
Software UART using ST7LITE0 12-bit autoreload timer

Introduction

This application note describes a software implementation of a Universal Asynchronous Receiver/Transmitter (UART). This can be used on devices with no on-chip SCI peripheral.

In this example, a software UART is implemented for the ST7LITE0, using the 12-bit Autoreload timer and two I/O ports for asynchronous receive and transmit. The UART software provides the following features:

- Half-duplex operation
- Asynchronous operation
- Flexible data formats (7 or 8 data bits, 1 or 2 stop bits)
- Baud rate: 2400 to 19200 baud

To test this interrupt-driven software UART, you can use the “Hyperterminal” application running on a Windows PC.

The program code is quite small (357 bytes) and can easily be adapted to specific application requirements.

[Table 1](#) lists the microcontrollers and software concerned by this application note.

Table 1. Applicable products and software

Type	Part numbers or product categories
Microcontrollers	ST7LITE02Y0, ST7LITE05Y0, ST7LITE09Y0
Software	STSW-ST7094

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1 UART communication

The main features of a standard UART are summarized below.

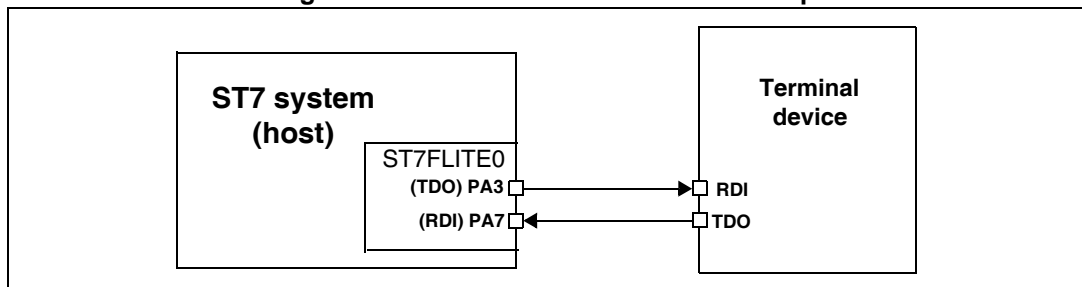
1.1 Main features

The UART offers a flexible means of full-duplex data exchange with external equipment requiring an industry standard NRZ asynchronous serial data format.

The UART allows a very wide range of baud rates and different baud rates for transmission and reception.

In UART communication, a minimum of only two signals are needed, one for transmission and one for reception. No clock signal is needed as it works in asynchronous mode. Each device has to have a Transmit Data Output pin (the PA3 pin is used in our example for the ST7FLITE0) and a Receive Data Input pin (PA7 pin in our example). (Refer to [Figure 1](#).)

Figure 1. ST7 UART communication set-up



You must be very careful to identify the use of each pin. A simple method is to put the device in transmission and check with an oscilloscope if a transmission frame is present or not.

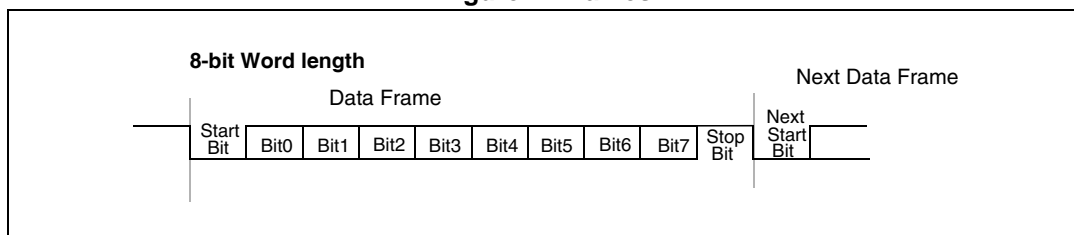
1.2 Baud rate

Transmission and reception can be driven by their own baud rate generator. However, be aware that, for a correct communication, the receiver must have a reception baud rate strictly equal to the transmission baud rate of the transmitter. If not, the communication will be corrupted. As long as this condition is met, a wide range of baud rates is possible.

