW to HIGH while the SCL pin is HIGH. A stop transfer can be used only after the transmitting device releases the bus. See [Figure 4](#).



**Figure 4. Start and Stop Transfer Timing**

*Data Transfer*

Data is transmitted on the rising edge of SCL. Data can only be changed while SCL is LOW. The receiving device samples the bus after SCL goes HIGH. There is one clock pulse per bit of data transmitted. See [Figure 5](#).



**Figure 5. Data Transfer Timing**

*Acknowledge Transfer*

The acknowledge transfer is a type of handshaking convention used to signify that a successful transfer of data has taken place. After the transmitting device sends out the eighth bit of a byte of data, it releases the bus. The master sends out a ninth clock signal and the receiver acknowledges the transfer by pulling SDA LOW. Once the transmitter reads the LOW condition of SDA, it proceeds by taking over the bus and sending out the next byte of data.

If the DS1307 is transmitting data and the master wants to end further transmissions, the master sends a NO ACK signal (HIGH) back to the DS1307. This tells the DS1307 that no more transfers are needed and the stop transfer condition will be initiated soon. See [Figure 6](#) for these different timing patterns.

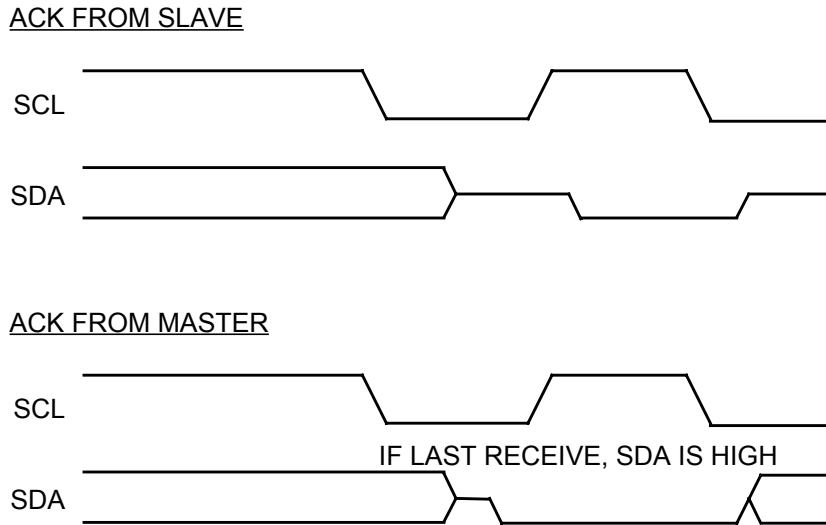


Figure 6. Acknowledge Timing

2-Wire Protocol Example

An example of the protocol needed to write \$10 to address \$07 of the DS1307 is:

1. The master transmits a start transfer.
2. The master transmits the DS1307 7-bit identification code, %1101000.
3. Since this is a data write transfer, the master then transmits a 0.
4. Since a byte has just been transmitted, the receiver (DS1307) will now send out a LOW to acknowledge the transfer.
5. The master reads the SDA pin for a LOW.
6. The master sends out the address of \$07 to the DS1307 and receives back an acknowledge.
7. The master sends out the data, \$10, to the DS1307 and receives back an acknowledge. The DS1307 writes \$10 to address \$07.
8. Finally, a stop transfer is sent to the DS1307 to complete the transaction.





10 hours when in 24-hour mode. When using 12-hour mode, bit 5 is a 1 for p.m. and a 0 for a.m.

	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
\$00	CLOCK HALT	10 SECONDS			SECONDS			
\$01	X	10 MINUTES			MINUTES			
\$02	X	12	A/P	10 HR	HOURS			
		24	10 HR					
\$03	X	X	X	X	X	DAY		
\$04	X	X	10 DATE		DATE			
\$05	X	X	10 MONTH		MONTH			
\$06	10 YEAR				YEAR			
\$07	OUT	X	X	SQWE	X	X	RS1	RS0

Figure 8. DS1307 Register Map

*Control Register*

The control register is used to control the SQW/OUT pin.

OUT — Controls the output level of the SQW/OUT pin when SQWE = 0.

