Introduction to Serial Communication

- Serial communication involves transmission of one bit of information at a time.
- One bit is sent, a time delay occurs, next bit is sent.
- Used to interface to printers, keyboards, scanners, etc.
- Universal asynchronous receiver/transmitter (UART) is the interface chip that implements the transmission.
- A serial channel is collection of signals (or wires) that implement the communication.
- Data terminal equipment (DTE) is the computer.
- Data communication equipment (DCE) is the modem.

Definitions

- A frame is a complete and nondivisible packet of bits.
- Includes both information (e.g. data, characters) and overhead (start bit, error checking, and stop bits).
- Parity is generated at the transmitter and checked at the receiver to help detect errors in transmission.
- Even parity makes number of 1s even (data+parity).
- Odd parity makes number of 1s odd (data+parity).
- Bit time is the time between each bit.
- Baud rate is total number bits transmitted per time.
Bandwidth

- *Information* is data user wishes to transmit:
  - Characters to be printed.
- *Overhead* is bits added to achieve transmission:
  - Start bit(s), stop bit(s), parity, etc.

\[
\text{Bandwidth} = \frac{\text{information bits/frame}}{\text{total bits/frame}} \times \text{baud rate}
\]

A Desktop Network

Various Serial Channels

Other Types of Channels
RS232 Cables

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RS232 DB9 Pin Assignments

<table>
<thead>
<tr>
<th>Pin</th>
<th>Signal</th>
<th>Description</th>
<th>True</th>
<th>DTE</th>
<th>DCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DCD</td>
<td>Data Carrier Detect</td>
<td>+12</td>
<td>In</td>
<td>Out</td>
</tr>
<tr>
<td>2</td>
<td>RxD</td>
<td>Receive Data</td>
<td>-12</td>
<td>In</td>
<td>Out</td>
</tr>
<tr>
<td>3</td>
<td>TxD</td>
<td>Transmit Data</td>
<td>-12</td>
<td>Out</td>
<td>In</td>
</tr>
<tr>
<td>4</td>
<td>DTR</td>
<td>Data Terminal Rdy</td>
<td>+12</td>
<td>Out</td>
<td>In</td>
</tr>
<tr>
<td>5</td>
<td>SG</td>
<td>Signal Ground</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>DSR</td>
<td>Data Set Ready</td>
<td>+12</td>
<td>In</td>
<td>Out</td>
</tr>
<tr>
<td>7</td>
<td>RTS</td>
<td>Request to Send</td>
<td>+12</td>
<td>Out</td>
<td>In</td>
</tr>
<tr>
<td>8</td>
<td>CTS</td>
<td>Clear to Send</td>
<td>+12</td>
<td>In</td>
<td>Out</td>
</tr>
<tr>
<td>9</td>
<td>RI</td>
<td>Ring Indicator</td>
<td>+12</td>
<td>In</td>
<td>Out</td>
</tr>
</tbody>
</table>

RS232 Interfaces

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RS232 Specifications

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RS422/RS423/RS485 Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>RS232D</th>
<th>RS423A</th>
<th>RS422</th>
<th>RS485</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drivers on one line</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>32</td>
</tr>
<tr>
<td>Receivers on one line</td>
<td>1</td>
<td>10</td>
<td>10</td>
<td>32</td>
</tr>
<tr>
<td>Max distance (ft)</td>
<td>50</td>
<td>4,000</td>
<td>4,000</td>
<td>4,000</td>
</tr>
<tr>
<td>Max data rate</td>
<td>20kb/s</td>
<td>100kb/s</td>
<td>10Mb/s</td>
<td>10Mb/s</td>
</tr>
<tr>
<td>Max driver output</td>
<td>±25V</td>
<td>±6V</td>
<td>±0.25/+6V</td>
<td>-7/+12V</td>
</tr>
<tr>
<td>Receiver input</td>
<td>±15V</td>
<td>±12V</td>
<td>±7V</td>
<td>-7/+12V</td>
</tr>
</tbody>
</table>

