Lecture 27

March 28, 2012

Lab on MC9S12 IIC Interface and the DS1307 Real Time Clock

Asynchronous Serial Data Transfer

Dallas Semiconductor DS1307 Real Time Clock

- The DS 1307 is a real-time clock with 56 bytes of NV (non-volatile) RAM
- It uses the IIC bus, with address 1101000_2
- It stores date and time
  - Data are stored in BCD format
- It uses a 32.768 kHz crystal to keep time
- It can generate a square wave output
  - Frequency of square wave can be 1 Hz, 4.096 kHz, 8.192 kHz or 32.768 kHz
- It uses a battery to hold the date and time when your board is not powered

Using the Dallas Semiconductor DS1307 Real Time Clock

- Set up the IIC bus
  - Find the SCL frequency, SDA hold time, Start and Stop hold times
  - Determine the value to write to `IBFD` to meet those times
- To set the time,
  - Send the Start condition
  - Write address of clock (with $R/\overline{W}$ low)
  - Write a 0 (to select seconds register),
  - Write second, minute, hour, day of week, day of month, month, year, control
    - Control determines whether or not to enable square wave, and selects frequency
  - Send the Stop condition
- To read the clock,
  - Send the Start condition
  - Write the address of the clock (with $R/\overline{W}$ low), then write a 0 (to select seconds register).
  - Send the Stop condition
  - Send the Start condition
  - Write the address of the clock (with $R/\overline{W}$ high)
  - Read the time registers.
  - Send the Stop condition
- If you want to store some data which will remain between power cycles, you can write it to the 56 bytes of NV RAM

Lab on IIC Bus

- Next week's lab
  1. Communicate with Dallas Semiconductor DS 1307 Real Time Clock
     (a) Set time and date in clock
     (b) Read time and date from clock and display
  2. Display time and date on LCD display
- Hardest program this semester
- Need to use functions
- How to write to LCD display discussed in class notes of March 21 (Lecture 24)

```
char msg[] = "hello, world!";
openlcd();
while (1) {
   msg1 = "...";
   put2lcd(0x80,CMD);    // Move to first line
   puts2lcd(msg1);
   msg2 = "...";
   put2lcd(0xC0,CMD);    // Move to second line
   puts2lcd(msg2);
}
```

- Need C functions to write to and read from RTC over the IIC bus
- Notes from March 26 (Lecture 26) have functions to initialize IIC bus (`iic_init()`), start a transfer by writing address and R/$\overline{\text{W}}$ bit (`iic_start()`), transmit a byte of data (`iic_transmit()`), and stop the transfer (release IIC bus, `iic_stop()`).
- Need C functions to switch to receive mode (`iic_swrcv()`) and receive data over IIC bus (`iic_receive`).
- Need to put functions together to write to the RTC, read from the RTC, and display the time/date on the LCD display
- To write data to LCD display, data has to be in the form of an ASCII string
- Data from RTC is in form of BCD data
- For example, year is `0x09`

```
msg[0] = ((year>>4)&0x0f) + '0';
msg[1] = ((year)&0x0f) + '0';
msg[2] = '/';
...
msg[8] = 0;
put2lcd(0x80,CMD);    // Move to first line
puts2lcd(msg);
```

Lab on IIC Bus

- To read data from RTC, need to do the following:
  - Put IIC bus into transmit mode, send START condition, send slave address (with $R/\overline{W} = 0$), then send address of first register to read.
  - Put IIC bus into transmit mode, send START condition, send slave address (with $R/\overline{W} = 1$), switch to receive mode, read dummy byte from IBRD to start IIC clock, then receive data.
- Need function `iic_swrcv()` to switch from transmit to receive mode, and read dummy byte from IBCR.
- When receiving multiple bytes from slave, need to send NACK after last byte in order to tell slave to release bus.
  - If you don't do this, slave will hold onto bus, and you cannot take over bus for next operation
- Look at the flow chart from Page 39 of the IIC manual (next page) to see what to do
- I have three receive functions:
  1. `iic_receive()`: Used for receiving all but last two bytes
     - Waits for IBIF flag to set, indicating new data
     - Clears IBIF after it has been set
     - Reads data from IBDR, which starts next read
  2. `iic_receive_m1()`: Used for receiving next to last byte
     - Waits for IBIF flag to set, indicating new data
     - Clears IBIF after it has been set
     - Sets TXAK bit so there will be no ACK sent on reading the last byte
     - Reads data from IBDR, which starts next read
  3. `iic_receive_last()`: Used for receiving last byte
     - Waits for IBIF flag to set, indicating new data
     - Clears IBIF after it has been set
     - Clears TXAK bit so ACK is re-enabled
     - Clears $MS/\overline{SL}$ bit to generate a STOP bit after this transfer is complete
     - Sets $Tx/\overline{Rx}$ bit so MC9S12 will not start SCLK to receive another byte after reading from IBDR.
     - Reads data from IBDR

