

## Objectives

- To establish bidirectional communications with an external host computer via the serial interface of the microcontroller
- To write a set of functions for the input and output of clear text and numerical data from and to a terminal program

## Introduction

Serial communication is central to many embedded computer systems. Being able to communicate with a microcontroller through its Serial Communication Interface (SCI) provides the developer with 'eyes' to see what is going on inside the chip. When working with a new microcontroller, one of the first tasks commonly is the writing of a few communication routines through which error messages and status information can be displayed and control signals can be passed to the program.

The MC9S12DP256B/C comes with two independent serial interface units (SCI0 and SCI1). A small memory resident monitor program has been installed on all Dragon12 boards in our laboratory. This program is started upon a hardware reset. It uses interface SCI0 to communicate with an external debugger on the host, e.g. the Hi-Wave source level debugger which has been integrated into the CodeWarrior IDE. The monitor/debugger facilitates the download of user programs into RAM or Flash EEPROM, as well as their on-chip debugging using *hardware breakpoints*; hardware breakpoints allow a program to be interrupted, even if it has been installed in ROM. Interface SCI0 is configured for a line speed of 115200 bps, with 8 data bits, no parity checking and one stop bit ( $115200 \cdot 8 / N - 1$ ). The second serial communication interface, SCI1, is available for general use.<sup>1</sup>

Figure LMP6-1 shows the principal elements of an SCI unit on the MC9S12DP256B/C. The line speed is controlled by programming the *baud rate generator*. This unit produces an internal clock signal which determines the timing on both the transmission line (*sci\_tx\_od*) as well as the reception line (*sci\_rx\_ind*). Incoming data is stored in the *Receive Shift Register* before being copied to the *SCI Receive Data Register*. Similarly, outgoing data needs to be written to the *SCI Transmit Data Register*, from where it is copied to the *Transmit Shift Register*. Note that both the Transmit Data register as well as the Receive Data register are memory mapped at the same address. Read instructions to this address accesses the Receive Data register, whereas write instructions addresses the Transmit Data register.

All special function registers of the SCI unit are shown in Figure LM6-2. The unit offset is to be added to the base address of the selected SCI unit in the memory map of the MC9S12DP256B/C. This is commonly done within header file which defines all special function registers (here: *mc9s12dp256.h*).

---

<sup>1</sup> Note: Strictly speaking, both serial communication interfaces are 'for general use' – provided no serial port based debugging is required.

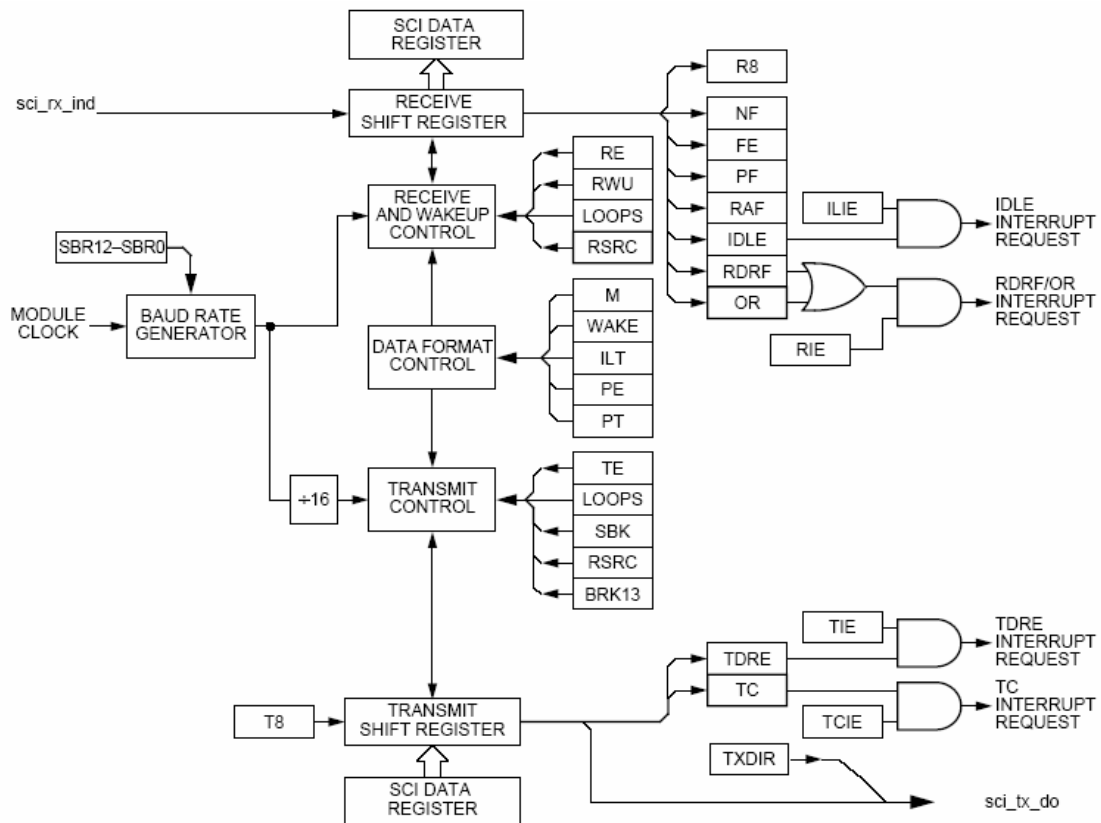


Figure LMP6-1 The Serial Communication Interface (SCI)