EIA-530 and RS449 Pin Assignments

(See Table 7.4)

Connectors for EIA-530/RS-449/AppleTalk

<table>
<thead>
<tr>
<th>AppleTalk Pin</th>
<th>RS232 Pin</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>8-RxD+</td>
<td>4-Gnd</td>
<td>Two grounds connected and RxD+ is grounded</td>
</tr>
<tr>
<td>3-TxD-</td>
<td>2-RxD</td>
<td>Serial data from the Macintosh to the external device</td>
</tr>
<tr>
<td>5-RxD-</td>
<td>3-TxD</td>
<td>Serial data from the external device to the Macintosh</td>
</tr>
</tbody>
</table>

RS422 Specifications

<table>
<thead>
<tr>
<th>Output Voltage</th>
<th>Input Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>True or Mark</td>
<td>$-6 \leq A - B \leq -2V$</td>
</tr>
<tr>
<td>Transition</td>
<td>$-2 \leq A - B \leq +2V$</td>
</tr>
<tr>
<td>False or Space</td>
<td>$+2 \leq A - B \leq +6V$</td>
</tr>
</tbody>
</table>
RS485 Half-Duplex Serial Channel

Current Loop Channel

Modem Serial Interface

Optical Channel
Serial Communication Interface

- Most embedded microcomputers support SCI.
- Common features include:
  - A baud rate control register used to select transmission rate.
  - A mode bit M used to select 8-bit (M=0) or 9-bit (M=1) data frames.
- Each device can create its own serial port clock with period that is integer multiple of the E clock period.

Transmitting in Asynchronous Mode

- Common features in the transmitter:
  - TxD data output pin, with TTL voltage levels.
  - 10- or 11-bit shift register, not directly accessible.
  - Serial communications data register (SCDR), write only, separate from receive reg. though same address.
  - T8 data bit for 9-bit data mode.

Control Bits for the Transmitter

- Transmit Enable (TE), set to 1 to enable transmitter.
- Send Break (SBK), set to 1 to send blks of 10 or 11 0s.
- Transmit Interrupt Enable (TIE), set to arm TDRE flag.
- Transmit Complete Enable (TCIE), set to arm TC flag.
Status Bits Generated by the Transmitter

- Transmit Data Register Empty flag (TDRE), set when SCDR empty, clear by reading TDRE and writing SCDR.
- Transmit Complete flag (TC), set when transmit shift register done shifting, cleared by reading TC flag then writing SCDR.

Pseudo Code for Transmission Process

```
TRANSMIT
Set TxD=0          Output start bit
Wait 16 clock times Wait 1 bit time
Set n=0            Bit counter
TLOOP
Set TxD=bn         Output data bit
Wait 16 clock times Wait 1 bit time
Set n=n+1          
Goto TLOOP if n<=7
Set TxD=T8         Output T8 bit
Wait 16 clock times Wait 1 bit time
Set TxD=1          Output a stop bit
Wait 16 clock times Wait 1 bit time
```

Receiving in Asynchronous Mode

- Common features in the receiver:
  - RxD data input pin, with TTL voltage levels.
  - 10- or 11-bit shift register, not directly accessible.
  - Serial communications data register (SCDR), read only, separate from transmit reg. though same address.
  - R8 data bit for 9-bit data mode.
Control Bits for the Receiver

- Receiver Enable (TE), set to 1 to enable receiver.
- Receiver Wakeup (RWU), set to 1 to allow a receiver input to wake up the computer.
- Receiver Interrupt Enable (RIE), set to arm RDRF flag.
- Idle Line Interrupt Enable (ILIE), set to arm IDLE flag.

Status Bits Generated by the Receiver

- Receive Data Register Full flag (RDRF), set when new data available, clear by reading RDRF and SCDR.
- Receiver Idle flag (IDLE), set when receiver line is idle, clear by reading IDLE, then reading SCDR.
- Overrun flag (OR), set when input data lost because previous frame not read, clear by reading OR and SCDR.
- Noise flag (NF), set when input is noisy, clear by reading NF flag, then reading SCDR.
- Framing error (FE), set when stop bit is incorrect, clear by reading FE, then reading SCDR.

