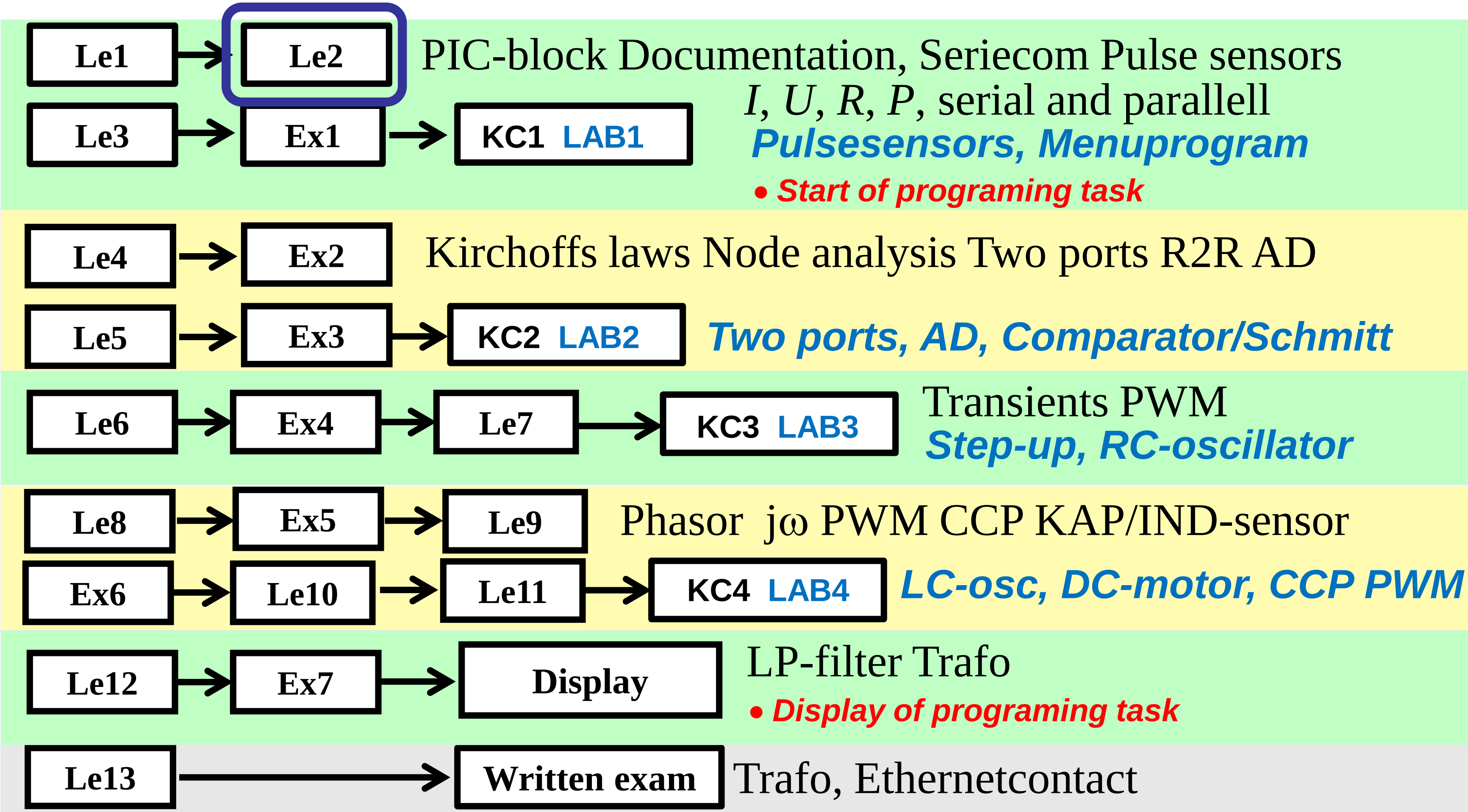
IE1206 Embedded Electronics



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Communication

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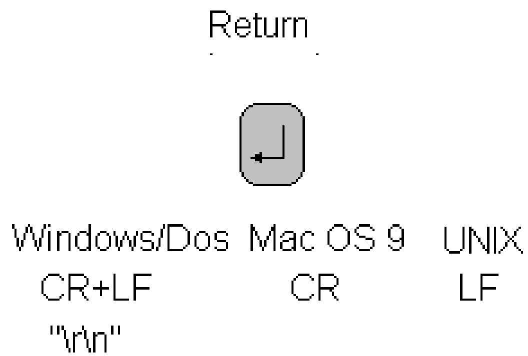
ASCII-table

	0	1	2	3	4	5	6	7
0	NUL	DLE	space	0	@	P	`	p
1	SOH	DC1 XON	!	1	A	Q	a	q
2	STX	DC2	"	2	B	R	b	r
3	ETX	DC3 XOFF	#	3	C	S	c	s
4	EOT	DC4	$	4	D	T	d	t
5	ENQ	NAK	%	5	E	U	e	u
6	ACK	SYN	&	6	F	V	f	v
7	BEL	ETB	'	7	G	W	g	w
8	BS	CAN	(	8	H	X	h	x
9	HT	EM	)	9	I	Y	i	y
A	LF	SUB	*	:	J	Z	j	z
B	VT	ESC	+	;	K	[	k	{
C	FF	FS	,	<	L	\	l	|
D	CR	GS	-	=	M	]	m	}
E	SO	RS	.	>	N	^	n	~
F	SI	US	/	?	O	_	o	del

Every letter is stored in a **Byte**, **char**.