1 = SQW/OUT pin HIGH

0 = SQW/OUT pin LOW

SQWE — Enables the oscillator square wave on the SQW/OUT pin

1 = Square wave enabled

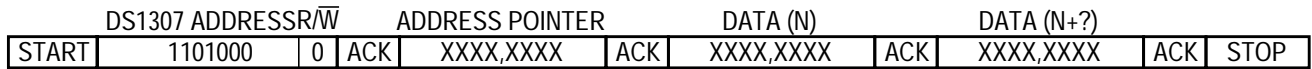
0 = Square wave disabled

RS — Square wave output frequency

- RS1 = 0 and RS0 = 0 → 1 Hz
- RS1 = 0 and RS1 = 1 → 4.096 kHz
- RS1 = 1 and RS1 = 0 → 8.192 kHz
- RS1 = 1 and RS1 = 1 → 32.768 kHz

Data Write Sequence

The first byte transmitted in a write to the DS1307 is its 7-bit identification code followed by the  $R/\overline{W}$  bit. For writes, this bit will be 0. The next byte transmitted is the DS1307 address pointer. After this, bytes of data to be written to the DS1307 RAM are transmitted. After each byte of data is written, the address pointer is incremented. See **Figure 9**.

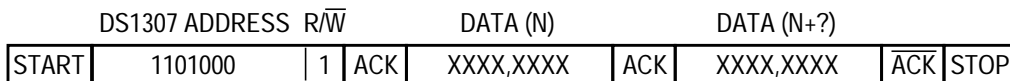


**Figure 9. Data Write Sequence**

Data Read Sequence

The first byte transmitted in a read from the DS1307 is its 7-bit identification code followed by the  $R/\overline{W}$  bit. For reads, this bit will be 1. Then the DS1307 will begin transmitting data back to the master. As long as the DS1307 receives clocks and acknowledgments, it keeps transmitting data. The starting address is the previous address pointer from the last write transaction. If needed, a write sequence with only an address can be used to initialize the address pointer for reads.

**NOTE:** Remember that for the last byte read, the master sends back a No ACK to the DS1307.



**Figure 10. Data Read Sequence**

MC68HC705J1A Hardware Interface

With only 20 pins, the J1A is one of the smallest members of the HC05 Family. It has a total of 1240 bytes of erasable programmable read-only memory (EPROM) and includes 14 I/O (input/output) pins. The schematic used for testing the J1A to DS1307 interface on the MMEVS development system is shown in **Figure 11**. The pins used to drive the DS1307 on the J1A are listed here also.

- Port A, bit 0 — This I/O pin (SCL) is configured as an output to drive the serial clock pin, SCL, of the DS1307.
- Port A, bit 1 — This I/O pin (SDA) is used to transmit and receive data on the SDA pin of the DS1307.

For further information on the HC705J1A, consult the *MC68HC705J1A Technical Databook* (MC68HC705J1A/D).