1.3 Frame

Any transmission is Least Significant Bit first. A data word is usually 8 bits long. A data frame begins with a «start bit», which is a '0' bit and ends with a stop bit, which is a '1' bit (see [Figure 2](#)).

Figure 2. Frames



In some cases, a 9th bit can be used, as a parity bit or as a second stop bit.

2 RS232 communication with a PC

2.1 Main features

Electrical and protocol characteristics of RS232 are different from those used by the UART. In RS232 communication, high level is typically +7V and low level is typically -7V, while the ST7LITE0 I/Os work at CMOS levels (0, +5V).

Furthermore, the polarities are different. A '1' bit coming from the UART corresponds to a '0' bit in RS232, and a '0' bit to a '1' bit. It is true for all bits including the start and stop bits. So it is necessary to implement a conversion between the PC and the ST7LITE0. In the application, a MAX232 is used for this purpose.

2.2 PC configuration

The PC will be used as a terminal interface. "Hyperterminal", the terminal application software, is used as an interfacing software to test the function [.zip file attached]. The test environment is Windows.

Under Windows, open the Hyperterminal application. To configure it, go to the port settings and set the parameters to your application requirements. The options in this window must be the same as the ones defined for your ST7LITE0 communication device, except the port.

After selecting the right serial communication port, select the same baud rate as the one set for the ST7LITE0. As the PC accepts only one baud rate, transmission and reception baud rates will have the same value. Data word can be 8/7 bits, but you can choose to use 1 or 2 stop bits.

«Flow control» can be either Xon/Xoff or none. The PC is then correctly configured.

3 ST7FLITE0 configuration

3.1 Clock source

This application is implemented using an ST7FLITE0 device with an 8 MHz internal clock. PLL * 8 is used to generate this 8 MHz clock.

3.2 Input initialization

Two pins of the ST7FLITE0 are used:

- PA3: pin of PortA
- PA7: pin of PortA with interrupt

Pin PA3 is a normal input/output port pin with no alternate function, used for transmission. During the initialization, it is configured as an output.

Pin PA7 is a normal input/output port pin with no alternate function, used for data receive. During the initialization, it is configured as an input. While in receive mode, at start, the same pin is used with interrupt enabled (“ei1”) to sense the start bit. So this pin is configured with “pull up interrupt input” by setting PADDR to 0 & PAOR to 1. To set the interrupt sensitivity “Falling edge only”, you have to set IS11=1 & IS10=0 in the EICR register.

Refer to the device datasheet for a detailed description of the I/O and interrupt control registers.

3.3 Auto-reload timer register configuration

The AT timer is based on a free running 12-bit upcounter with 12-bit auto reload register (ATR). Apart from this, it also includes other functions such as PWM signal generator, Output Compare Function, etc.

The “Output Compare” function is used for this application. To use it, the OE bit must be 0, otherwise the compare is done with the shadow register instead of the DCRx register. The software must then write a 12-bit value in the DCR0H and DCR0L registers. When the 12-bit upcounter (CNTR) reaches the value stored in the DCR0H and DCR0L registers, the CMPF0 bit in the PWM0CSR register is set and an interrupt request is generated, provided that the CMPIE bit is set.

The registers that are used in the application note are:

TIMER CONTROL STATUS REGISTER (ATCSR):

0	0	0	CK1	CK0	OVF	OVFIE	CMPIE
---	---	---	-----	-----	-----	-------	-------

- CK1, CK0: select the clock frequency of the counter.
 - For fcounter = fcpu, set CK1=1 and CK0=0
- CMPIE: allows to mask the interrupt generation when the CMPF bit is set:
 - 0: the CMPF interrupt is disabled
 - 1: the CMPF interrupt is enabled

PWM0 CONTROL/STATUS REGISTER (PWM0CSR):

0	0	0	0	0	0	OP0	CMPF0
---	---	---	---	---	---	-----	-------

- CMPF0: indicates that the upcounter value matches the DCR register value:
 - 0: the upcounter value does not match the DCR value.
 - 1: the upcounter value matches the DCR value.