”Hej!”
48 65 6A 21 00
01001000 01100101 01101010
00100

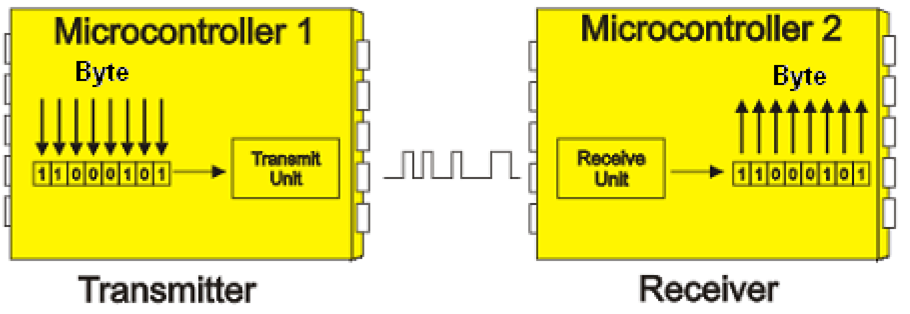


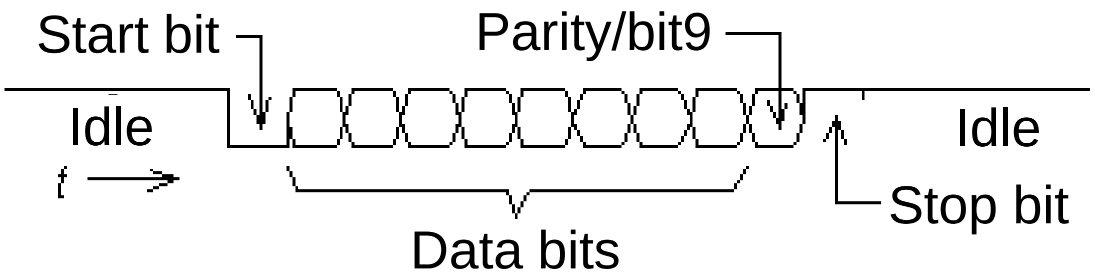
http://ascii-table.com/

PICKit 2 UART Tool uses **\r\n**

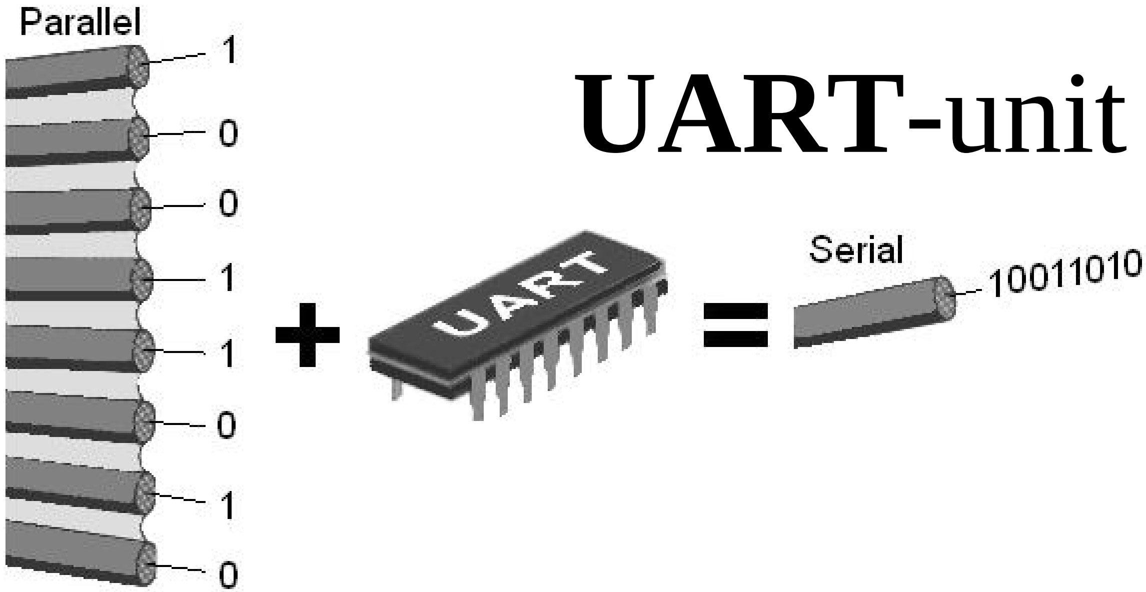
Serial communication

parallell-serial-parallell conversion





UART-unit



The serial/parallel conversion on a bit level is often taken care of with a special circuit called UART (Universal Asynchronous Receiver/Transmitter), so that the processor can deliver/receive full characters.

Such unit is built into most PIC processors (USART/EUSART).

Serial communication unit

Independently run serial communication unit

FIGURE 12-1: EUSART TRANSMIT BLOCK DIA

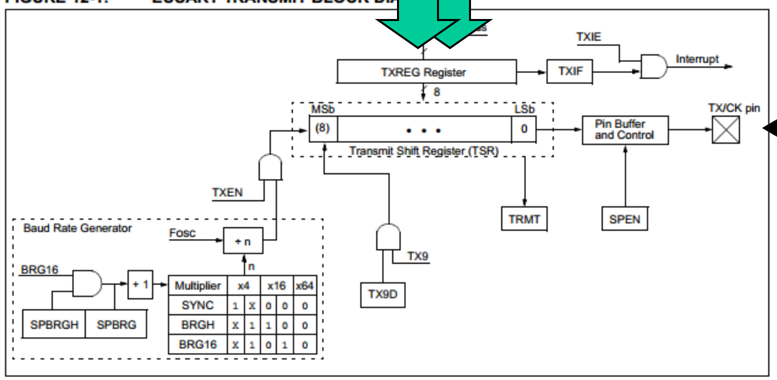
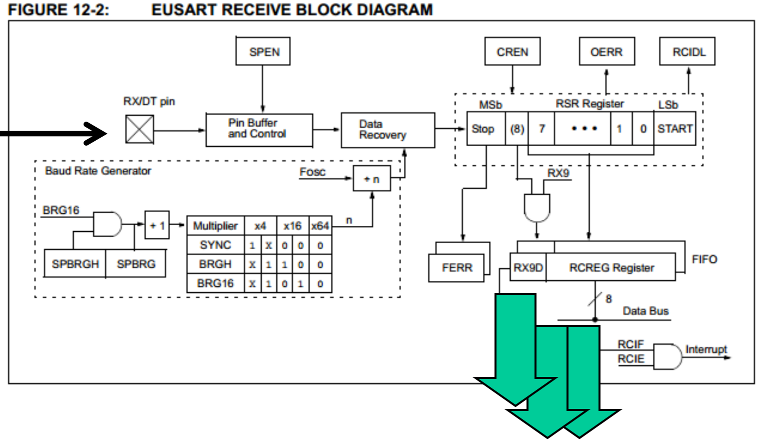


FIGURE 12-2: EUSART RECEIVE BLOCK DIAGRAM



The transmitter can hold two characters in the queue from the processor.

The receiver can receive up to three characters before the processor needs to act.

During communication, the processor can do other things!

PIC16F690 EUSART

PIC 16F690 contains a built-in serial communication unit, EUSART (Enhenced Universal Synchronous or Asynchronous Receiver and Transmitter).

As the name implies, this device is useful for both synchronous and asynchronous serial communication, but we will only use it for asynchronous serial communications.

EUSART consists of three parts.

- **SPBRG** (Serial unit Programable BaudRateGenerator) is a programable Baudgenerator for the transmission speed.
- **USART Transmitter** is the transmitter part.
- **USART Reciever** is the reciever part.

Bitrate

In serial communication, it is necessary that the transmitter and receiver are operating with the same in advance agreed upon rate. The rate at which bits are transferred is called the **Bitrate** [bit/sec].

Frequently used Bitrate's are multiples of 75 bit/sek as: 75, 150, 300, 600, 1200, **9600**, 19200 och 38400 bit/sek.

Bitrate clock is taken from a baud rate generator.