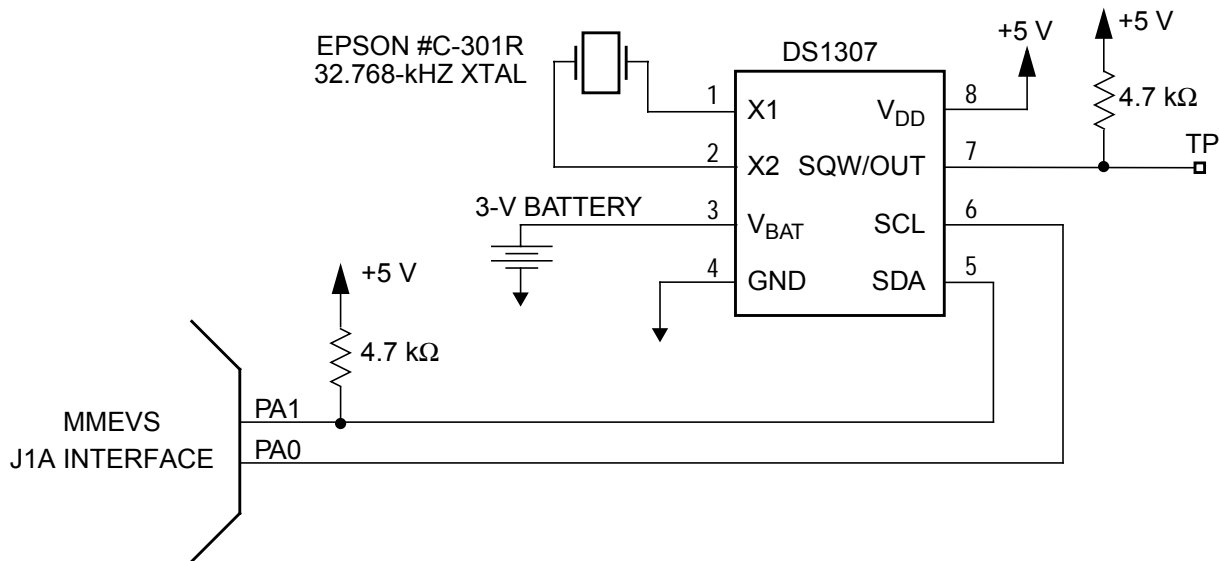


Figure 11. J1A-to DS1307 Interface Test Circuit

## MC68HC705J1A Software Interface

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I/O driving or manipulation is the process of toggling I/O pins with software instructions to create a certain hardware peripheral. The HC05 CPU provides special instructions specifically to manipulate single I/O pins.

Five subroutines were created to provide an easy application programming interface (API). These routines are:

- **START\_SER** — Sends out a start condition on the bus
- **STOP\_SER** — Sends out a stop condition on the bus
- **TXD** — The master takes the contents of AccA and transmits it MSB first to the DS1307. The master also checks for acknowledgement from the DS1307.
- **RXD** — After the master addresses the DS1307 with its identification code and the read bit, the DS1307 transmits a byte of data back to the master. This routine reads that byte and puts it into AccA. The master also generates an acknowledgment back to the DS1307.
- **RXD\_LAST** — This routine is just like RXD but it is used for the last byte read from the DS1307. It does not generate an acknowledgment back to the DS1307.

The flowcharts for the DS1620 serial I/O drivers are shown in [Flowcharts for the Test Interface](#). These routines were written especially for the DS1307 and may not be able to properly drive other MCU peripherals with 2-wire serial buses.

A typical application would use the SQW/OUT pin on the DS1307. When configuring this pin for a 1-Hz signal, feed the signal to the  $\overline{\text{IRQ}}$  pin of an MCU. An interrupt routine can be created to read the contents of the DS1307 every time a 1-Hz signal hits the  $\overline{\text{IRQ}}$  pin. This should take minimal CPU bandwidth and provide the user an easy way to retrieve time and date information.

The main test routine was written to verify the bus interface between the DS1307 and the J1A. It writes a known date and time into the DS1307

and then reads it back out. The data read is put into a RAM buffer on the HC05. When the emulator is stopped, read the contents of the HC05 RAM buffer to verify the transmission process.

The test routine sequence is shown in **Figure 15**. The assembly code for the test routine is provided in the section titled **Code Listing**.

The sequence of tests is:

1. Configure the device to turn on a 1-Hz signal on the SQW/OUT pin.
  - a. Transmit a start condition.
  - b. Transmit the DS1307 code to write to the device of %11010000.
  - c. Transmit the control register address and then \$10.
  - d. Transmit a stop condition.
2. Write start time.
  - a. Transmit a start condition.
  - b. Transmit the DS1307 code to write to the device of %11010000.
  - c. Transmit the starting address of \$00, the seconds register.
  - d. Transmit Saturday, June 20, 1998, 4:30:00 p.m. (By writing a 0 to bit 7 of the seconds register, the crystal circuit has been turned on.)
  - e. Transmit a stop condition.
3. Read time and date, store away to HC05 RAM buffer.
  - a. Transmit a start condition.
  - b. Transmit the DS1307 code to write to the device of %11010000.
  - c. Transmit the starting address of \$00.
  - d. Transmit a stop condition.
  - e. Transmit a start condition.

- f. Transmit the DS1307 code to read from the device of %11010001.
- g. Read the date and time and store away to HC05 RAM.
- h. Transmit a stop condition.

Since the real-time clock is running, you can restart the code at step 3 and verify that it is keeping time.