PWM OUTPUT CONTROL REGISTER (PWMCR):

0	0	0	0	0	0	0	OE0
---	---	---	---	---	---	---	-----

- OE0: When set to 1, the PWM0 output is enabled

Timer initialization

Write to DCRx registers with the required value. The Output Compare function must be enabled. To do this, reset the OE bit in the PWMCR register: this will disable the PWM output.

To configure fcounter = fcpu, set CK1=1 and CK0=0 an

To enable the CMPF interrupt, set CMPIE=1 in the ATCSR register.

4 UART implementation

4.1 Baud rate definition

The Autoreload timer is used to generate the baud rate. The autoreload timer clock (fCOUNTER) is the same as the fcpu clock, which is an 8 MHz internal clock.

The example below describes how this baud is generated:

- baudrate = 2400
- fcpu = 8MHz (so clock period is 125 ns)
- In the application fCOUNTER = fcpu

So to get 2400 baud the "Prescaler" required is,

$$\begin{aligned} \text{Prescaler} &= \text{fcpu} / \text{baud} \\ \text{Prescaler} &= 8 * 10^6 / 2400 \\ &= 0.0033333333 * 10^6 \\ &= 3333.33 \text{ decimal} \\ &= \text{D05 Hex (= 1 bit delay count)} \end{aligned}$$

So in software DCRx will be

$$\text{DCR0H} = \text{0D} + \text{CNTRH}$$

$$\text{DCR0L} = \text{05} + \text{CNTRL}$$

to generate one bit delay when 2400 baud is required

For half bit period "Prescaler" is,

$$\begin{aligned} \text{Prescaler} &= \text{one bit} / 2 \\ &= 1666.66 \text{ (decimal)} \\ &= \text{682 Hex (= 1/2 bit delay)} \end{aligned}$$

$$\text{DCR0H} = \text{06} + \text{CNTRH}$$

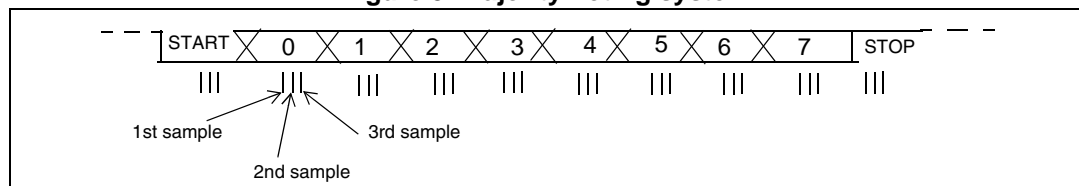
$$\text{DCR0L} = \text{82} + \text{CNTRL}$$

The software provided with this application note has been functionally tested in the range 2400 to 19200 baud.

4.2 Majority-voting system

Compared to the transmit section, the receive section is complex. Thus, to avoid possible errors in detecting the exact bit status because of line noise, etc., this program uses a majority-voting system. When the ST7LITE0 is in receive mode, it reads (samples) each bit three times in the middle of the bit time. To determine its exact state, it compares the number of 1's with the number of 0's. If there are more '1's than '0's, the bit received is a '1', else it is a '0'. (see [Figure 3](#))

Figure 3. Majority-voting system



This section is only used for the receive part. You can change it to suit your requirements.

4.3 Status handling

To keep track of the status during a program execution, the software uses the “sci_status” variable. Bits 0-4 of this variable are used to hold the system status.



Definition of each flag:

SP: Reception mode sampling phase

BR: Byte Received flag

RE: Reception Enable

BS: Byte Sent flag

TE: Transmission Enable

4.4 Transmit and receive implementation

The transmission mode gets executed after power on. To transmit data, the program uses port pin PA3 in output mode with the “Output Compare” interrupt. One bit is transmitted during each interrupt, generated after a bit delay when the 12-bit upcounter (CNTR) reaches the value (=1 bit delay) stored in the DCR0H and DCR0L registers. For a duty cycle register (DCR0L/DCR0H), the value depends on the required baud rate and clock frequency.