Baud Rate Generator **BRG**

REGISTER 12-1: TXSTA: TRANSMIT STATUS AND CONTROL REGISTER

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R-1	R/W-0
CSRC	TX9	TXEN[1]	SYNC	SENDB	BRGH	TRMT	TX9D
bit 7							bit 0

REGISTER 12-3: BAUDCTL: BAUD RATE CONTROL REGISTER

R-0	R-1	U-0	R/W-0	R/W-0	U-0	R/W-0	R/W-0
ABDOVF	RCIDL	—	SCKP	BRG16	—	WUE	ABDEN
bit 7							bit 0

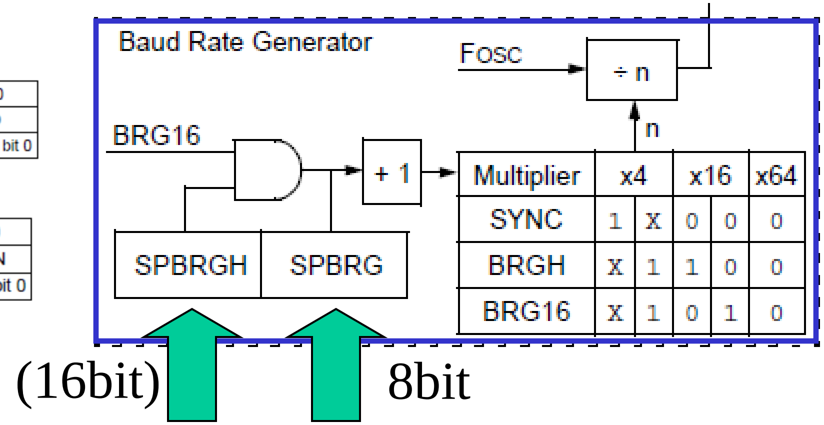


TABLE 12-3: BAUD RATE FORMULAS

Configuration Bits		BRG/EUSART Mode	Baud Rate Formula
BRG16	BRGH		
0	0	8-bit/Asynchronous	Fosc/[64 (n+1)]
0	1	8-bit/Asynchronous	Fosc/[16 (n+1)]
1	0	16-bit/Asynchronous	
1	1	16-bit/Asynchronous	Fosc/[4 (n+1)]

One bit **BRGH** determines the low-speed or high-speed mode. One bit **BRG16** introduces 16-bit divisor.

- *Our settings:*

```
/* 9600 Baud @ 4 MHz */
BRG16=0; BRGH=1; SPBRG = 26-1;
```

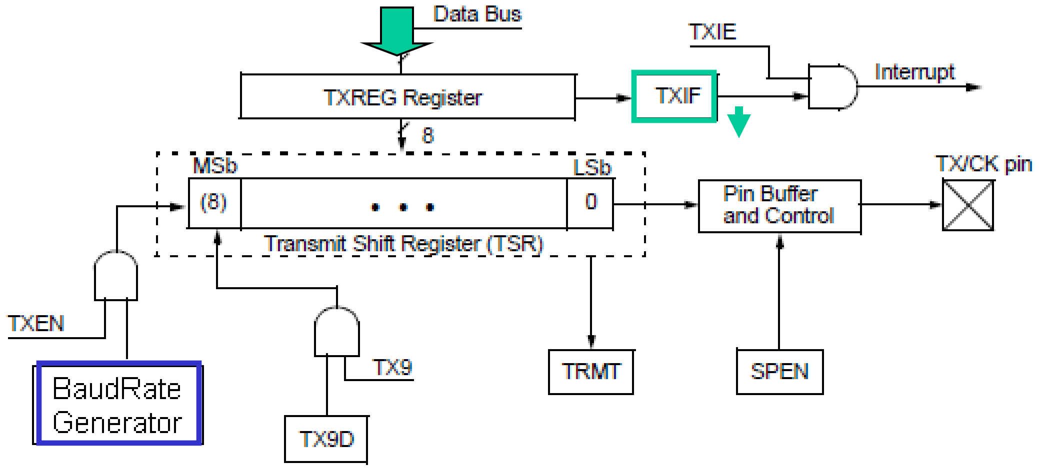
A register **SPBRG** contains a divisor 8/16-bits.

Baud Rate Generator **BRG**

The extensive setting options are there to be able to find a combination that gives the most accurate bitrate as possible.

Two processors that communicate asynchronously with each other must have Bitrate's that conforms better than ±2,5%. Otherwise you risk the communication to be distorted.

Transmitter



To send a character, it is enough to put it in the **TXREG** register. When the transmitterregister TSR is "redy" the character is copied to this and is shifted out serial on the pin TX/CK. If there is If you have a further character to send you can now put it in the "waiting queue" for TXREG. As fast as TSR is empty the next character will be loaded from TXREG automaticaly to TSR.

In the blockdiagram the flag **TXIF** (Transmitter Interupt Flag) will tell if the transmitter register TXREG is full or not. The flag is zeroed automatically when a character is loaded to TSR.

Transmitter settings

REGISTER 12-1: TXSTA: TRANSMIT STATUS AND CONTROL REGISTER

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R-1	R/W-0
CSRC	TX9	TXEN[(1)]	SYNC	SENDB	BRGH	TRMT	TX9D
bit 7							bit 0

bit 6 = 0 **TX9**: No nine bit transmission.

bit 5 = 1 **TXEN**: Transmit Enable bit. Must be on.

bit 4 = 0 **SYNK**: Usart mode select bit. We chose ***asynchronous*** operation.

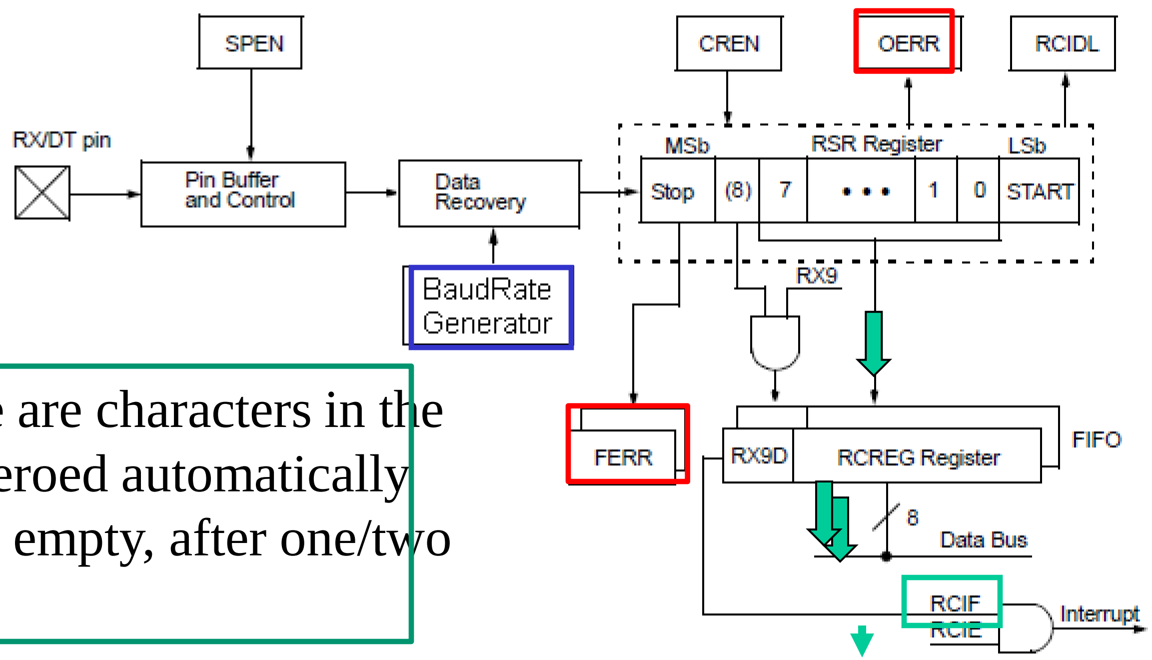
bit 2 = 1 **BRGH**: High Baudrate select bit. We chose high speed mode.

