

Serial Communications

Lecture Notes Adapted from

<http://www.eas.asu.edu/~sserc/226/>

Early Serial Communication

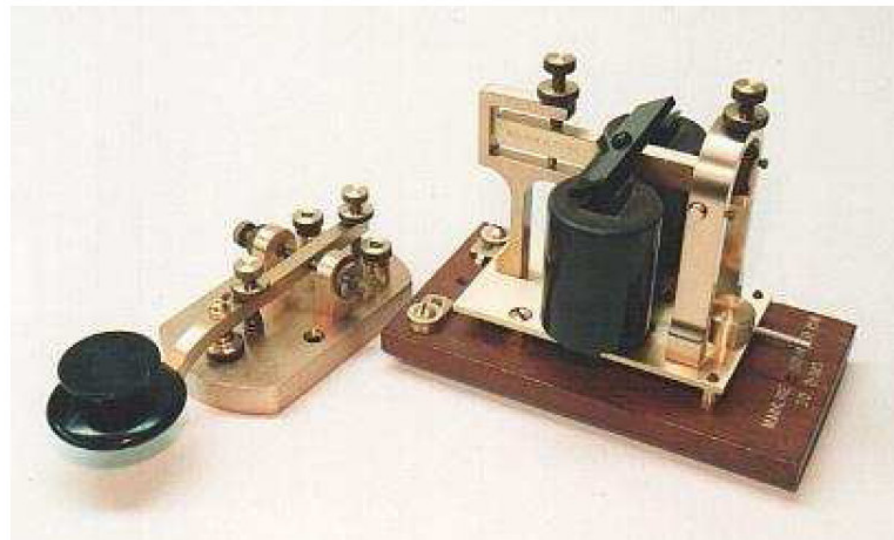
Morse code key

Letters

A	•—
B	—•••
C	—•—•
D	—••
E	•
F	••—•
G	—•—•
H	••••
I	••
J	•— — —
K	—•—
L	•—••
M	— —
N	—•
O	— — —
P	•— —•
Q	—•—•—
R	•—•
S	•••
T	—
U	••—
V	•••—
W	•— —
X	—••—
Y	—•— —
Z	— —••

Numbers

1	• — — — —
2	•• — — —
3	••• — —
4	•••• —
5	•••••
6	—••••
7	— —•••
8	— — —••
9	— — — —•
0	— — — — —