This routine demonstrates the interface software needed to communicate with the DS1307. Although the J1A was used, any HC05 device could utilize this interface code. Minor adjustments of port pins and memory maps might be necessary.

## Development Tools

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The interface was created and tested using these development tools:

- M68MMPFB0508 — Freescale MMEVS platform board
- X68EM05J1A — Freescale J1A emulation module
- Win IDE Version 1.02 — Editor, assembler, and debugger by P&E Microcomputer Systems

Flowcharts for the Test Interface

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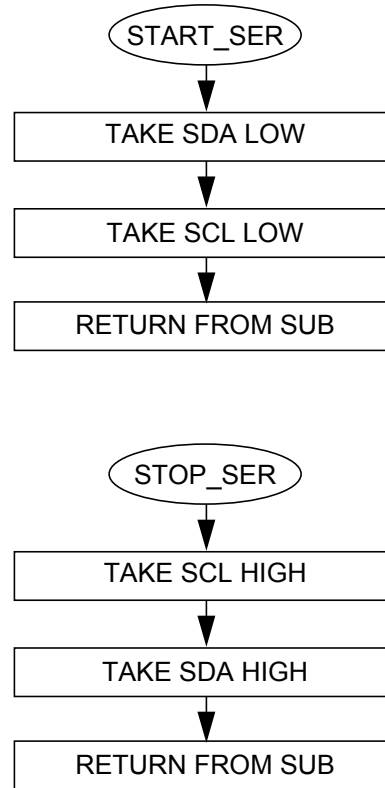