bit 1 TRMT: Flag is ”1” if TSR is empty.

Reciever

Characters received from the pin RX/DT to the reciever register RSR. When the reception of a character is done it is brought over to **RCREG** which is a FIFO-buffer. This buffer contains two characters that are read in the order they arrived.

The buffer means that a program can do other things during the time it takes to receive three characters.



The flag **RCIF** tells if there are characters in the buffer or not. This flag is zeroed automatically when the buffer is read and empty, after one/two characters.

Flags OERR, FERR warns for erroneously received characters

Reciever settings

REGISTER 12-2: RCSTA: RECEIVE STATUS AND CONTROL REGISTER[1]

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R-0	R-0	R-x
SPEN	RX9	SREN	CREN	ADDEN	FERR	OERR	RX9D
bit 7							bit 0

bit 7 = 1 **SPEN**: Enables the serieal port.

bit 6 = 0 **RX9**: No recieve of nine bit.

bit 4 = 1 **CREN**: Continuous Receive Enable bit. Use the buffer.

bit 2 and **bit 1** **FERR OERR** Flags for erroneously received characters.

The bit/bitvariabele **RCIF** indicates when there are characters to fetch.

Initiation of the serieal port

```
void initserial( void )
/* initialise serialcom port 16F690  */
{
  SPEN = 1;
  BRGH = 1; /* Async high speed      */
  BRG16= 0; /* SPRG n is 8-bit       */
  TXEN = 1; /* transmit enable       */
  SPBRG = 26-1; /* 9600 Baud @ 4 MHz */
  CREN = 1; /* Continuous receive    */
  RX9 = 0;  /* 8 bit reception       */
  TRISB.7 = 0; /* TX is output       */
  TRISB.5 = 1; /* RX is input        */
}
```

- Done once in the beginning of program.

Seriecom-functions

```
char getchar( void ) /* recieves one char */
{
  char d_in;
  while ( !RCIF ) ;  /* wait for char  */
  d_in = RCREG;
  return d_in;
}
```

Note! Blocking function!

Here you will wait until a character is received!

```
void putchar( char d_out ) /* sends one char   */
{
  /* wait until previous character transmitted */
  while (!TXIF) ;
  TXREG = d_out;
}
```

Warning! Recievern can lock!

The program must read the receiver unit before it has received three characters - otherwise it lock itself!
When connecting the serial connector one may "trembles" on hand such that the "contact bounces" becomes many characters received. If the receiving device then "freezes" this is obviously a very difficult/impossible "bug" to find!

The solution is an unlocking routine to use if necessary. You should call such a unlocking routine directly before you expects input via the serial port.

OverrunRecover()

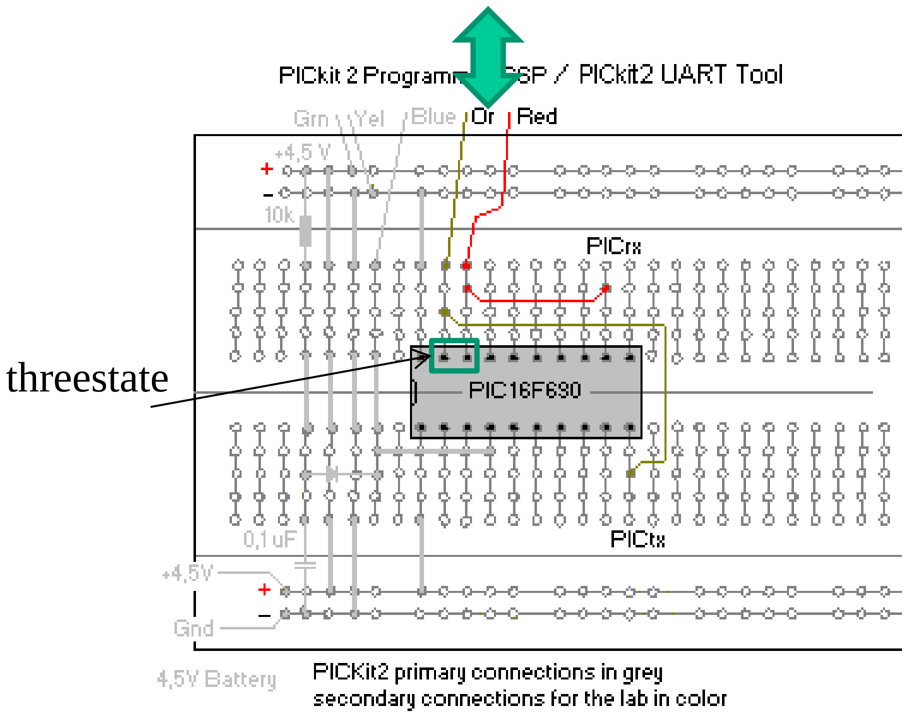
```
void OverrunRecover( void )
{
  char trash;
  trash = RCREG;
  trash = RCREG;
  CREN = 0;
  CREN = 1;
}
```

- *Unlocking procedure.*

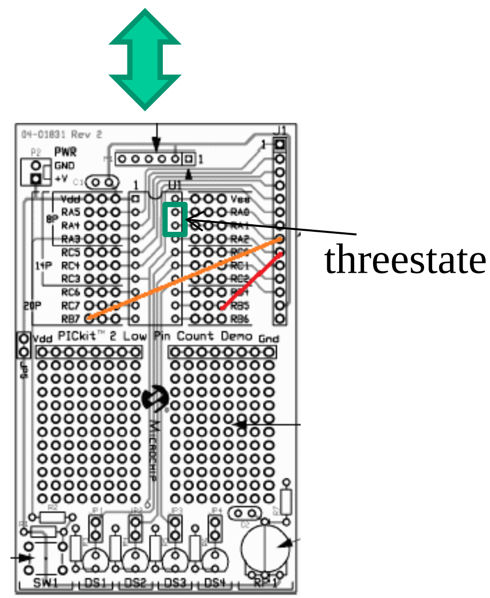
> **Note:** If the receive FIFO is overrun, no additional characters will be received until the overrun condition is cleared. See ***Section 12.1.2.5 "Receive Overrun Error"*** for more information on overrun errors.