Later Serial Communication



Data Terminal Equipment



Data
Communications
Equipment

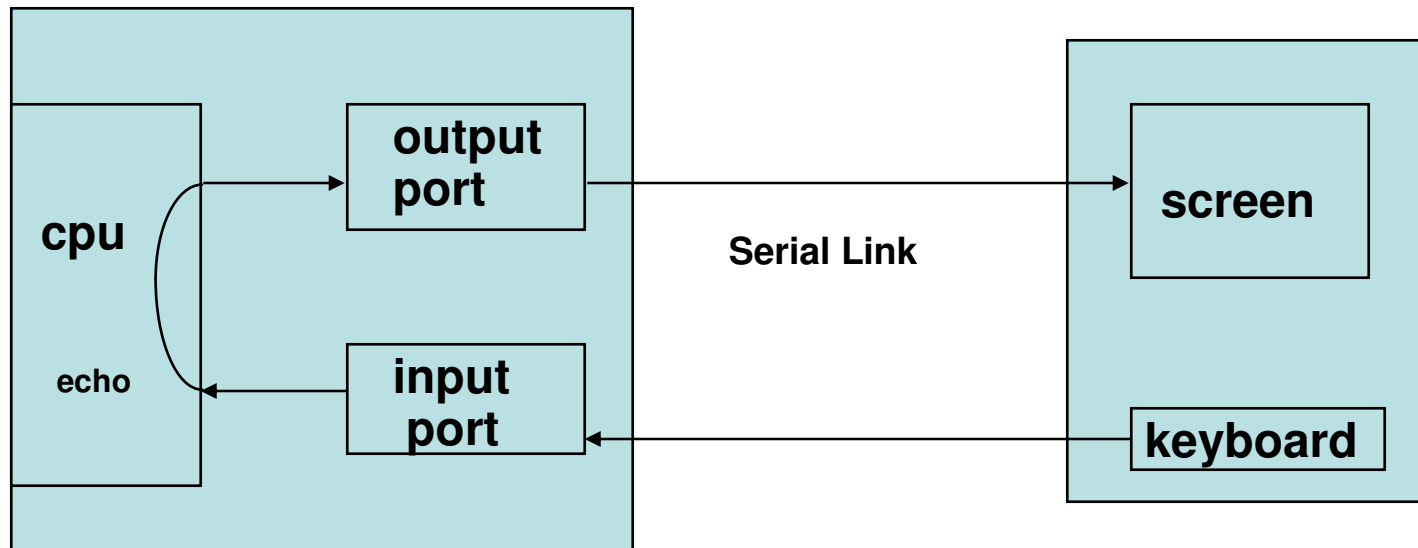
Serial Communication

Serial communications means that information is transmitted from source to destination over a single pathway.

Serial Data Links

A simplex serial data link transmits data in only one direction.

Usually, two serial data links are between a computer and terminal: one for transmission in each direction. This is called full-duplex operation.

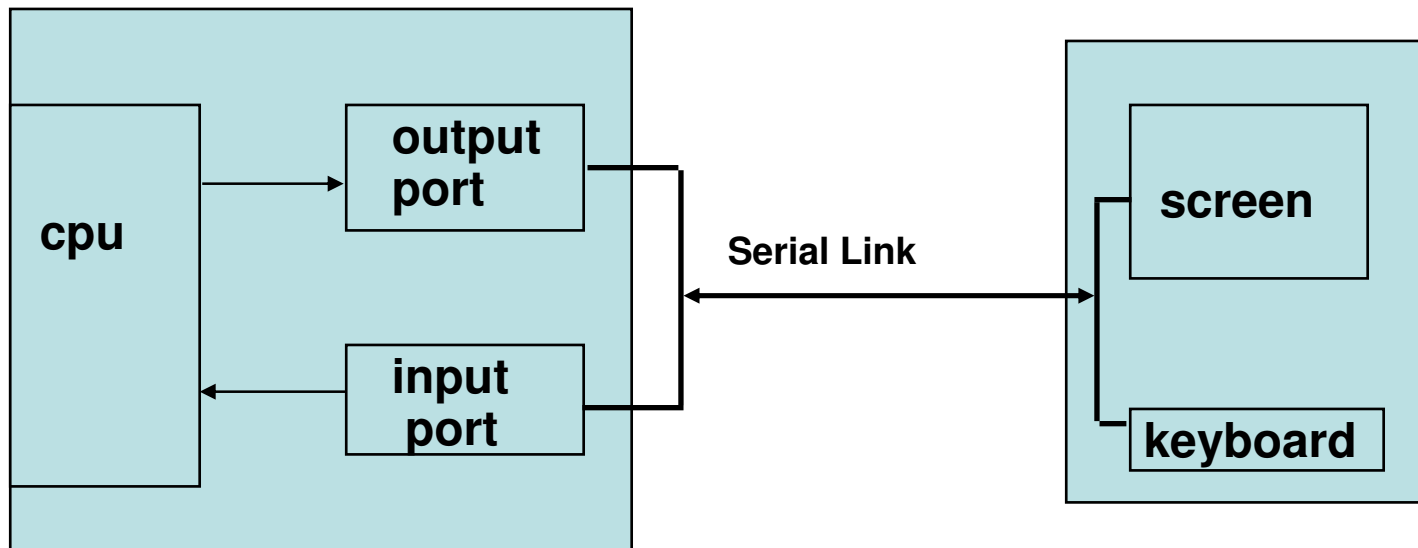


The computer echoes the character back to the terminal.