Figure 12. START\_SER and STOP\_SER Subroutines



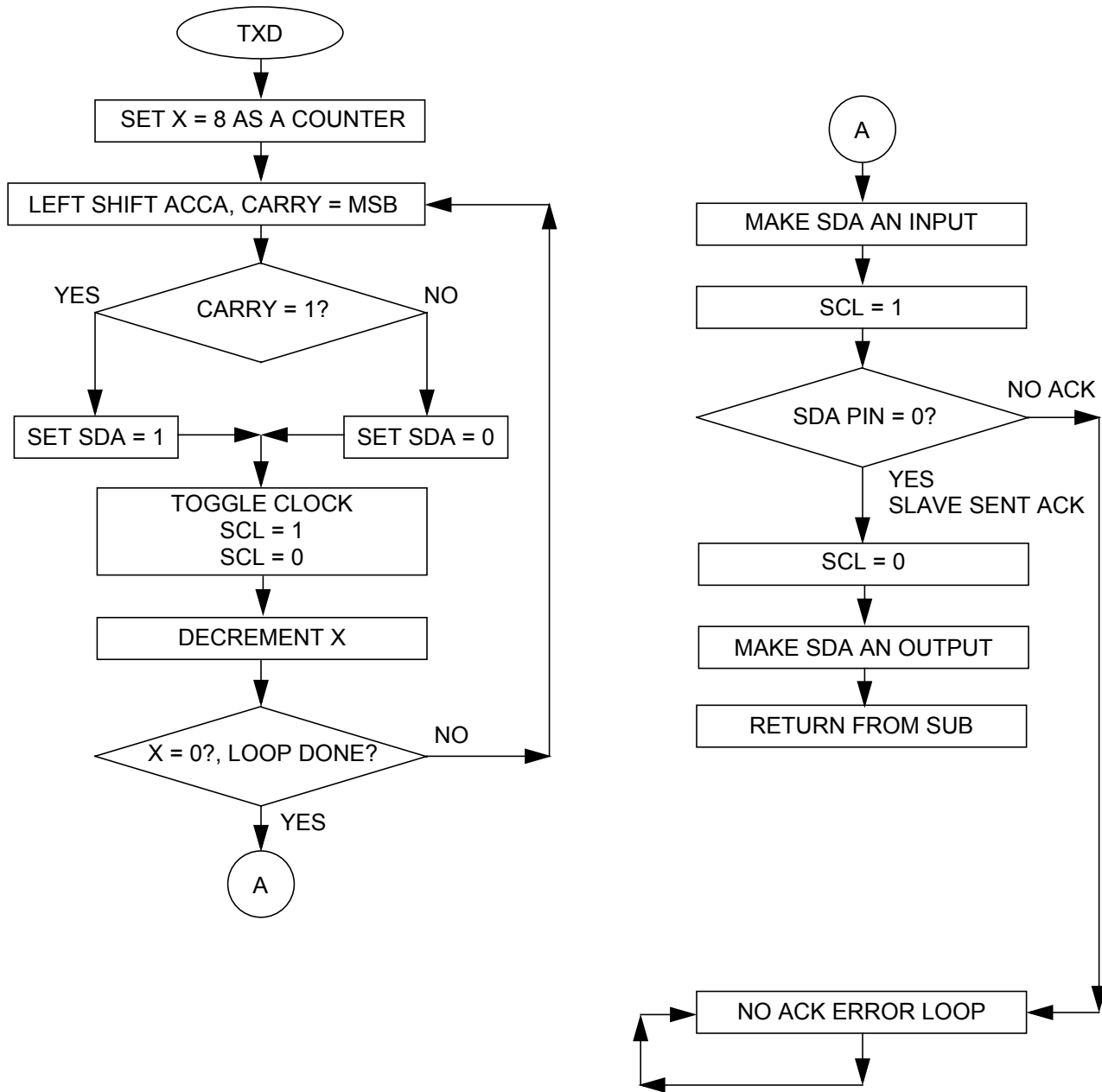