Offset	Use	Access
\$000	SCI Baud Rate Register High (SCIBDH)	Read/Write
\$001	SCI Baud Rate Register Low (SCIBDL)	Read/Write
\$002	SCI Control Register1 (SCICR1)	Read/Write
\$003	SCI Control Register 2 (SCICR2)	Read/Write
\$004	SCI Status Register 1 (SCISR1)	Read
\$005	SCI Status Register 2 (SCISR2)	Read/Write
\$006	SCI Data Register High (SCIDRH)	Read/Write
\$007	SCI Data Register Low (SCIDRL)	Read/Write

Figure LMP6-2 The special function registers of the SCI unit

The line speed of the SCI unit is controlled through the two 8-bit SCI BauD Rate Registers, SCIBDH and SCIBDL (Figure LMP6-3). The 13-bit value ( $BR = [SBR12 \dots SBR0]$ ) defines a pre-scale value which is used to reduce the input clock of the SCI unit to the required line speed. This SCI input clock is  $1/16^{\text{th}}$  of the central bus clock, i. e.  $24 \text{ MHz} / 16 = 1.5 \text{ MHz}$ . The baud rate can thus be calculated using:

$$f_{line} = \frac{f_{bus}}{16 \cdot BR}$$

SCI Baud Rate

Registers

(SCIxBDH/L)

Address Offset: \$000

	7	6	5	4	3	2	1	0
R	0	0	0	SBR12	SBR11	SBR10	SBR9	SBR8
W								
RESET:	0	0	0	0	0	0	0	0

 = Unimplemented or Reserved

Address Offset: \$001

	7	6	5	4	3	2	1	0
R	SBR7	SBR6	SBR5	SBR4	SBR3	SBR2	SBR1	SBR0
W								
RESET:	0	0	0	0	0	1	0	0


 = Unimplemented or Reserved

Figure LMP6-2 The special function registers of the SCI unit

Writing to the high byte of the baud rate register is ineffective until the low-byte has been written as well. Complete the following table to work out the required values for the specified baud rates (Table LMP6-1).

Baud rate (bps)	BR	SCIxBDL	SCIxBDH	Error (rel.)
1200	1250	226	4	0 %
2400				
4800	313 or 312	57 or 56	1	-0.16 % or +0.16 %
9600				
19200	78	78	0	+0.16 %
38400				
57600				
115200				

Table LMP6-1 Baud rate generation, 24 MHz bus clock

Note that some of the above baud rates can not be produced without error. Dividing the CPU clock rate (24 MHz) by 16·19200 or 307200 yields 78.125, i. e. a fractional

number. The nearest integer number is 78. Therefore, when requesting a line speed of 19200 bps, the baud rate generator actually generates a clock signal of  $24 \cdot 10^6 / (16 \cdot 78) = 19230.77$  bps. This is a relative error of  $30.77 / 19200 = +1.6 \cdot 10^{-3}$  or 0.16 %. Most serial communication equipment can cope with relative baud rate errors of up to 6 %. This relative error should always be kept as small as possible.

Control registers SC<sub>I</sub>xCR1 and SC<sub>I</sub>xCR2 specify all other parameters of the interface, e.g. the number of bits per data word (8/9), the type of parity checking (even/odd/none), whether the reception/transmission complete interrupts are enabled, whether the receiver/transmitter is enabled, etc. (see: Figure LMP6-3).

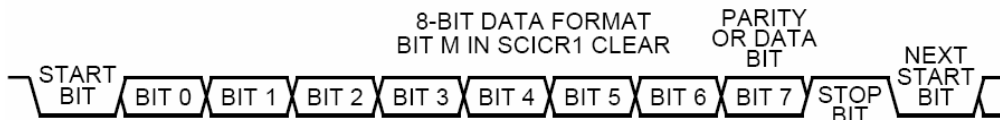


Figure LMP6-3 Serial communication – start bit, data, stop bit

The status registers can be used to check the current state of the interface when waiting for incoming data (Receive Data Register Full – RDRF) and/or prior to initiating a data transmission (Transmit Data Register Empty – TDRE). There are also flags that indicate the end of a transmission (Transmission Complete – TC) as well as various error conditions, e.g. when the Receive Data Register is overwritten by new incoming data before the program has managed to read the previous value (Overrun – OR), etc.

There are two SCI Data Registers, SC<sub>I</sub>xDRH and SC<sub>I</sub>xDRL. Regular 8-bit communication only makes use of SC<sub>I</sub>xDRL.