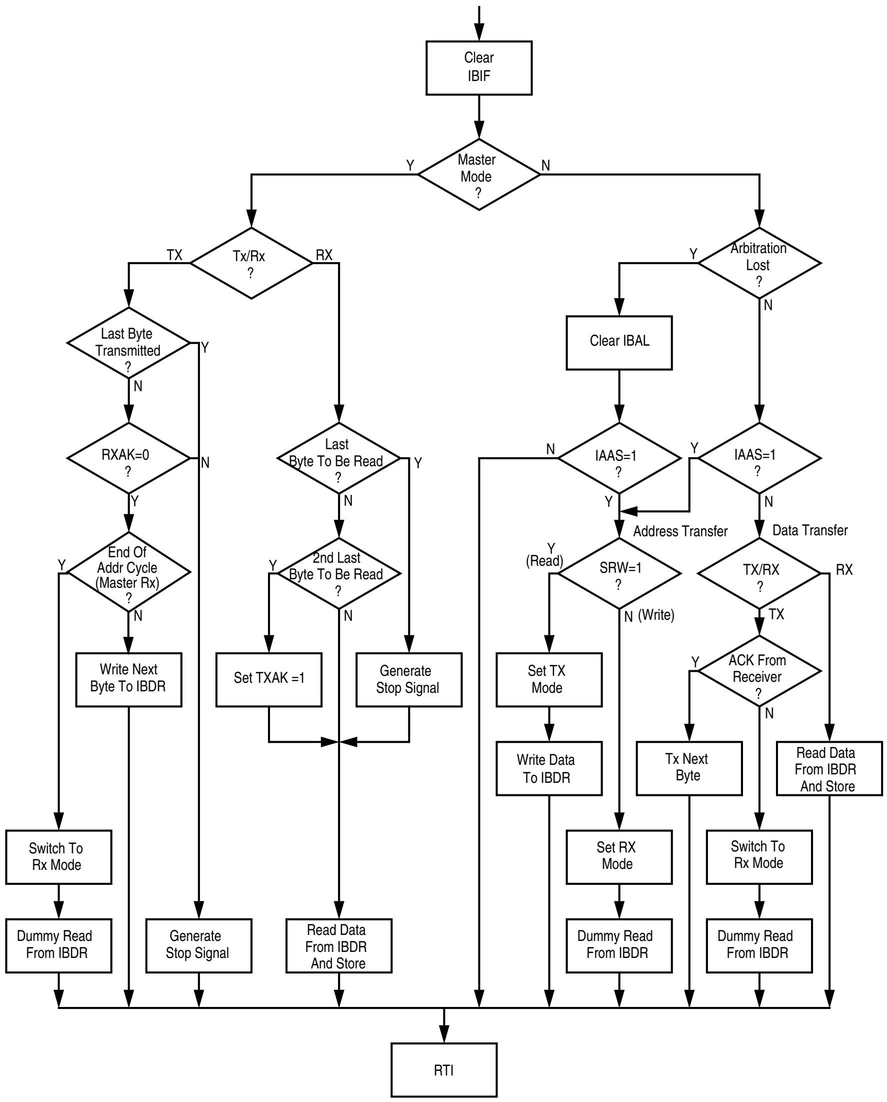
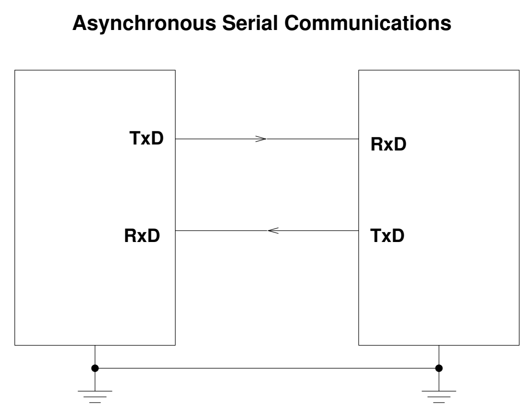
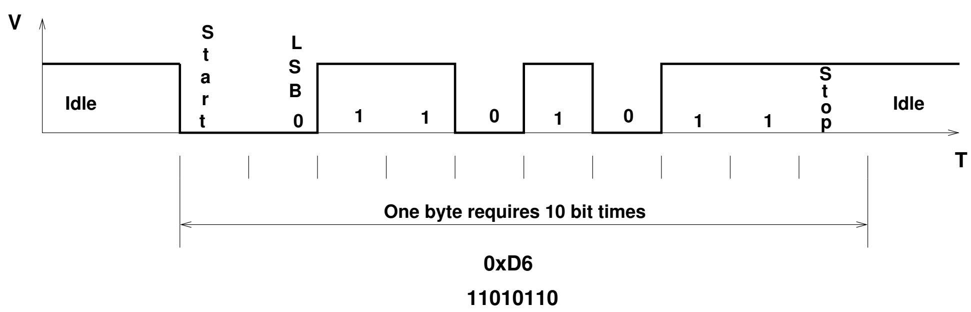