Figure 13. TXD Subroutine

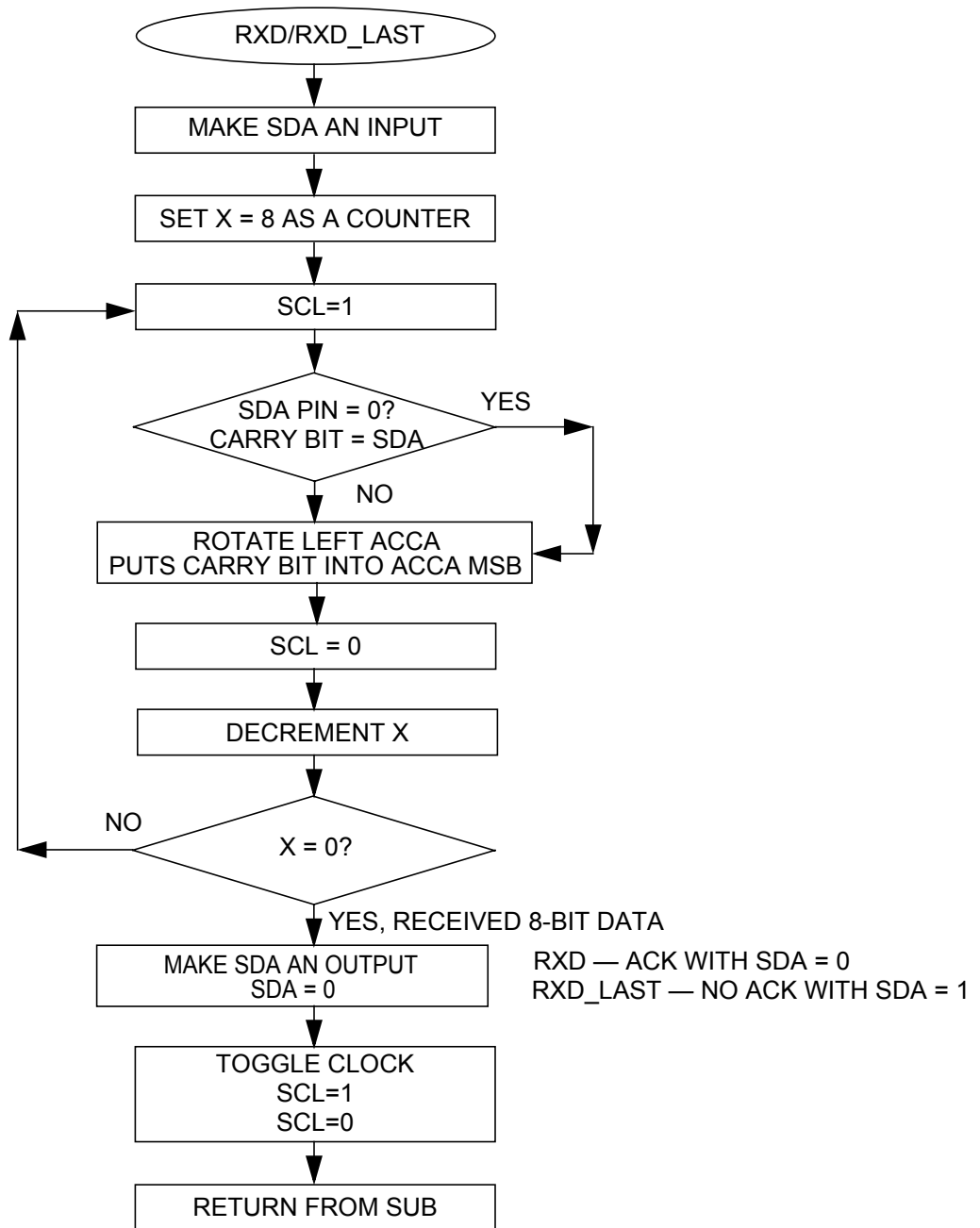
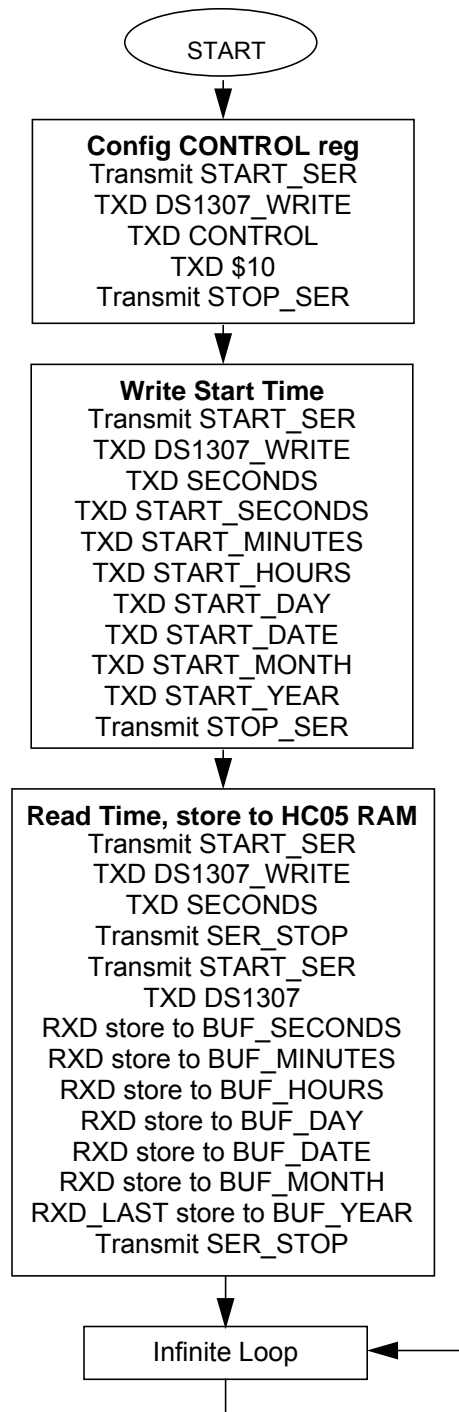