Serial Communication

With half-duplex operation, there is only one line for transmission and the characters are printed locally.

We can transmit in either direction, but it takes time to turn the line around.



- **Since digital data are transmitted as a stream of bits, synchronization is required between the source and destination of the data.**
 - **Asynchronous communication transmits one character at a time by adding start and stop bits to the character code.**
 - **Synchronous transmission transmits a block of data and a clock signal or known known bit pattern that can be used for synchronization.**
 - **A block number and check sum are also transmitted.**

ASCII

Character Encoding

- The asynchronously transmitted character is composed of
 - 5 to 8 data bits,
 - an optional parity bit, and
 - either 1, 1.5, or 2 stop bits.

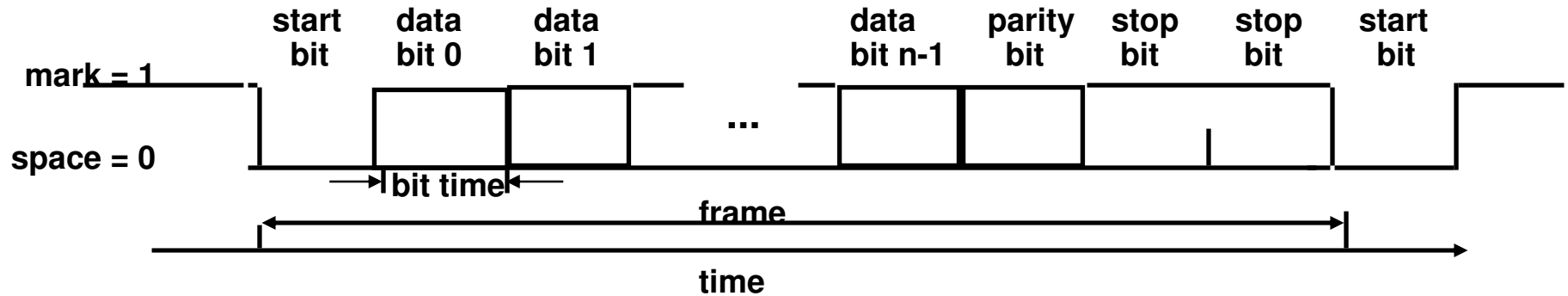
- The most used form of character encoding is the American Standard Code for Information Interchange (ASCII).
 - This is a seven bit code which allows for 128 characters.

 - Codes that are less than 20H are not alpha-numeric characters but control codes such as carriage return or backspace.

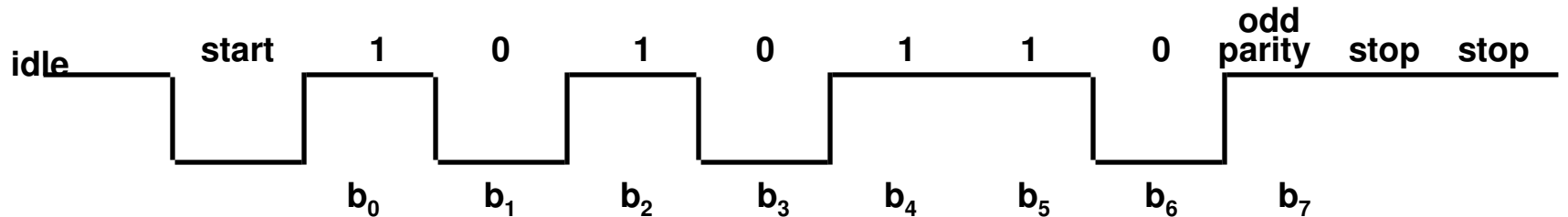
 - numbers 0 - 9 are encoded as 30H -39H.
 - capitol letters A - Z have codes 41H - 5AH , and
 - lower case letters a - z are 61H - 7FH.