Figure 5-1 Flow-Chart of Typical IIC Interrupt Routine

Asynchronous Data Transfer

- In asynchronous data transfer, there is no clock line between the two devices
- Both devices use internal clocks with the same frequency
- Both devices agree on how many data bits are in one data transfer (usually 8, sometimes 9)
- A device sends data over an TxD line, and receives data over an RxD line
  - The transmitting device transmits a special bit (the start bit) to indicate the start of a transfer
  - The transmitting device sends the requisite number of data bits
  - The transmitting device ends the data transfer with a special bit (the stop bit)
- The start bit and the stop bit are used to synchronize the data transfer

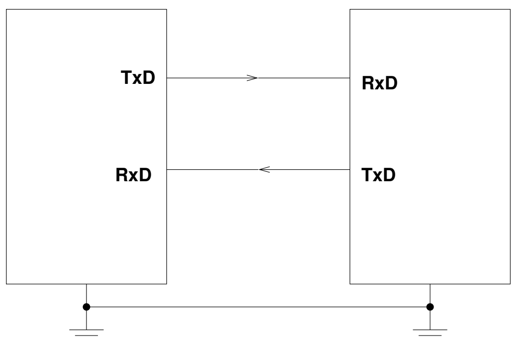


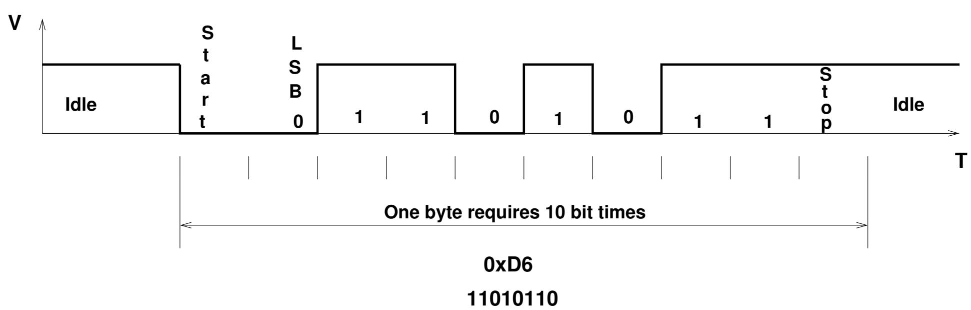


Asynchronous Data Transfer

- The receiver knows when new data is coming by looking for the start bit (digital 0 on the RxD line).
- After receiving the start bit, the receiver looks for 8 data bits, followed by a stop bit (digital high on the RxD line).
- If the receiver does not see a stop bit at the correct time, it sets the Framing Error bit in the status register.
- Transmitter and receiver use the same internal clock rate, called the Baud Rate.
- At 9600 baud (the speed used by D-Bug12), it takes 1/9600 second for one bit, 10/9600 second, or 1.04 ms, for one byte.