### **Implementation**

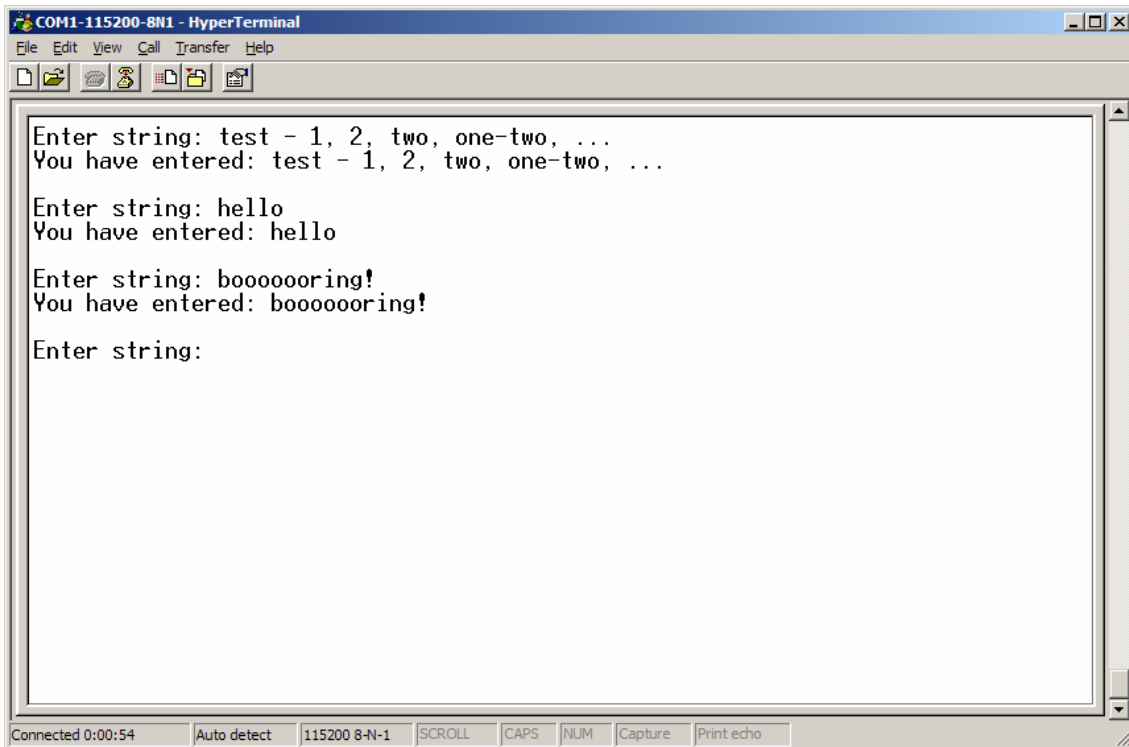
Write a serial communication module for SCI1 (e.g. 'SCI1.c'), including the following functions:

```
void SCI1_Init(unsigned long baudrate)
void SCI1_OutChar(char myChar)
char SCI1_InChar(void)
void SCI1_OutString(char *myString)
void SCI1_InString(char *myString, unsigned int maxLength)
```

All functions are to be exported as 'external' in a corresponding header file 'SCI1.h'. The *string* functions should make call upon the *character* functions to transmit/receive the individual characters. Function *SCI1\_InString* receives a pointer to a buffer of length 'maxLength'. The function should never accept more data as there is space on this buffer; all received characters are to be echoed back to the sending host (commonly a terminal program). If you are keen, you could catch non-printable characters such as 'backspace' and 'delete' or the 'arrows' and move the cursor accordingly.

Write a *main* module which calls upon the functions of your new serial communications module to read *strings* from a terminal connected to the serial connector 'P2' on the Dragon12 board. Set the communication speed to 115200 bps with 8 data bits and no parity checking. The program should then echo back whatever the user has typed on

the terminal before waiting for the next input (infinite loop). Figure LMP6-4 shows a screen shot of what the output of this program could look like.



```
COM1-115200-8N1 - HyperTerminal
File Edit View Call Transfer Help
[Icons]
Enter string: test - 1, 2, two, one-two, ...
You have entered: test - 1, 2, two, one-two, ...

Enter string: hello
You have entered: hello

Enter string: booooooring!
You have entered: booooooring!

Enter string:

Connected 0:00:54 Auto detect 115200 8-N-1 SCROLL CAPS NUM Capture Print echo
```

Figure LMP6-4 Output of the test program; SCI1 runs at 115200

## Extensions

[1]

Write communication routines which read and write signed and unsigned decimal numbers as well as signed and unsigned hexadecimal numbers:

```
unsigned int  SCI1_InUnsignedDec(void)
signed int    SCI1_InSignedDec(void)
```

and

```
unsigned int  SCI1_InUnsignedHex(void)
signed int    SCI1_InSignedHex(void)
```

[2]

Modify 'SCI1.c' to implement interrupt driven background communication as shown in class. An elegant version of this program would make use of ring buffers – the macros introduced in lecture MP7 are fairly generic and should also run on the MC9S12.