

- **Using the MC9S12 IIC Bus with DS 1307 Real Time Clock**
- DS1307 Data Sheet
- Asynchronous Serial Communications
- The MC9S12 Serial Communications Interface (SCI)

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 Serial Clock Line (SCL) frequency, Serial Data line (SDA) hold time, Start and Stop hold times
 - Determine the value to write to IIC Bus Frequency Divider Register (IBFD) to meet those times
- **To set the time,**
 - Send the Start condition
 - Write address of clock (with R/ \hat{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/ \hat{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/ \hat{W} high for reading)
 - 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

- Lab on the IIC Bus
 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 a previous class notes

```
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

- Need C functions to initialize IIC bus (**iic_init()**), start a transfer by writing address and R/Wbit (**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

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/W = 0), then send address of first register to read.
 - Put IIC bus into transmit mode, send START condition, send slave address (with R/W = 1), switch to receive mode, read dummy byte from IBDR to start IIC clock, then receive data.

- Need function `iic_swrcv()` to switch from transmit to receive mode, and read dummy byte from IBDR.

- 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

- We have to 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

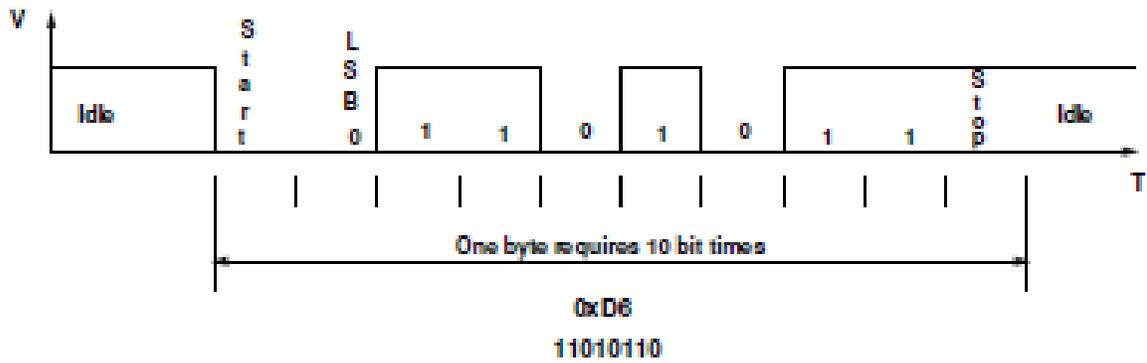
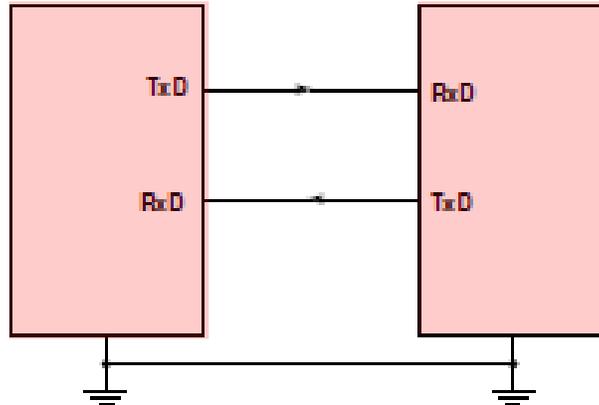
 2. `iic_receive_m1()`: Used for receiving next to last byte
 - Waits for IBIF flag to set, indicating new data
 - Clears IBIF after it has been set
 - Sets TXAK bit so there will be no ACK sent on reading the last byte
 - Reads data from IBDR, which starts next read

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/SL bit to generate a STOP bit after this transfer is complete
 - Sets Tx/Rx bit so MC9S12 will not start SCLK to receive another byte after reading from IBDR.
 - Reads data from IBDR

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 Serial Communications



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 $1/9600$ seconds for one bit, for a total of $10/9600$ seconds, or 1.04 ms, for one byte.

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 uses 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.