Asynchronous Serial Communications





Asynchronous Serial Protocols

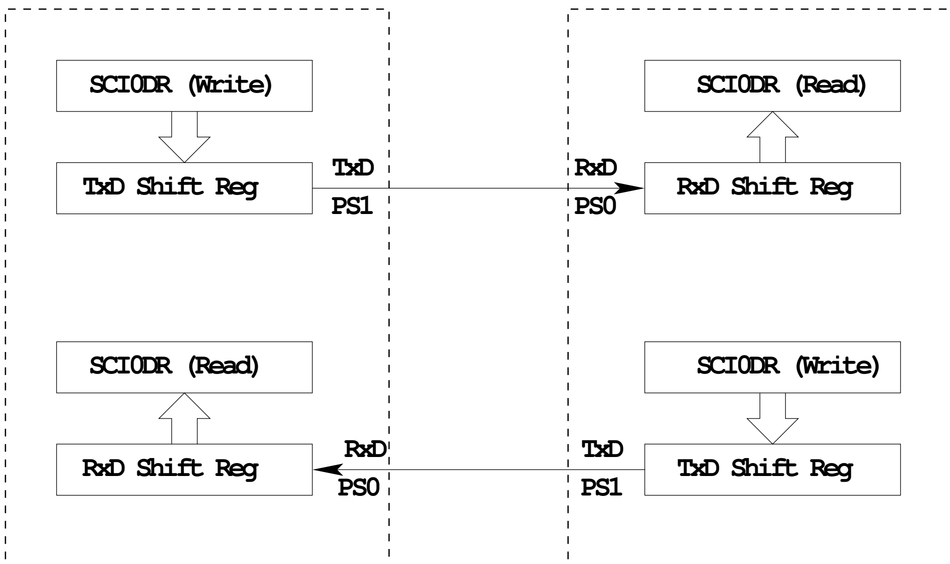
- The SCI interface on the MC9S12 uses voltage levels of 0 V and +5 V. The RS-232 standard uses voltage levels of +12 V and -12 V.
  - The Dragon12-Plus board uses a Maxim MAX232A chip to shift the TTL levels from the MC9S12 to the RS-232 levels necessary for connecting to a standard serial port. 0 V from the SCI is converted to +12 V on the DB-9 connector and +5 V from the SCI is converted to -12 V on the DB-9 connector.
  - The RS-232 standard can work on cables up to a length of 50 feet.
- Another asynchronous standard is RS-485. Dragon12-Plus board can use SCI1 in RS-485 mode
  - RS-485 is a two-wire differential asynchronous protocol
  - Multiple devices can connect to the same two wires
  - Only one device on the RS-485 bus can transmit; all the other devices are in receive mode
  - The Dragon12-Plus DS75176 differential-to-single ended converter to convert the single-ended SCI1 data to differential RS-485 data
  - Bit 0 of Port J determines if the RS-485 should be in receive mode or transmit mode
  - RS-485 can work with cables up to a length of 1,000 feet.

Parity in Asynchronous Serial Transfers

- The HCS12 can use a parity bit for error detection.
  - When enabled in SCI0CR1, the parity function uses the most significant bit for parity.
  - There are two types of parity – even parity and odd parity
    * With even parity, and even number of ones in the data clears the parity bit; an odd number of ones sets the parity bit. The data transmitted will always have an even number of ones.
    * With odd parity, and odd number of ones in the data clears the parity bit; an even number of ones sets the parity bit. The data transmitted will always have an odd number of ones.
  - The HCS12 can transmit either 8 bits or 9 bits on a single transfer, depending on the state of M bit of SCI0CR1.
  - With 8 data bits and parity disabled, all eight bits of the byte will be sent.
  - With 8 data bits and parity enabled, the seven least significant bits of the byte are sent; the MSB is replaced with a parity bit.
  - With 9 data bits and parity disabled, all eight bits of the byte will be sent, and an additional bit can be sent in the sixth bit of SCI0DRH.
    * It usually does not make sense to use 9 bit mode without parity.
  - With 9 data bits and parity enabled, all eight bits of the byte are sent; the ninth bit is the parity bit, which is put into the MSB of SCI0DRH in the receiver.