Seriecom - **Hardware**

1) PICKIT 2 UART Tool by the programing wires



Or and Red jumpers for PICkit2 UART Tool



Jumpers on the starterkit

Place jumpers between PIC-processorn **serial port** to the **programing wires** (**Or**, **Red**).

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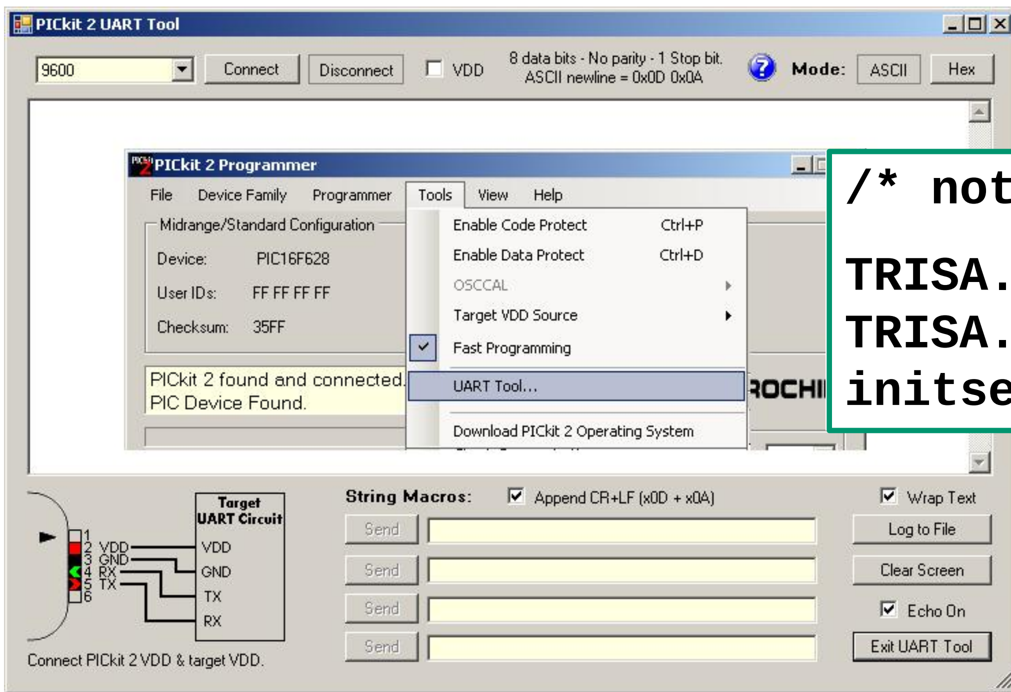
Seriecom – **Console program**

1) PICKIT 2 UART Tool, can be used as a console program through the programing wires.

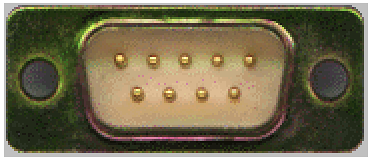



```
/* not disturb UART-Tool */

TRISA.0 = 1;
TRISA.1 = 1;
initserial();
```

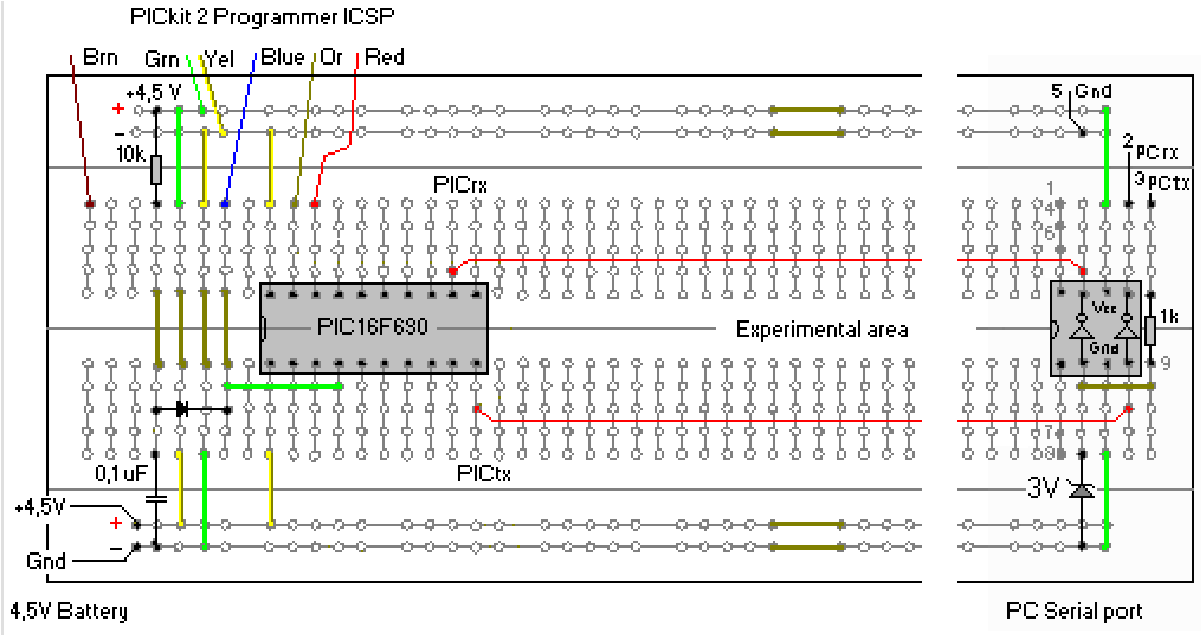
Threestate on the programing wires!