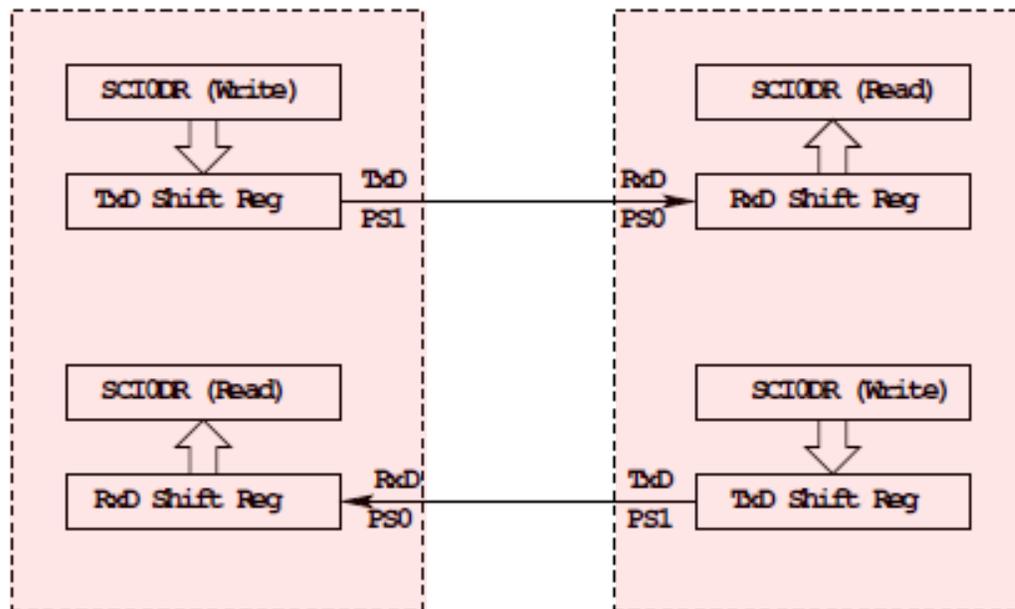
Parity in Asynchronous Serial Transfers

- 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 are 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 μ s.
- 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 μ s 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 COMMUNICATIONS

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

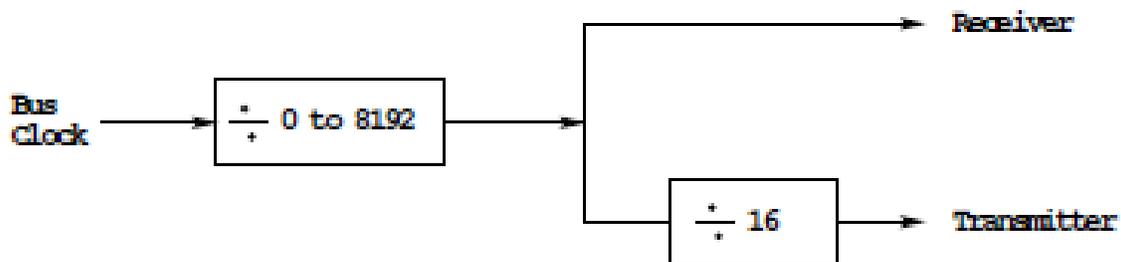
Odd parity -- the number of ones in data word is odd

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

$$\text{SCIBaudRate} = \text{Bus Clock} / (16 \times \text{SCI1BR}[12:0])$$



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

Bits SBR[12:0]	Receiver Clk (Hz)	Transmitter Clk(Hz)	Target Baudrate	Error (%)
39	615385	38462	38400	0.16
78	307692	19231	19200	0.16
156	153846	9615	9600	0.16
312	76923	4808	4800	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)
- SCI1CR1 is used for special functions, such as setting the number of data bits to 9.
- Control register SCI1CR2 is used for normal SCI operation.