- **When start and stop bits and a parity bit are added to the ASCII code, 9 to 11 bits are transmitted.**
- **The rate of transmission of a data bit stream in bits per second (bps or b/s) is called the bit rate.**
- **Standard bit rates are**
 - 110 (the old teletype or TTY rate),
 - 300 (early PC modems),
 - 1200, 2400, 9600, 14.4K, 19.2K, 28.8K, 38.4K, 57.6K, and 115.2 bps.

Character Transmission



General bit format for asynchronous serial data.



$$[b_7 \ b_6 \ b_5 \ b_4 \ b_3 \ b_2 \ b_1 \ b_0] = [1 \ 0 \ 1 \ 1 \ 0 \ 1 \ 0 \ 1]$$

↑ parity bit (set to produce an odd number of 1's.)

Typical transmission - 7 character bits plus parity. The character code is 35H which is the code for the number 5.

BAUD Rate

Data transmission rates are also specified in terms of baud rates.

A baud is a unit of signaling speed that is equal to the number of discrete events occurring per second.

The key idea here is that an event contains more than one bit of information.

Therefore, the baud rate can be less than the bit rate.

**With only two levels of logic the baud rate equals the bit rate.
However, inside a modem, the logic levels are converted to tones.**

- **A typical implementation is to transmit sine waves with different phases,**
 - e.g., $\sin(bt + 0\omega)$, $\sin(bt + 90\omega)$, $\sin(bt + 180\omega)$, and $\sin(bt + 270\omega)$.
- **The transmission can switch to any phase and since there are four possible phases, it takes two bits to code this information, i.e. $0\omega = 00$, $90\omega = 01$, etc.**
- **Detecting the phase at a particular time produces 2 bits of information.**
 - Therefore, the bit rate is twice as fast as the baud rate in this case.
- **A 9600 bps modem typically has a baud rate of 2400 baud.**
- **Transmission rates are sometimes referred to in units of characters/second.**
 - For example, if we have 10 bits/ character transmitted at 30 characters/sec., then the transmission rate is $(10 \text{ b/ch})(30 \text{ ch/s}) = 300 \text{ b/s}$.

RS - 232C

The TTL logic signals are not what is transmitted between equipment such as modems computers and terminals.

One standard that describes the signals for communicating is the RS-232C standard.

RS-232

Defined in early 1960s

Serial, Asynchronous, Full-duplex,

Voltage-based, point-to-point, 100 ft+ cables

+12V)
+3V) } SPACE = 0

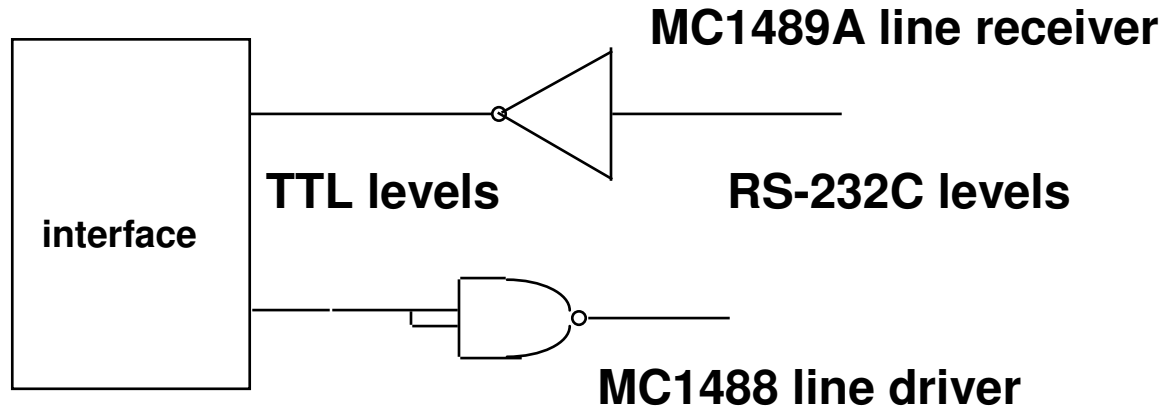
-3V)
-12V) } MARK = 1



- **This standard causes as much trouble as any standard you can name because it deals with two types of equipment,**
 - data communications equipment (DCE) and
 - data terminal equipment (DTE).
- **Typically, a modem is DCE and a terminal or computer is DTE.**
- **The problem is that the cable to connect DCE to DTE is different from the cable to connect DTE to DTE.**
- **Also, nonstandard use of the control signals is a problem.**
- **Murphy's law says that if you need to connect to a serial port, you always have the wrong cable.**