For receive mode, the program uses port pin PA7 in input mode along with its interrupt and output compare functions. To sense the start bit, the “ei1” interrupt is used and configured as “Falling edge only”. In this interrupt routine, the program sets the ATR - the output compare value for a half bit delay^(a) - and disables the “ei1” interrupt to use PA7 in normal input mode, in order to receive the entire frame. This half bit delay is used to sample a bit in the middle of it. After receiving a start bit in an output compare interrupt, the same interrupt routine gets executed each time a bit must be received. To receive each bit correctly, the majority-voting system is implemented in this interrupt routine.

The interrupt strategy used in the software to transmit and receive allows other applications to work at the same time.

Note: Error handling: This program does not handle communication errors (e.g. Frame Errors). No handshaking is implemented. For better performance at high baud rates, it is recommended to use character transmission rather than string transmission.

a. The user can adjust this value depending on the baud rate.

5 Hardware setup

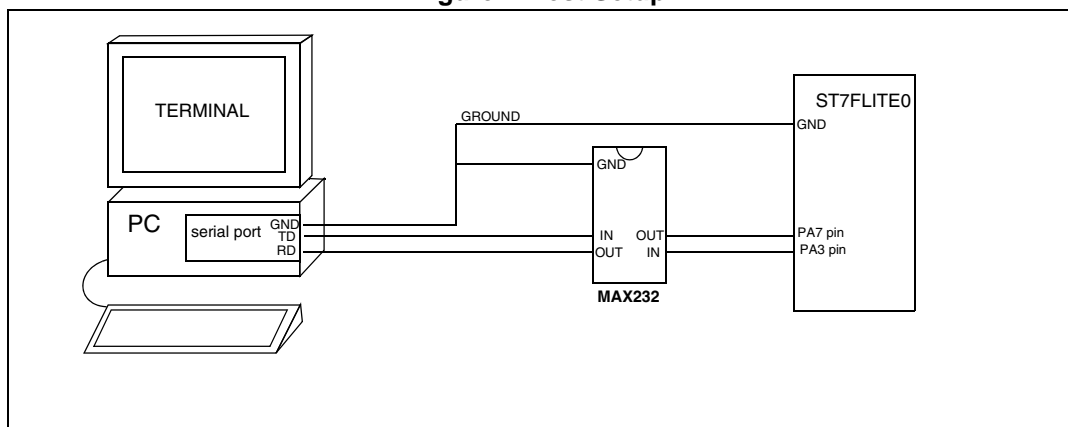
A general system configuration is shown in *Figure 1*. The ST7FLITE0 is connected to an RS-232 line driver chip which is in turn connected to any RS-232-compatible device. The RS-232 line driver is needed to convert the 5-volt logic level of the ST7FLITE0 to the proper RS-232 line voltages, and vice versa.

Figure 4 shows a specific example of a hardware setup required for UART in which the ST7FLITE0 processor and RS-232 Driver/ Receiver are used. You can use different driver/receiver in your application. For example, you can use an MC14C88/ 89 as a low cost solution.

The Receive Data pin (RD) of the PC serial port must correspond to the PA3 pin of the ST7FLITE0, and the Transmit Data pin (TD) to the PA7 pin.

Caution: The three main devices (PC, ST7LITE0, MAX232) must have the same electrical reference (GND). For a detailed description of MAX232, please refer to the datasheet.

Figure 4. Test Setup



6 Functional software flow

The character format used is "ASCII". Before starting a communication, you should configure the communication parameters to your requirements. You can select the baud rate, number of bits and stop bits in different combinations. However, for a correct communication, the receiver must have a reception baud rate strictly equal to the transmission baud rate of the transmitter. If not, the communication will be corrupted. So you have to configure the "Hyperterminal" correctly.

To configure the device, you must set `del_1bh`, `del_1bl`, `del_sampl`, `del_samph`, `STOP_BIT` and `TxRx_data_Inth` correctly in your software.

After power on, the ST7FLITE0 goes to transmit mode. It initiates the communication by transmitting character "\$" in ASCII format and then goes to receive mode. The PC then receives this character on its serial port, which can be viewed in the Hyperterminal window.