Seriecom - **Hardware**



PC-serieport

2) PC with serial port



Inverter

ICL7667

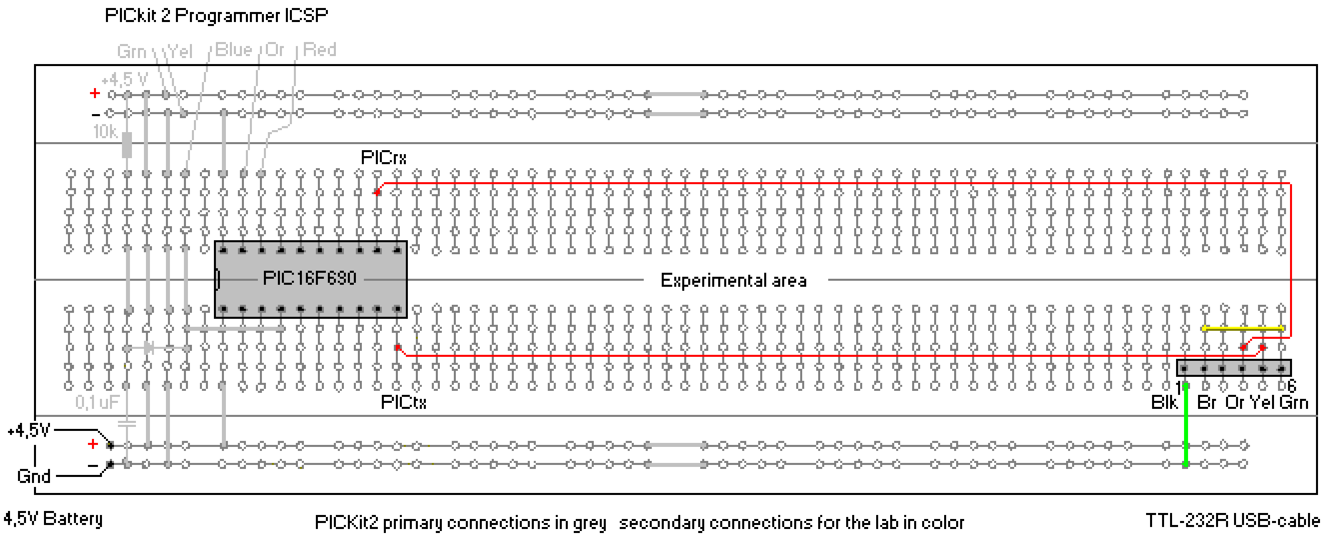
Invert signals to/from PIC-processor serial port before it is connected to PC serial port. (Should be ±12V, but inverters use to be enough).
(There are special circuits that generate ±12V signals for serial communication.)

Serial communication **USB-serial-TTL**

Noninverted logic levels

Most PC lacks nowadays serial port, a driver can install a virtual USB serial port.

The driver is now already in Windows

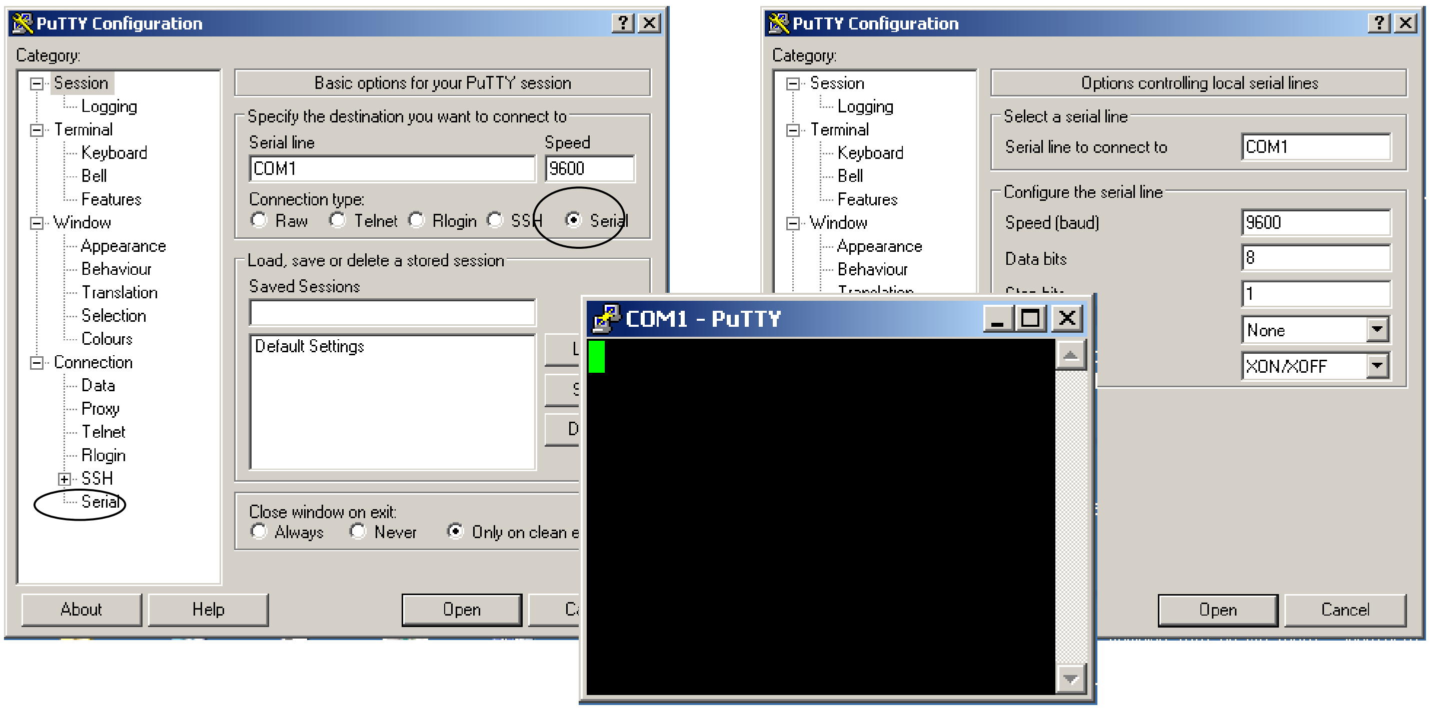


FTD Chip

3) FTDI TTL232R connects ***directly*** to the processor pins.

Console program to **PC**

If you uses a USB-virtual serial port – first find out the COM port number (with Device / Device Manager)…



PuTTY

PuTTY

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Testprogram: **echo()/crypto()**

If PIC-processor "echoes" the characters so does the communication work.

```
void main( void)
{
  char c;
  TRISB.6 = 1; /* not to disturb UART-Tool */
  TRISB.7 = 1; /* not to disturb UART-Tool */
  initserial();
  delay10(100); /* 1 sek delay */
  /* 1 sek to turn on VDD and Connect UART-Tool */
  while( 1)
   {
     c = getchar( ); /* input 1 character */
     if( c == '\r'||c == '\n')
      putchar(c);
     else putchar(c); /* echo the character */
     /* putchar(c+1) => Crypto! */
   }
}
```

Safer version: crypto ! **A→B**

Serial communication directly, with with an optional pin!