- **RS-232C specifies 25 signal pins with a**
 - male DTE connector and
 - a female DCE connector.
- **Most of these signals are not used in most applications so a 9 pin subset is used.**
 - Actually in some cases, only three wires are used.
- **The mark and space signals are inverted by the standard to the following levels:**
 - A logic high or mark is between -3 V and -15 V under load
 - A logic low or space is between +3 V and +15 V under load.
- **Typically, +12 and -12 volts are used.**
- **The voltage swing is > the TTL 5 volts for noise immunity.**

RS-232C



Signal Conversion to and from TTL and RS-232C levels.

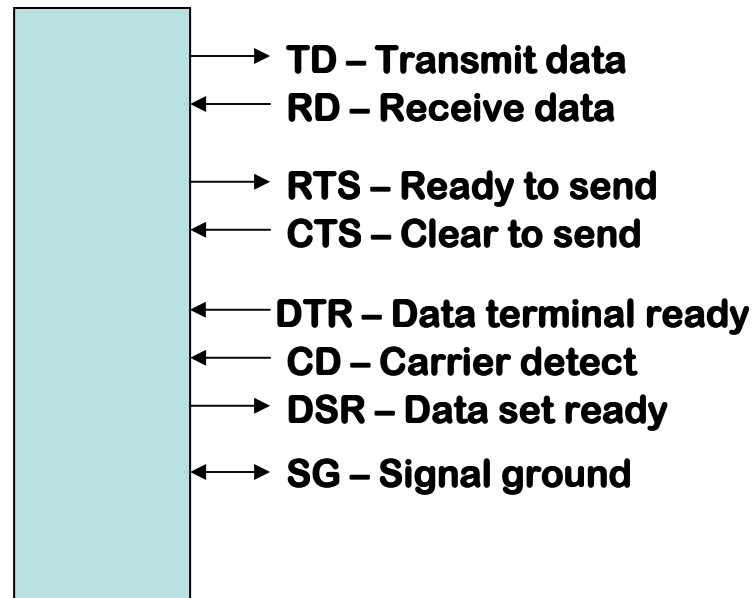
RS-232 Signals



Signal DB-9 DTE ... Meaning

	pin	DCE	
RxD	2	←	Data received by DTE
TxD	3	→	Data sent by DTE
SG	5	—	Ground
DSR	6	←	Data Set Ready (I'm alive)
DTR	4	→	Data Terminal Ready (me, too)
DCD	1	←	Carrier Detect (hear a carrier)
RTS	7	→	Request To Send (Yo?)
CTS	8	←	Clear To Send (Yo!)
RI	9	←	Ring Indicator