You then have to press a key (character) to transmit. After pressing a character key, it gets transmitted and the ST7LITE0 receives it. The ST7LITE0 then sends the same received character to the PC. This sequence can be repeated continuously (see [Figure 5](#)).

6.1 Main software routines

The UART software consists of 4 main routines:

- `Tx_data`
- `Rx_data`
- `EI1_Interrupt`
- `OPCOMP_int`

Tx_data: This routine is used to transmit data in bit format stored in variable "TX_byte". It also takes care of the synchronization and of the output compare interrupt. The AT timer is initialized to the application configuration inside this routine.

Rx_data: This routine is used to receive data on the input pin in bit format and stores it in "RX_byte". To detect a start bit, it initializes the PA7 pin in interrupt mode.

EI1_Interrupt: This "ei1" interrupt routine gets executed only once during receive data when PA7 receives a start (high to low edge) bit. It also initiates the AT timer for a half bit duration.

OPCOMP_int: This routine gets executed in both transmit and receive modes. During a `Tx_data` routine execution, it gets executed for each data bit transfer. It is actually used to transmit data on the TxD (PA3) pin along with the start and stop bits.

In receive mode, it gets executed for each data bit received, including the start and stop bits.

The majority-voting system is implemented in the same section of code.

6.2 Software flow charts

The flowcharts below represent the application program flow.