Asynchronous Data Transfer

- The HCS12 has two asynchronous serial interfaces, called the SCI0 and SCI1 (SCI stands for Serial Communications Interface)
- SCI0 is used by D-Bug12 to communicate with the host PC
- When using D-Bug12 you normally cannot independently operate SCI0 (or you will lose your communications link with the host PC)
- The SCI0 TxD pin is bit 1 of Port S; the SCI1 TxD pin is bit 3 of Port S.
- The SCI0 RxD pin is bit 0 of Port S; the SCI1 RxD pin is bit 2 of Port S.
- In asynchronous data transfer, serial data is transmitted by shifting out of a transmit shift register into a receive shift register



SCI0DR receive and transmit registers are separate registers.
distributed into two 8-bit registers, SCI0DRH and SCI0DRL

An overrun error is generated if RxD shift register filled before SCI0DR read

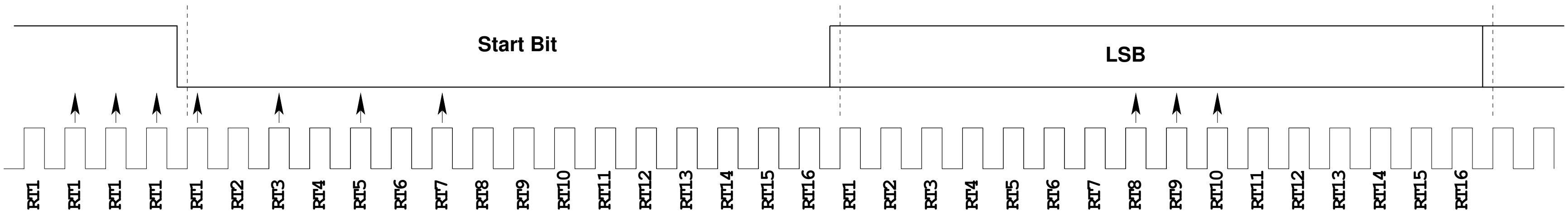
Timing in Asynchronous Data Transfers

- The BAUD rate is the number of bits per second.
- Typical baud rates are 1200, 2400, 4800, 9600, 19,200, and 115,000
- At 9600 baud the transfer rate is 9600 bits per second, or one bit in 104 μs.
- When not transmitting the TxD line is held high.
- When starting a transfer the transmitting device sends a start bit by bringing TxD low for one bit period (104 μs at 9600 baud).
- The receiver knows the transmission is starting when it sees RxD go low.
- After the start bit, the transmitter sends the requisite number of data bits.
- The receiver checks the data three times for each bit. If the data within a bit is different, there is an error. This is called a noise error.
- The transmitter ends the transmission with a stop bit, which is a high level on TxD for one bit period.
- The receiver checks to make sure that a stop bit is received at the proper time.
- If the receiver sees a start bit, but fails to see a stop bit, there is an error. Most likely the two clocks are running at different frequencies (generally because they are using different baud rates). This is called a framing error.
- The transmitter clock and receiver clock will not have exactly the same frequency.
- The transmission will work as long as the frequencies differ by less 4.5%(4% for 9-bit data).

Timing in Asynchronous Data Transfers

ASYNCHRONOUS SERIAL COMMUNIATIONS

Baud Clock = 16 x Baud Rate



Start Bit – Three 1's followed by 0's at RT1,3,5,7
(Two of RT3,5,7 must be zero –
If not all zero, Noise Flag set)

Data Bit – Check at RT8,9,10
(Majority decides value)
(If not all same, noise flag set)

If no stop bit detected, Framing Error Flag set

Baud clocks can differ by 4.5% (4% for 9 data bits)
with no errors.