Serial ports – RS-232 standard

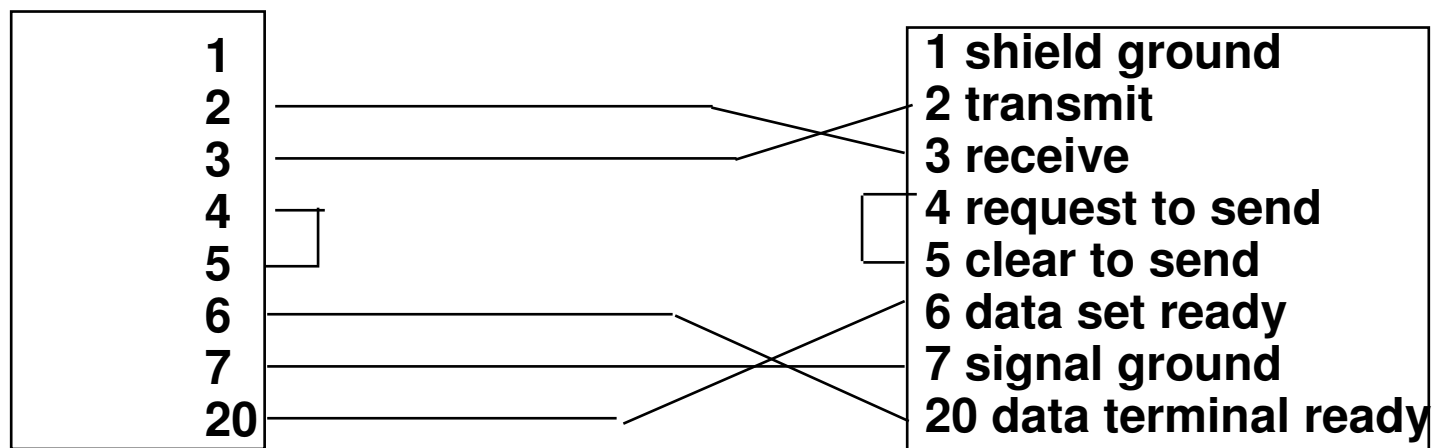


Signals for a DTE (Data Terminal Equipment – modem is a DCE (Data Communication Equipment))

Signal meanings – RS232

- Transmit data group
 - TD – transmit data – data from DTE to DCE
 - RTS – ready to send – DTE asserts before sending data and waits for CTS before sending
 - CTS – clear to send – DCE sends in response to RTS
- Receive data group
 - TD – transmit data – data from DCE to DTE
 - DSR – data set ready – DCE asserts before sending data and waits for DTR before sending
 - DTR – data terminal ready – DTE sends in response to DSR
 - CD – carrier detect – modem is receiving a carrier from a modem at other end
- SG – signal ground – common return for all lines
- Note: Not all manufacturers use the control lines

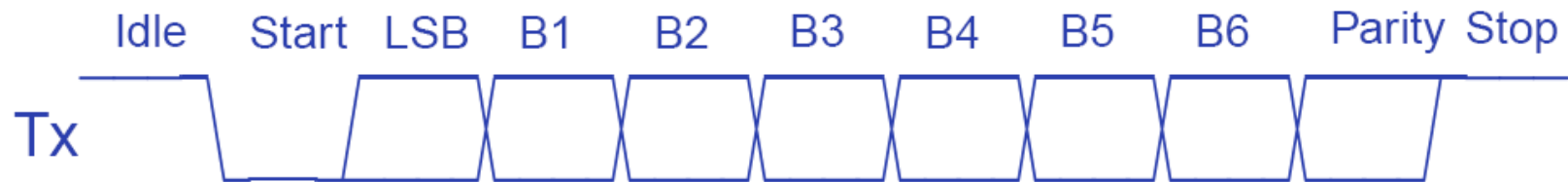
Connecting DTE to DCE equipment uses a straight through cable with wires connected to the proper pins. A DTE to DTE connection requires a null modem cable.



Null modem connection.

Variants

Parity bit: (Even = true when even number of 1s)



Two stop bits:



