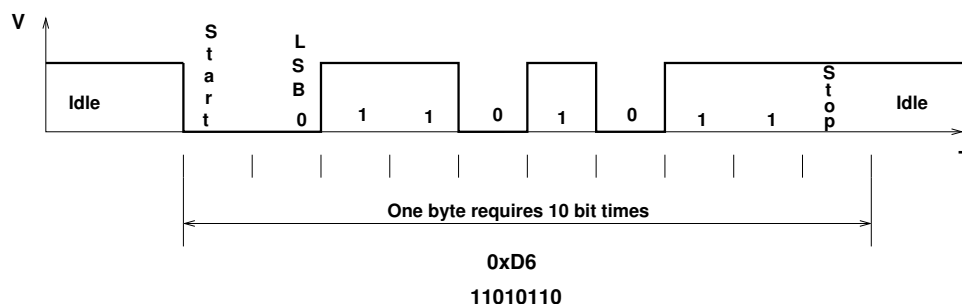
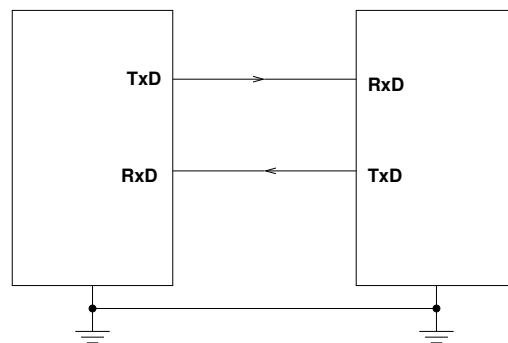


## Asynchronous Data Transfer

- 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

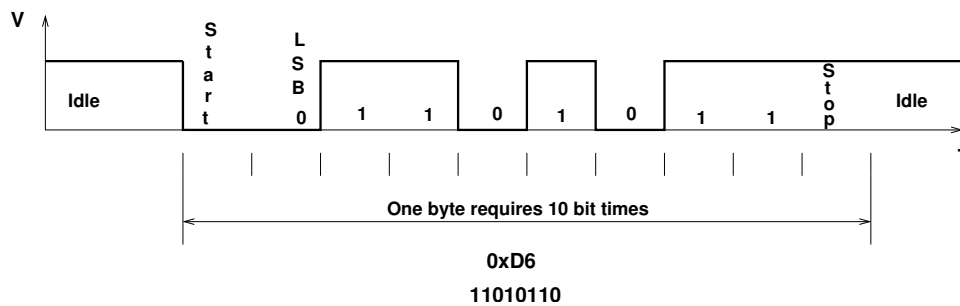
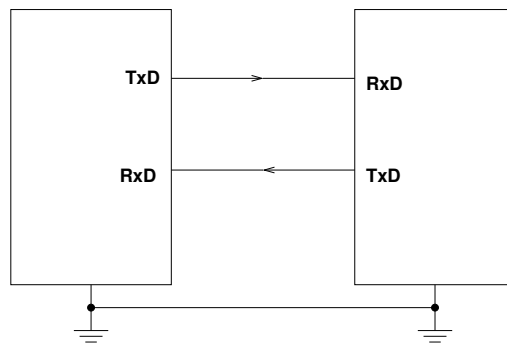
Asynchronous Serial Communications



## Asynchronous Data Transfer

- The receiver knows when new data is coming by looking for the start bit (digital 0 on the Rx/D line).
- After receiving the start bit, the receiver looks for 8 data bits, followed by a stop bit (digital high on the Rx/D 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