- 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	SCT1EDH - 0x00D0
---	---	---	-------	-------	-------	------	------	------------------

SBR7	SBR6	SBR5	SBR4	SBR3	SBR2	SBR1	SBR0	SCT1EDL - 0x00D1
------	------	------	------	------	------	------	------	------------------

LOOPS	SCISWAI	RSRC	M	WAKE	ILT	PE	PT	SCT1CR1 - 0x00D2
-------	---------	------	---	------	-----	----	----	------------------

TIE	TCIE	RIE	ILIE	TE	RE	FWU	SEK	SCT1CR2 - 0x00D3
-----	------	-----	------	----	----	-----	-----	------------------

TIRE	TC	RDRF	IDLE	OR	NF	FE	PF	SCT1SR1 - 0x00D4
------	----	------	------	----	----	----	----	------------------

0	0	0	0	0	BRK13	TMDIR	RAF	SCT1SR2 - 0x00D5
---	---	---	---	---	-------	-------	-----	------------------

R8	T8	0	0	0	0	0	0	SCT1DRH - 0x00D6
----	----	---	---	---	---	---	---	------------------

R7/T7	R6/T6	R5/T5	R4/T4	R3/T3	R2/T2	R1/T1	R0/T0	SCT1DRL - 0x00D7
-------	-------	-------	-------	-------	-------	-------	-------	------------------

1. SCI Baud Rate Registers (SCI BDH/L)

SBR12 – SBR0: SCI Baud Rate Bits

The baud rate for the SCI is determined by these 13 bits.

2. SCI Control Register 1 (SCICR1)

M: Data Format Mode Bit

1 = One start bit, nine data bits, one stop bit

0 = One start bit, eight data bits, one stop bit

WAKE: Wakeup Condition Bit

A logic 1 (address mark) in the most significant bit position of a received data character, or a logic 0, an idle condition on the RXD

PE: Parity Enable Bit

1 = Parity function enabled

0 = Parity function disabled

PT: Parity Type Bit

1 = Odd parity

0 = Even parity

3. SCI Control Register 2 (SCICR2)

TIE: Transmitter Interrupt Enable Bit

1 = Transmit data register enable (TDRE) interrupt requests enabled

0 = TDRE interrupt requests disabled

RIE: Receiver Full Interrupt Enable Bit

1 = Receiver data register full (RDRF) enabled

0 = RDRF disabled

TE: Transmitter Enable Bit

1 = Transmitter enabled

0 = Transmitter disabled

RE: Receiver Enable Bit

1 = Receiver enabled

0 = Receiver disabled

RWU: Receiver Wakeup Bit Standby state

1 = RWU enables the wakeup function and inhibits further receiver interrupt requests. Normally, hardware wakes the receiver by automatically clearing RWU.

0 = Normal operation

4. SCI Status Register 1 (SCISR1)

TDRE: Transmit Data Register Empty Flag

1 = Byte transferred to transmit shift register; transmit data register empty

0 = No byte transferred to transmit shift register

RDRF: Receive Data Register Full Flag

1 = Received data available in SCI data register

0 = Data not available in SCI data register

OR: Overrun flag

1 = Overrun

0 = No overrun

NF: Noise Flag

1 = Noise

0 = No noise

FE: Framing Error Flag

1 = Framing error

0 = No framing error

PF: Parity Error Flag

1 = Parity error

0 = No parity error

5. SCI Status Register 2 (SCISR2)

BRK13: Break Transmit character length

1 = Break character is 13 or 14 bit long

0 = Break Character is 10 or 11 bit long

TXDIR: Transmitter pin data direction in Single-Wire mode.

1 = TXD pin to be used as an output in Single-Wire mode

0 = TXD pin to be used as an input in Single-Wire mode

6. SCI Data Registers (SCIDRH/L)

R8: R8 is the ninth data bit received when the SCI is configured for 9-bit data format ($M = 1$).

T8: T8 is the ninth data bit transmitted when the SCI is configured for 9-bit data format ($M = 1$).

R7-R0: Received bits seven through zero for 9-bit or 8-bit data formats

T7-T0: Transmit bits seven through zero for 9-bit or 8-bit formats

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)
    | | | | | \___ Receiver disabled
    | | | | \___ Transmitter enabled
    | | | \___ No IDLE Interrupt
    | | \___ No Receiver Interrupt
    | \___ No Transmit Complete Interrupt
    \___ No Transmit 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"

#define enable() __asm(cli)

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)
    | | | | | \_____ Receiver enabled
    | | | | \_____ Transmitter disabled
    | | | \_____ No IDLE Interrupt
    | | \_____ Receiver Interrupts used
    | \_____ No Transmit Complete Interrupt
    \_____ No Transmit 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 interrupt */
    data[i] = SCI1DRL;
    i = i+1;
    return;
}
```