Baud: bits per second

Baud Application

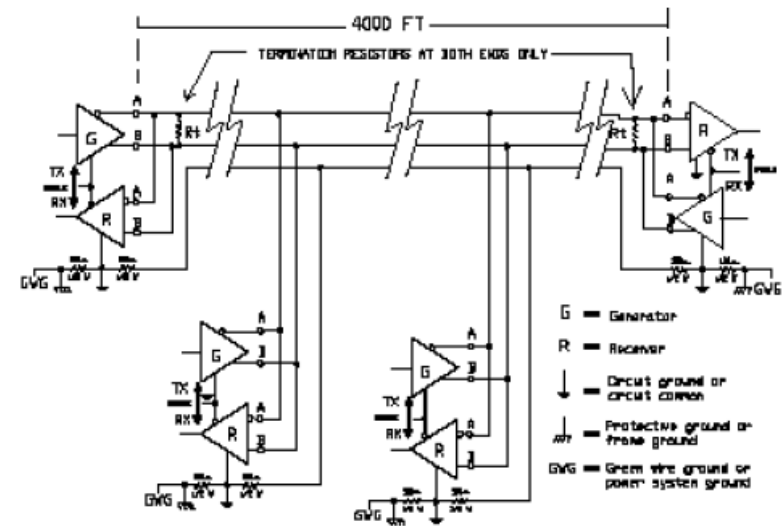
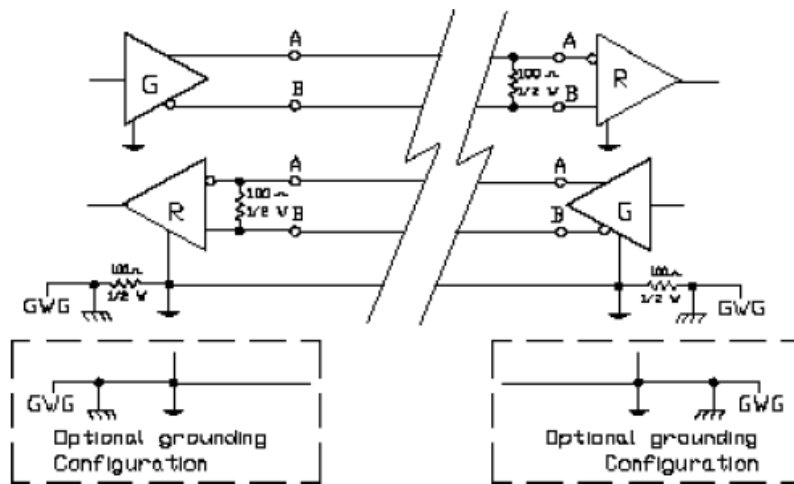
110	ASR-33 Teletype
300	Early acoustic modems
1200	Direct-coupled modems c. 1980
2400	Modems c. 1990
9600	Serial terminals
19200	
38400	Typical maximum

Physical Variants

Connectors: DB-25, DB-9, Mini DIN-8

RS-422: Differential signaling

RS-485: Bus-like



- **USART serial port**
 - **Universal Synchronous/Asynchronous Receiver/Transmitter**
- **Supports RS-232 or RS-485**

PIC17C4X Universal Synchronous Asynchronous Receiver Transmitter (USART)

- USART is a serial I/O module that can be configured as a full duplex asynchronous system or a half duplex synchronous system
- The USART has the following modes:
 - Asynchronous (full duplex)
 - Synchronous - Master (half duplex)
 - Synchronous - Slave (half duplex)
- The USART can communicate using a number of different protocols:
 - RS232
 - SPI
 - Microwire
 - I²C

PIC Peripherals: USART: UART

- Serial Communications Peripheral: Universal Synchronous/Asynchronous Receiver/Transmitter
- Only available in 14bit and 16bit cores
- Interrupt on TX buffer empty and RX buffer full
- Asynchronous communication: UART (RS-232C serial)
 - Can do 300bps - 115kbps
 - 8 or 9 bits, parity, start and stop bits, etc.
 - Outputs 5V so you need a RS232 level converter (e.g., MAX232)

PIC Peripherals: USART: USRT

- Synchronous communication: i.e., with clock signal
- SPI = Serial Peripheral Interface
 - 3 wire: Data in, Data out, Clock
 - Master/Slave (can have multiple masters)
 - Very high speed (1.6Mbps)
 - Full speed simultaneous send and receive (Full duplex)
- I²C = Inter IC
 - 2 wire: Data and Clock
 - Master/Slave (Single master only; multiple masters clumsy)
 - Lots of cheap I²C chips available; typically < 100kbps
(For example, 8pin EEPROM chips, ADC, DACs, etc.)