Bit-banging

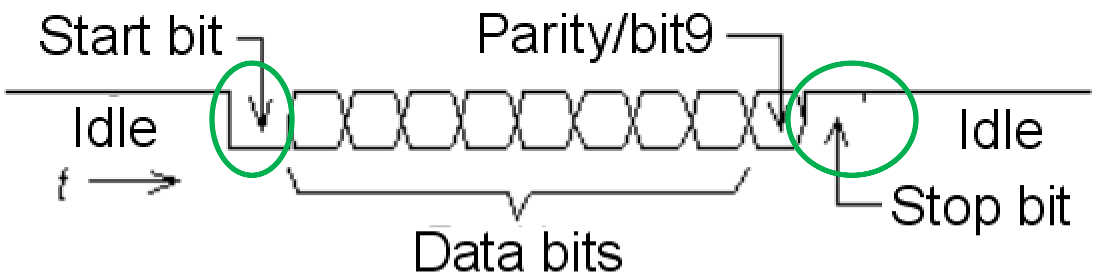
It is very common to program serial communication "bit by bit". Any port pin can be used. This is a very good debugging tool.

A suitable bitrate is then **9600**. T = 1/9600 = 104.17 µs. If the processor's clock frequency is 4 MHz a delay loop that takes 104 instructions is needed.

```
/* delay one bit 104 usec at 4 MHz        */
/* 5+18*5-1+1+9=104 without optimization */
i = 18;
do ;
while( --i > 0);
nop();
```

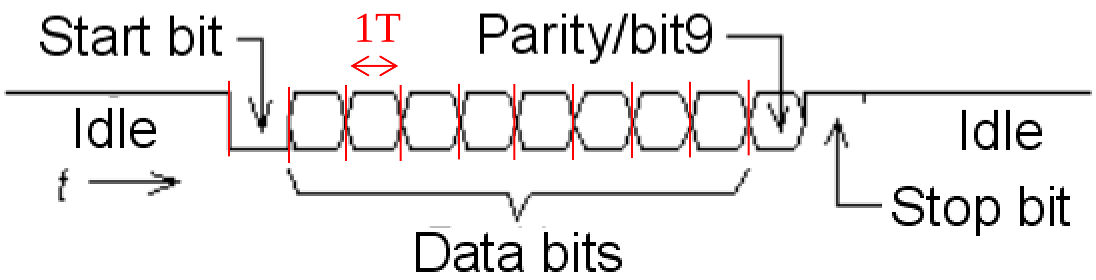
Loock at the assembly code and count the instructions. Every instruction takes 1 µs.

Bits and extra bits



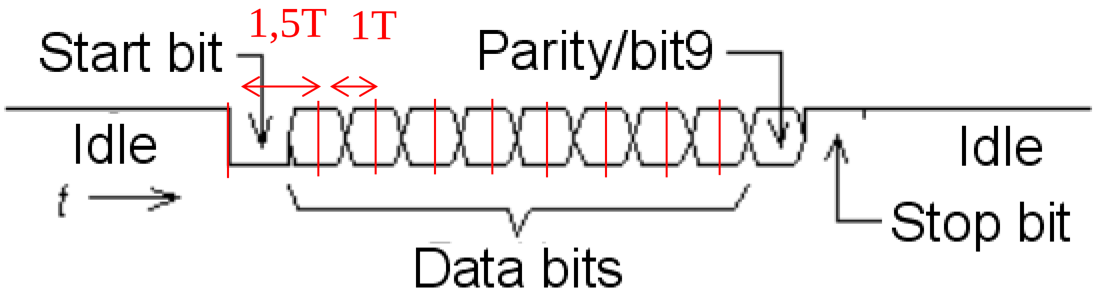
The asynchronous transfer technique means that for every byte one adds extra bits that will make it possible to separate out the byte from the bitstream. Often you in addition put in a bit for error indication.

Send a character …



- The data transfer starts with the data line is held low "0" during a time interval that is one bit long (T = 1/bitrate). This is ***start bit***.
- During 8 equally long time interval then follows the data bits, ones or zeros, with the least significant bit first and the most significant bit last.
- (Thereafter *could* a ***parity bit*** follow, an aid in the detection of transmission errors.)
- The transfer ends finally to the data line for at least one bit interval is high. This is the ***stop bit***.

Recieve a character



The reception of data is done by first waiting for the start bit negative edge, and then register the first data after 1.5T delay and then the next data bits after 1T (registration at the data bits "midpoints").

The receiver is ”resynchronized" again at every start bit edge.

Rotation av numbers

RLF	Rotate Left f through Carry
Syntax:	[*label*] RLF f,d
Operands:	$0 \leq f \leq 127$ $d \in [0,1]$
Operation:	See description below
Status Affected:	C
Description:	The contents of register 'f' are rotated one bit to the left through the Carry flag. If 'd' is '0', the result is placed in the W register. If 'd' is '1', the result is stored back in register 'f'.

Words:	1
Cycles:	1
<u>Example:</u>	`RLF REG1,0`

Before Instruction

```
REG1   =   1110 0110
C      =   0
```

After Instruction

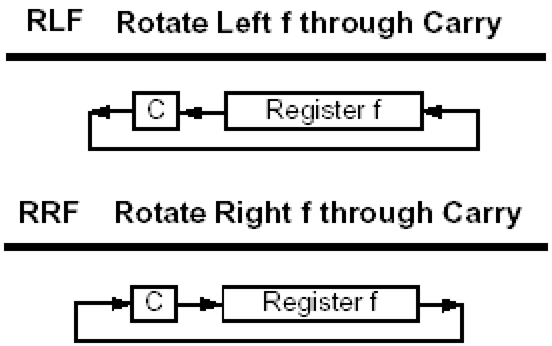
```
REG1   =   1110 0110
W      =   1100 1100
C      =   1
```

RRF	Rotate Right f through Carry
Syntax:	[*label*] RRF f,d
Operands:	$0 \leq f \leq 127$ $d \in [0,1]$
Operation:	See description below
Status Affected:	C
Description:	The contents of register 'f' are rotated one bit to the right through the Carry flag. If 'd' is '0', the result is placed in the W register. If 'd' is '1', the result is placed back in register 'f'.

PIC-processors has two instruktions for "rotate" numbers **RLF** and **RRF**.

These instructions, we need in the future…

Cc5x has ***internal*** functions **rl()** and **rr()**




```
char rl( char );
```

```
char rr( char );
```

C language has two shift operators shift right **`>>`** and shift left **`<<`** , no actual "rotate" -operator does not exist.

In order to nevertheless be able to use PIC processors' rotation instructions, the compiler **Cc5x** has added two ***internal*** functions **`char rl( char );`** and **`char rr( char );`**.
These functions directly generates assembly instryctions **`RLF`** and **`RRF`**.