Even parity -- the number of ones in data word is even

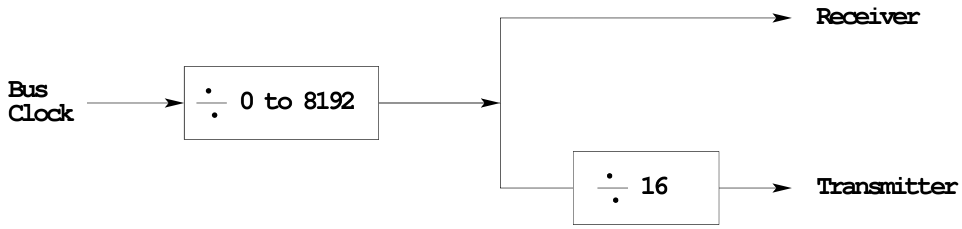
Odd parity -- the number of ones in data word is odd

When using parity, transmit 7 data + 1 parity, or 8 data + 1 parity

Baud Rate Generation

- The SCI transmitter and receiver operate independently, although they use the same baud rate generator.
- A 13-bit modulus counter generates the baud rate for both the receiver and the transmitter.
- The baud rate clock is divided by 16 for use by the transmitter.
- The baud rate is

$$mbox\texttt{SCIBaudRate} = \frac{\texttt{Bus Clock}}{16 \times \texttt{SCI1BR[12:0]}}$$



- With a 24 MHz bus clock, the following values give typically used baud rates.

Bits SPR[12:0]	Receiver Clock (Hz)	Transmitter Clock (Hz)	Target Baud Rate	Error (%)
39	615,384.6	38,461.5	38,400	0.16
78	307,692.3	19,230.7	19,200	0.16
156	153,846.1	38,461.5	9,600	0.16
312	76,693.0	38,461.5	4,800	0.16

SCI Registers

- Each SCI uses 8 registers of the HCS12. In the following we will refer to SCI1.
- Two registers are used to set the baud rate (`SCI1BDH` and `SCI1BDL`)
- Control register `SCI1CR2` is used for normal SCI operation.
- `SCI1CR1` is used for special functions, such as setting the number of data bits to 9.
- Status register `SCI1SR1` is used for normal operation.
- `SCI1SR2` is used for special functions, such as single-wire mode.
- The transmitter and receiver can be separately enabled in `SCI1CR2`.
- Transmitter and receiver interrupts can be separately enabled in `SCI1CR2`.
- `SCI1SR1` is used to tell when a transmission is complete, and if any error was generated.
- Data to be transmitted is sent to `SCI1DRL`.
- After data is received it can be read in `SCI1DRL`. (If using 9-bit data mode, the ninth bit is the MSB of SCI0DRH.)