Figure 14. RXD/RXD\_LAST Subroutines



**Figure 15. Flowchart for Main Test Routine**

Code Listing

```

*****
*
* File name: DS1307.ASM
* Example Code for the MC68HC705J1A Interface to the
*   Dallas DS1307 Serial Real Time Clock
* Ver: 1.0
* Date: June 1, 1998
* Author: Mark Glenewinkel
*   Freescale Field Applications
*   Consumer Systems Group
* Assembler: P&E IDE ver 1.02
*
* For code explanation and flow charts, please consult Freescale Application Note
*   "Add a Non-volatile Clock to the MC68HC705J1A" Literature # AN1759/D
*
*****

*** SYSTEM DEFINITIONS AND EQUATES *****
*** Internal Register Definitions
PORTA      EQU    $00          ;PortA
DDRA       EQU    $04          ;data direction for PortA

*** Application Specific Definitions
SER_PORT   EQU    $00          ;PORTA is SER_PORT
SCL        EQU    0T          ;PORTA, bit 0, clock signal
SDA        EQU    1T          ;PORTA, bit 1, data signal

DS1307_WRITE EQU    $D0          ;addresses the DS1307 for write
DS1307_READ  EQU    $D1          ;addresses the DS1307 for read
SECONDS      EQU    $00          ;DS1307 address for seconds
MINUTES      EQU    $01          ;DS1307 address for minutes
HOURS        EQU    $02          ;DS1307 address for hours
DAY          EQU    $03          ;DS1307 address for the day
DATE         EQU    $04          ;DS1307 address for the date
MONTH        EQU    $05          ;DS1307 address for the month
YEAR         EQU    $06          ;DS1307 address for the year
CONTROL      EQU    $07          ;DS1307 address for control

*** Memory Definitions
EPROM       EQU    $300          ;start of EPROM mem
RAM         EQU    $C0           ;start of RAM mem
RESET       EQU    $7FE          ;vector for reset

*** Time Start Definitions for test
*** Start on Saturday, June 20th, 1998, 4:30:00 PM
START_SECONDS EQU    $00          ;0 seconds
START_MINUTES EQU    $30          ;30 minutes
START_HOURS   EQU    $64          ;4 hours, PM, 12 Hour mode
START_DAY     EQU    $06          ;Saturday
START_DATE    EQU    $20          ;20th
START_MONTH   EQU    $06          ;June
START_YEAR    EQU    $98          ;1998

```

```

*** RAM VARIABLES *****
* Buffer for test reading data from the DS1307
      ORG      RAM
BUF_SECONDS  DB      1          ;buffer on HC05 for seconds
BUF_MINUTES  DB      1          ;buffer on HC05 for hours
BUF_DAY      DB      1          ;buffer on HC05 for the day
BUF_DATE     DB      1          ;buffer on HC05 for the date
BUF_MONTH    DB      1          ;buffer on HC05 for the month
BUF_YEAR     DB      1          ;buffer on HC05 for the year

*** MAIN ROUTINE *****
      ORG      EPROM          ;start at begining of EPROM
*** Intialize Ports
START     lda    #$03          ;init SER_PORT
          sta    SER_PORT
          lda    #$03          ;make SER_PORT pins outputs
          sta    DDRA

*** DS1307 configuration
*** Turn on osc, turn on SQW/OUT pin with 1 Hz signal
          jsr    START_SER      ;start serial transmission

          lda    #DS1307_WRITE  ;address the DS1307 device, write
          jsr    TXD
          lda    #CONTROL       ;send address of control reg
          jsr    TXD
          lda    #$10           ;send config data
          jsr    TXD

          jsr    STOP_SER       ;stop serial transmission

*** Write Starting Time to DS1307
          jsr    START_SER      ;start serial transmission

          lda    #DS1307_WRITE  ;address the DS1307 device, write
          jsr    TXD
          lda    #SECONDS       ;start address of DS1307
          jsr    TXD
          lda    #START_SECONDS ;write seconds
          jsr    TXD
          lda    #START_MINUTES ;write minutes
          jsr    TXD
          lda    #START_HOURS   ;write hours
          jsr    TXD
          lda    #START_DAY     ;write day
          jsr    TXD
          lda    #START_DATE    ;write date
          jsr    TXD
          lda    #START_MONTH   ;write month
          jsr    TXD
          lda    #START_YEAR    ;write year
          jsr    TXD

          jsr    STOP_SER       ;stop serial transmission

```

Application Note

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*** Read Time, store away in HC05 time buffer for verification
* Write starting address
    jsr    START_SER                ;start serial transmission

    lda    #DS1307_WRITE            ;address the DS1307 device, write
    jsr    TXD
    lda    #SECONDS                 ;start address of DS1307 read
    jsr    TXD

    jsr    STOP_SER                 ;stop serial transmission

* Read Time data put in HC05 buffer
    jsr    START_SER                ;start serial transmission