The Carryflag is reached as a internal bit variable **`bit Carry;`**

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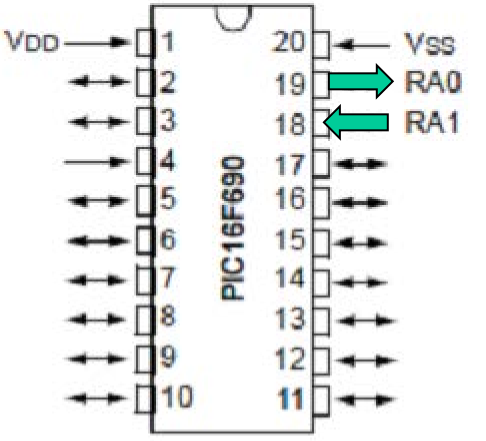
Debug-comunication

Chip-programing **and** comunication.

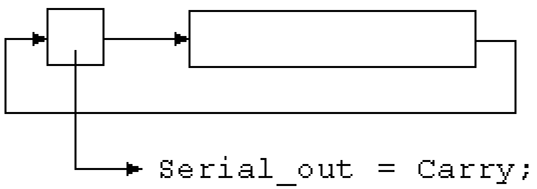


PICKit2 UART-tool can be used as a simple debuging tool. The same wires that are used for the chip programming are used by the UART-tool for serial communication.

What is needed is therefore a bitbanging-routine for serial communication with these pins.

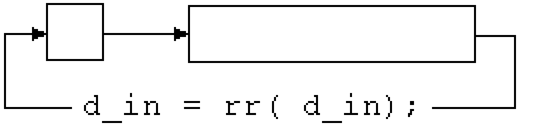
```
void initserial( void ) /* init PIC16F690 serialcom */
{
  ANSEL.0 = 0; /* No AD on RA0 */
  ANSEL.1 = 0; /* No AD on RA1 */
  PORTA.0 = 1; /* marking line */
  TRISA.0 = 0; /* output to PK2 UART-tool  */
  TRISA.1 = 1; /* input from PK2 UART-tool */
}
```

void putchar(char)




```
void putchar(char d_out)
{ char count, i;
  Serial_out = 0; /* set startbit */
  for(count = 10; count > 0; count--)
    { /* delay 104 usec            */
      i = 18; do ; while( --i > 0); nop();
      Carry = 1;
      d_out = rr(d_out);
      Serial_out = Carry;
    }
}
```

char getchar(void)



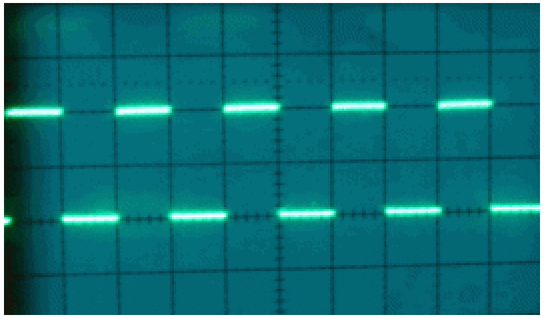

```
char getchar( void )
{
  char d_in, count, i;
  while( Serial_in == 1) /* wait for startbit */;
  /* 1.5 bit 156 usec no optimization         */
  i = 28; do ; while( --i > 0); nop(); nop2();
  for(count = 8; count > 0; count--)
    {
      Carry = Serial_in;
      d_in = rr( d_in );
      /* 1 bit 104 usec no optimization       */
      i = 18; do ; while( --ti > 0); nop();
    }
  return d_in;
}
```

Testprogram: **squarewave**

You can check if the bitrate is correct with an oscilloscope.

9600 bit/sek. If you transmitts continuously 8 bit with **start bit** and **stop bit** the letter ’**U**’ (1010101010) you will get a squarewave with *f* = 4800 Hz. This test is useful to know.

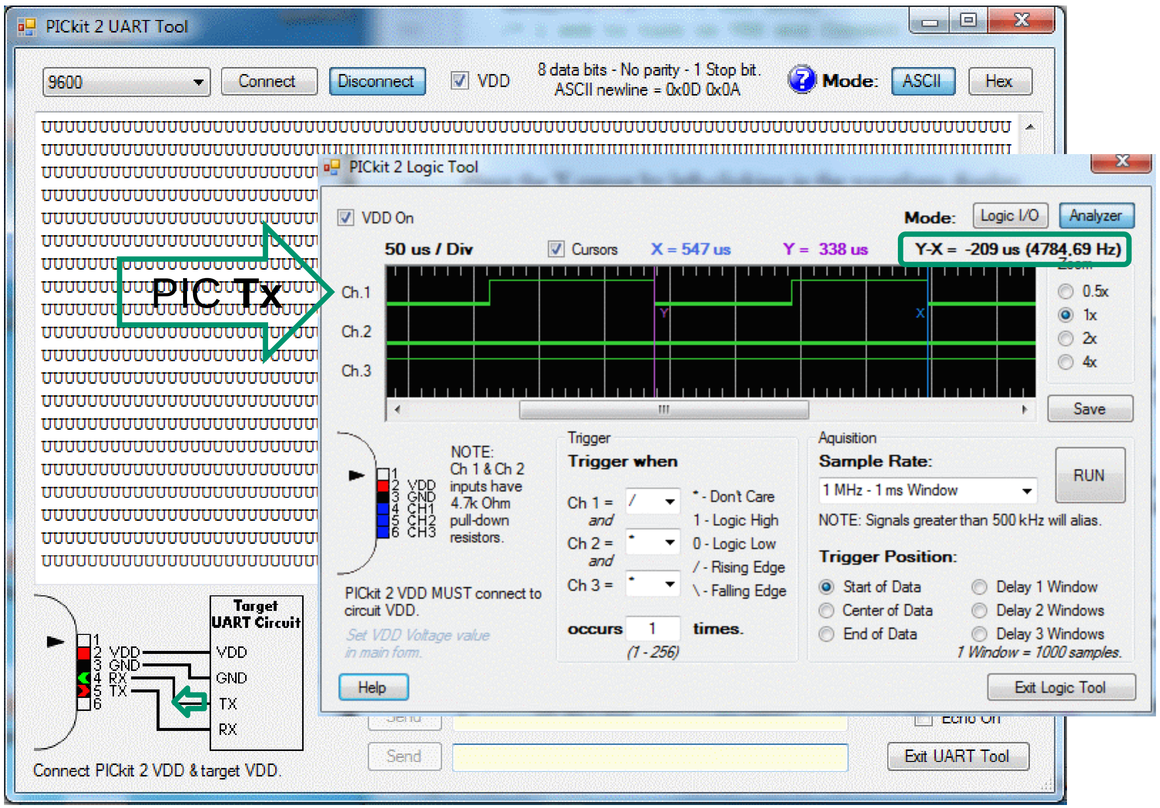
```
while(1) putchar('U');
```



If you don't have any oscilloscope?

```
while(1) putchar('U');
```

PICKit2 Logic Tool



We can see details such as that the stop bit are a little longer than the other bits.
To measure the frequency, click the markers in place with left and right mouse buttons. The frequency is 4785 Hz (≈4800).