Figure 5. Main flowchart

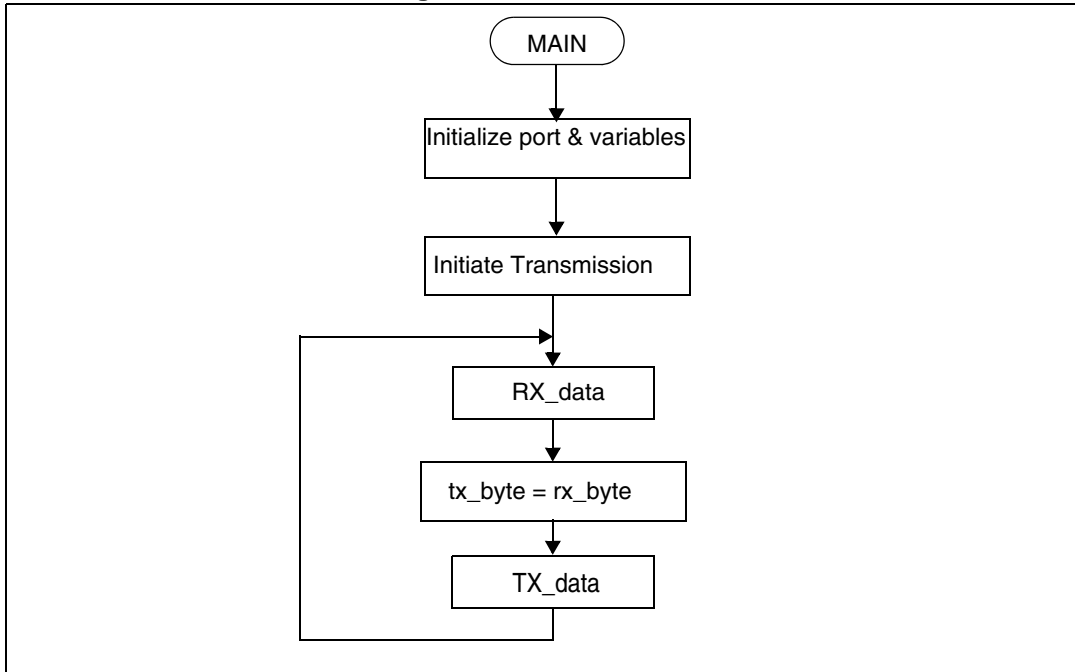


Figure 6. Output compare interrupt

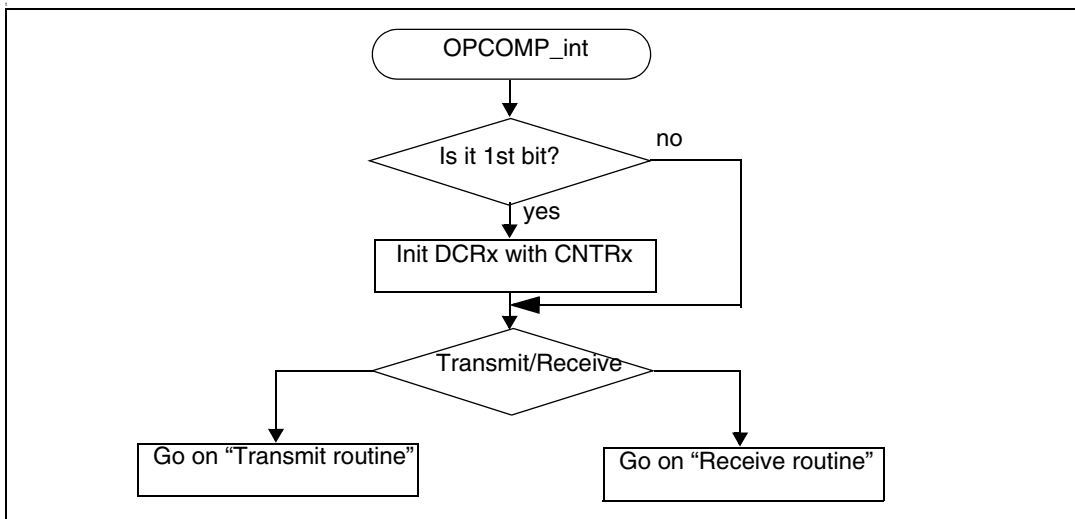


Figure 7. Transmit routine