Figures for Receiving

Pseudo Code for Receive Process

```
RECEIVE
Goto RECEIVE if RxD=1
Wait 8 clock times
Wait half a bit time
Goto RECEIVE if RxD=1
Set n=0

RLOOP
Wait 16 clock times
Set bn=RxD
Input data bit
Set n=n+1
Goto RLOOP if n<=7
Wait 16 clock times
Read 8 bit
Set R8=RxD
Wait 1 bit time
Set FE=1 if RxD=0
Framing error if no stop bit
```

Baud Rate Selection for MC68HC11

<table>
<thead>
<tr>
<th>Address</th>
<th>NR</th>
<th>BR2</th>
<th>BR1</th>
<th>BR0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>WR</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SCR2</th>
<th>SCR1</th>
<th>SCR0</th>
<th>Divisor_BR</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>128</td>
</tr>
</tbody>
</table>

SCI Data Register (SCDR)

<table>
<thead>
<tr>
<th>Address</th>
<th>NR</th>
<th>BR7</th>
<th>BR6</th>
<th>BR5</th>
<th>BR4</th>
<th>BR3</th>
<th>BR2</th>
<th>BR1</th>
<th>BR0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real</td>
<td>R8</td>
<td>R6</td>
<td>R5</td>
<td>R4</td>
<td>R3</td>
<td>R2</td>
<td>R1</td>
<td>R0</td>
<td></td>
</tr>
<tr>
<td>WR</td>
<td>T2</td>
<td>T1</td>
<td>T0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SCI Control Register 1 (SCCR1)

<table>
<thead>
<tr>
<th>Address</th>
<th>NR</th>
<th>BR7</th>
<th>BR6</th>
<th>BR5</th>
<th>BR4</th>
<th>BR3</th>
<th>BR2</th>
<th>BR1</th>
<th>BR0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real</td>
<td>R8</td>
<td>T8</td>
<td>T7</td>
<td>T6</td>
<td>T5</td>
<td>T4</td>
<td>T3</td>
<td>T2</td>
<td>T1</td>
</tr>
<tr>
<td>WR</td>
<td>WAKE</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SCI Control Register 2 (SCCR2)

<table>
<thead>
<tr>
<th>Address</th>
<th>NR</th>
<th>BR7</th>
<th>BR6</th>
<th>BR5</th>
<th>BR4</th>
<th>BR3</th>
<th>BR2</th>
<th>BR1</th>
<th>BR0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real</td>
<td>TIE</td>
<td>TCIE</td>
<td>DEIE</td>
<td>DE</td>
<td>TE</td>
<td>RE</td>
<td>RWU</td>
<td>SBK</td>
<td></td>
</tr>
<tr>
<td>WR</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

SCI Status Register (SCSR)

<table>
<thead>
<tr>
<th>Address</th>
<th>NR</th>
<th>BR7</th>
<th>BR6</th>
<th>BR5</th>
<th>BR4</th>
<th>BR3</th>
<th>BR2</th>
<th>BR1</th>
<th>BR0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real</td>
<td>TDRE</td>
<td>TC</td>
<td>RDRF</td>
<td>OR</td>
<td>IDLE</td>
<td>OR</td>
<td>MF</td>
<td>1E</td>
<td></td>
</tr>
<tr>
<td>WR</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

- TIE - Transmit interrupt enable
- TCIE - Transmit complete interrupt enable
- RIE - Receive interrupt enable
- ILIE - Idle line interrupt enable
- TE - Transmitter enable
- RE - Receiver enable
- RWU - Receiver wake-up control
- SBK - Send break

- R8 - Receive data bit 8 (used if M=1)
- T8 - Transmit data bit 8 (used if M=1)
- M - Mode, 1 creates 11-bit frame (else 10-bit frame)
- WAKE - Wake up by address mark (1) or idle (0)