    lda    #DS1307_READ            ;address the DS1307 device, read
    jsr    TXD
    jsr    RXD
    sta    BUF_SECOND               ;read seconds, store to buffer
    jsr    RXD
    sta    BUF_MINUTES              ;read minutes, store to buffer
    jsr    RXD
    sta    BUF_HOURS                ;read hours, store to buffer
    jsr    RXD
    sta    BUF_DAY                  ;read the day, store to buffer
    jsr    RXD
    sta    BUF_DATE                 ;read the date, store to buffer
    jsr    RXD
    sta    BUF_MONTH                ;read the month, store to buffer
    jsr    RXD_LAST
    sta    BUF_YEAR                 ;read the year, store to buffer

    jsr    STOP_SER                ;stop serial transmission

DUMMY    bra    DUMMY               ;test sequence is over

*** SUBROUTINES *****
*** Sends out Start command on bus
START_SER bclr    SDA,SER_PORT      ;SDA=0
          bclr    SCL,SER_PORT      ;SCL=0
          rts

*** Sends out Stop command on bus
STOP_SER  bset    SCL,SER_PORT      ;SCL=1
          bset    SDA,SER_PORT      ;SDA=1
          rts

*** Routine takes contents of AccA and transmits it serially to
*** the DS1307, MSB first
*** Looks for ACK, goes to ERROR routine if no ACK
TXD       ldx    #8T                ;set counter

WRITE     asla                    ;Carry bit = MSB
          bcc    J1
          bset   SDA,SER_PORT        ;SDA=1
          bra   CLOCK_IT             ;branch to clock_it
J1        bclr   SDA,SER_PORT        ;SDA=0
          brn   J1                   ;evens it out

```

```

CLOCK_IT      bset   SCL,SER_PORT      ;SCL=1
               bclr   SCL,SER_PORT      ;SCL=0
               decx   ;decrement counter
               bne    WRITE
* Check for ACK
               bclr   SDA,DDRA           ;SDA is input
               bset   SCL,SER_PORT      ;SCL=1
               brclr  SDA,SER_PORT,J2    ;if SDA=0, slave ACK

ACK_ERROR     bra    ACK_ERROR           ;no slave ACK, error loop

J2            bclr   SCL,SER_PORT      ;SCL=0
               bset   SDA,DDRA           ;SDA is output
               rts    ;return from sub

*** Routine clocks the DS1307 to read data from SDA, MSB first
*** 8 bit contents are put in AccA
*** Generates ACK back to slave
RXD           bclr   SDA,DDRA           ;make the SDA pin on J1A input
               ldx    #8T               ;set counter

READ          bset   SCL,SER_PORT      ;SCL=1
               brclr  SDA,SER_PORT,J3    ;carry bit = SDA
J3            rola   ;put carry bit into AccA MSB
               bclr   SCL,SER_PORT      ;SCL=0

               decx   ;decrement counter
               bne    READ
* ACK back to slave
               bset   SDA,DDRA           ;make the SDA pin on J1A output
               bclr   SDA,SER_PORT      ;SDA=0
               bset   SCL,SER_PORT      ;SCL=1
               bclr   SCL,SER_PORT      ;SCL=0
               rts    ;return from sub

*** Routine clocks the DS1307 to read data from SDA, MSB first
*** 8 bit contents are put in AccA
*** Generates NO ACK back to slave, signals last read to DS1307
RXD_LAST     bclr   SDA,DDRA           ;make the SDA pin on J1A input
               ldx    #8T               ;set counter

READ_LAST    bset   SCL,SER_PORT      ;SCL=1
               brclr  SDA,SER_PORT,J4    ;carry bit = SDA
J4            rola   ;put carry bit into AccA MSB
               bclr   SCL,SER_PORT      ;SCL=0

               decx   ;decrement counter
               bne    READ_LAST
* NO ACK back to slave
               bset   SDA,DDRA           ;make the SDA pin on J1A output
               bset   SDA,SER_PORT      ;SDA=1
               bset   SCL,SER_PORT      ;SCL=1
               bclr   SCL,SER_PORT      ;SCL=0
               rts    ;return from sub

*** VECTOR TABLE *****
               ORG    RESET
               DW     START
    
```

### References

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*MC68HC705J1A Technical Data*, Freescale document order number MC68HC705J1A/D, 1996.

*M68HC05 Applications Guide*, Freescale document order number M68HC05AG/AD, 1996.

*DS1307 Datasheet*, Dallas Semiconductor, 1997.

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