0	0	0	**SBR12**	**SBR11**	**SBR10**	**SBR9**	**SBR8**	**SCI1BDH – 0x00D0**

SBR7	**SBR6**	**SBR5**	**SBR4**	**SBR3**	**SBR2**	**SBR1**	**SBR0**	**SCI1BDL – 0x00D1**

LOOPS	SCISWAI	RSRC	**M**	**WAKE**	ILT	**PE**	**PT**	**SCI1CR1 – 0x00D2**

TIE	TCIE	**RIE**	ILIE	**TE**	**RE**	**RWU**	SBK	**SCI1CR2 – 0x00D3**

TDRE	TC	**RDRF**	IDLE	**OR**	**NF**	**FE**	**PF**	**SCI1SR1 – 0x00D4**

0	**0**	**0**	**0**	**0**	**BRK13**	**TXDIR**	RAF	**SCI1SR2 – 0x00D5**

R8	**T8**	**0**	**0**	**0**	**0**	**0**	**0**	**SCI1DRH – 0x00D5**

R7/T7	**R6/T6**	**R5/T5**	**R4/T4**	**R3/T3**	**R2/T2**	**R1/T1**	**R0/T0**	**SCI1DRL – 0x00D7**

Example program using the SCI Transmitter

```
#include "derivative.h"
/* Program to transmit data over SCI port */

main()
{
    /**************************************************************
     * SCI Setup
    **************************************************************/
    SCI1BDL = 156;    /* Set BAUD rate to 9,600 */
    SCI1BDH =   0;

    SCI1CR1 = 0x00;  /* 0 0 0 0 0 0 0 0
                        | | | | | | | |
                        | | | | | | | \____ Even Parity
                        | | | | | | \______ Parity Disabled
                        | | | | | \________ Short IDLE line mode (not used)
                        | | | | \__________ Wakeup by IDLE line rec (not used)
                        | | | \____________ 8 data bits
                        | | \______________ Not used (loopback disabled)
                        | \________________ SCI1 enabled in wait mode
                        \__________________ Normal (not loopback) mode
                     */


    SCI1CR2 = 0x08;  /* 0 0 0 0 1 0 0 0
                        | | | | | | | |
                        | | | | | | | \____ No Break
                        | | | | | | \______ Not in wakeup mode (always awake)
                        | | | | | \________ Reciever disabled
                        | | | | \__________ Transmitter enabled
                        | | | \____________ No IDLE Interrupt
                        | | \______________ No Reciever Interrupt
                        | \________________ No Tranmit Complete Interrupt
                        \__________________ No Tranmit Ready Interrupt
                     */
    /**************************************************************
     * End of SCI Setup
    **************************************************************/

    SCI1DRL = 'h';   /* Send first byte */
    while ((SCI1SR1 & 0x80) == 0) ;   /* Wait for TDRE flag */
    SCI1DRL = 'e';   /* Send next byte */
    while ((SCI1SR1 & 0x80) == 0) ;   /* Wait for TDRE flag */
```

```
    SCI1DRL = 'l';   /* Send next byte */
    while ((SCI1SR1 & 0x80) == 0) ;   /* Wait for TDRE flag */
    SCI1DRL = 'l';   /* Send next byte */
    while ((SCI1SR1 & 0x80) == 0) ;   /* Wait for TDRE flag */
    SCI1DRL = 'o';   /* Send next byte */
    while ((SCI1SR1 & 0x80) == 0) ;   /* Wait for TDRE flag */

}
```

Example program using the SCI Receiver

```
/* Program to receive data over SCI1 port */

#include "derivative.h"
#include "vectors12.h"

interrupt void sci1_isr(void);

volatile unsigned char data[80];
volatile int i;

main()
{
    /*************************************************************
     * SCI Setup
    *************************************************************/
    SCI1BDL = 156;    /* Set BAUD rate to 9,600 */
    SCI1BDH =   0;

    SCI1CR1 = 0x00;  /* 0 0 0 0 0 0 0 0
                        | | | | | | | |
                        | | | | | | | \____ Even Parity
                        | | | | | | \______ Parity Disabled
                        | | | | | \________ Short IDLE line mode (not used)
                        | | | | \__________ Wakeup by IDLE line rec (not used)
                        | | | \____________ 8 data bits
                        | | \______________ Not used (loopback disabled)
                        | \________________ SCI1 enabled in wait mode
                        \__________________ Normal (not loopback) mode
                     */


    SCI1CR2 = 0x04;  /* 0 0 1 0 0 1 0 0
                        | | | | | | | |
                        | | | | | | | \____ No Break
                        | | | | | | \______ Not in wakeup mode (always awake)
                        | | | | | \________ Reciever enabled
                        | | | | \__________ Transmitter disabled
                        | | | \____________ No IDLE Interrupt
                        | | \______________ Reciever Interrupts used
                        | \________________ No Tranmit Complete Interrupt
                        \__________________ No Tranmit Ready Interrupt
                     */

    UserSCI1 = (unsigned short) &sci1_isr;
```

```
    i = 0;
    enable();

    /************************************************************
     * End of SCI Setup
    *************************************************************/
    while (1)
    {
        /* Wait for data to be received in ISR, then
         * do something with it
         */
    }
}

interrupt void sci1_isr(void)
{
    char tmp;

    /* Note:  To clear receiver interrupt, need to read
     * SCI1SR1, then read SCI1DRL.
     * The following code does that
     */
    if ((SCI1SR1 & 0x20) == 0) return;  /* Not receiver interrrupt */
    data[i] = SCI1DRL;
    i = i+1;
    return;
}
```