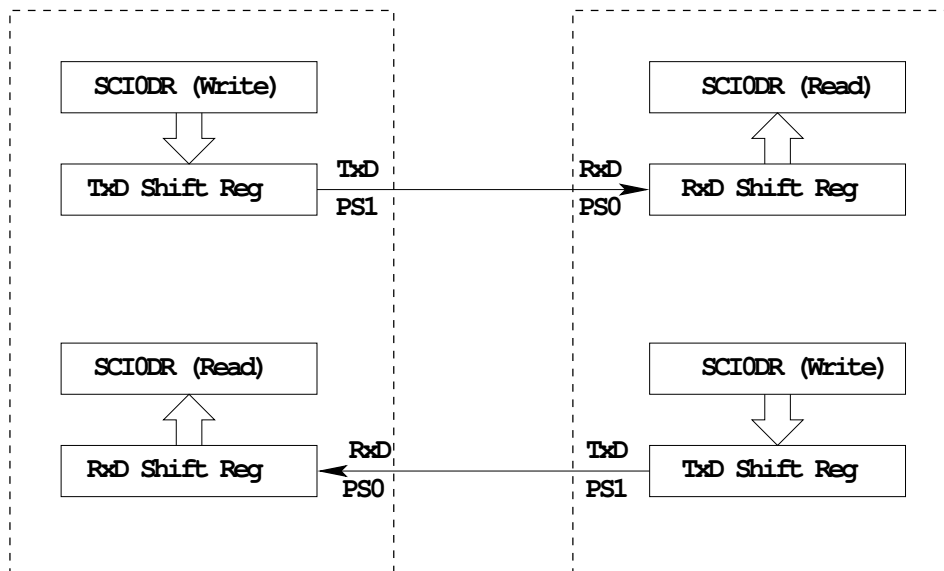


### Parity in Asynchronous Serial Transfers

- 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 D-Bug12 `printf()` function sends data to the host PC over SCI0
- 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

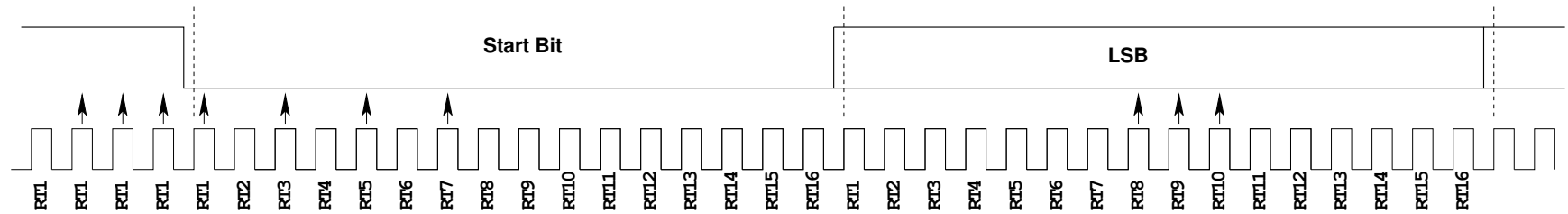
### Timing in Asynchronous Data Transfers

- 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  $\mu$ 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  $\mu$ 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

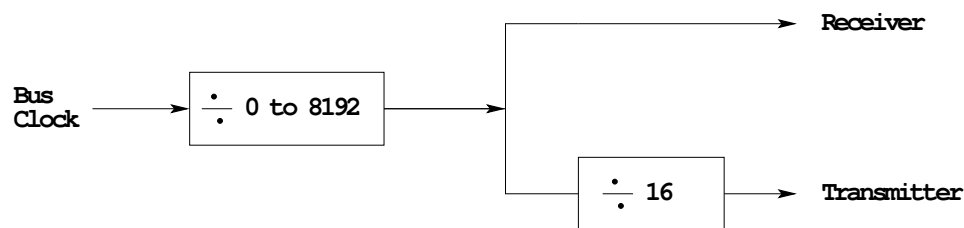
Odd parity -- the number of ones in data word is odd

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

$$mboxSCIbaudRate = \frac{\text{Bus Clock}}{16 \times \text{SCI1BR}[12:0]}$$



- 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 <hcs12.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 "hcs12.h"
#include "vectors12.h"

void INTERRUPT 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
     */
}

}

void INTERRUPT 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;
}
```