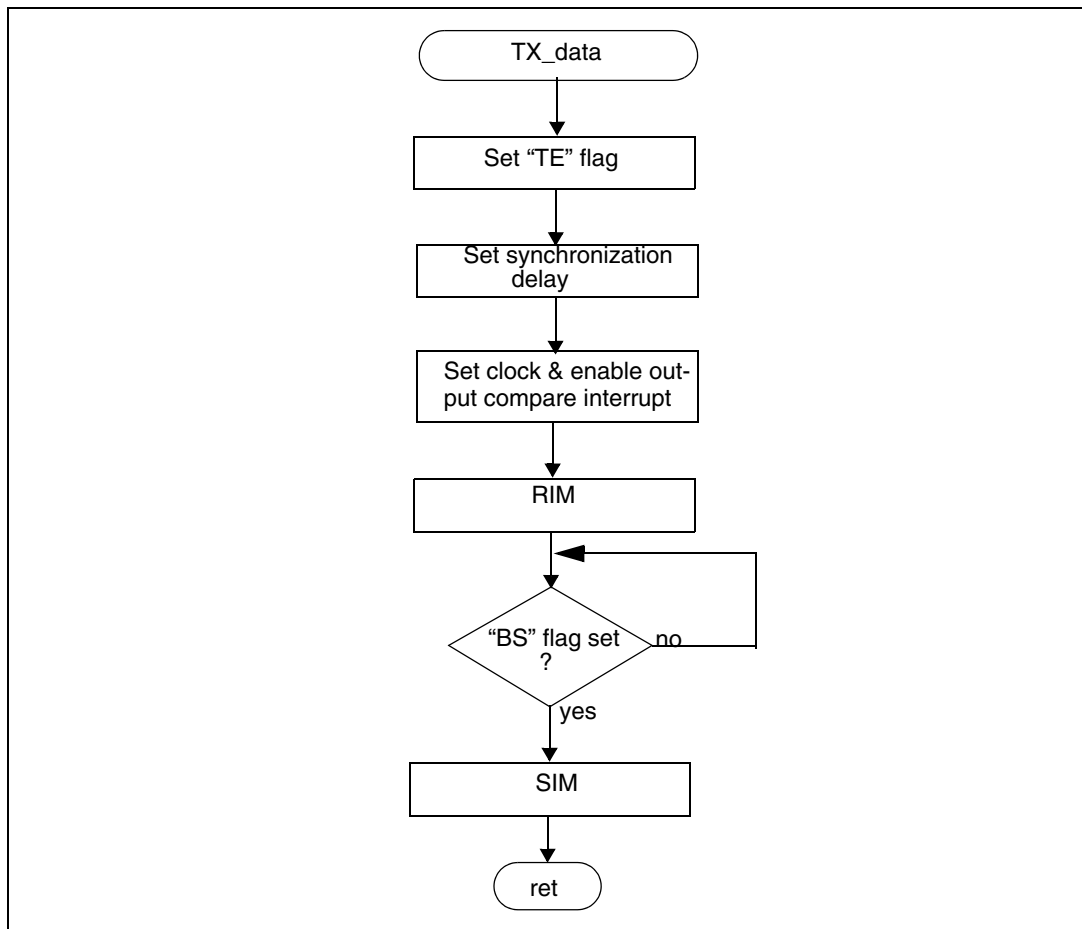


Figure 8. Receive data routine

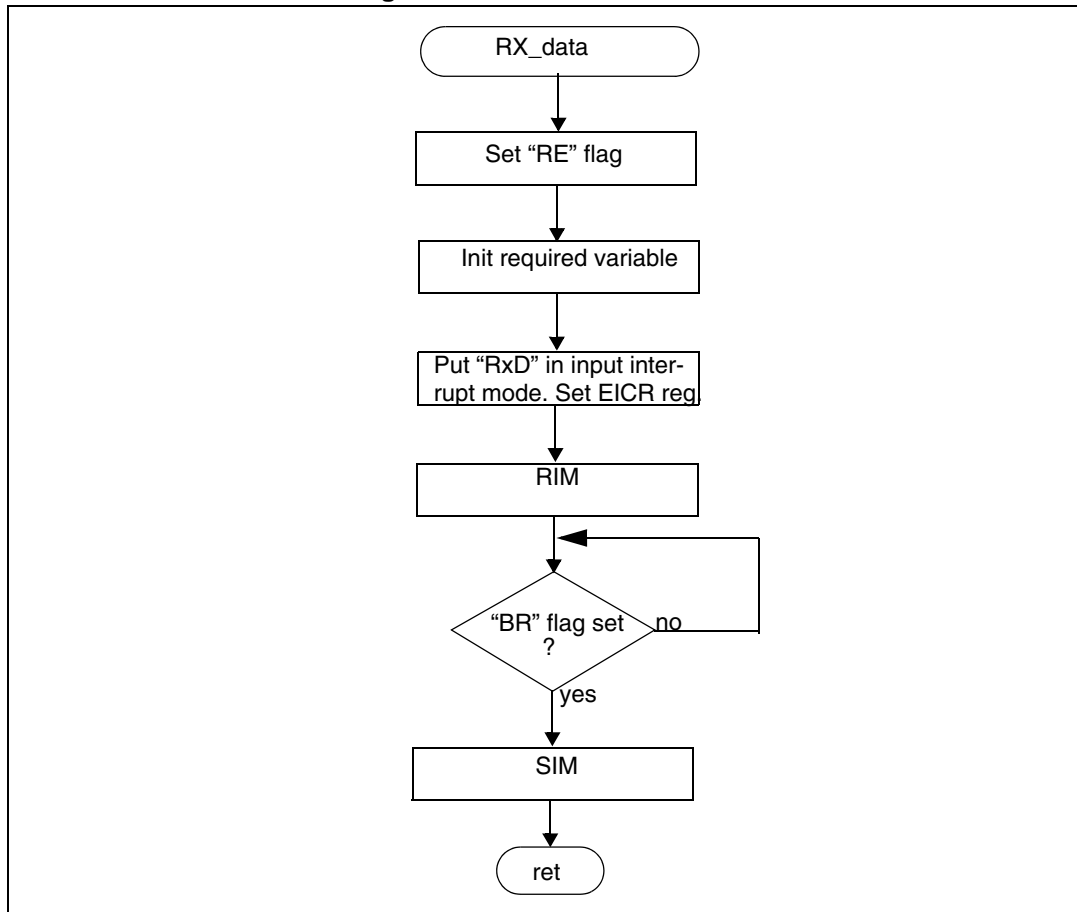


Figure 9. Output compare transmit flow

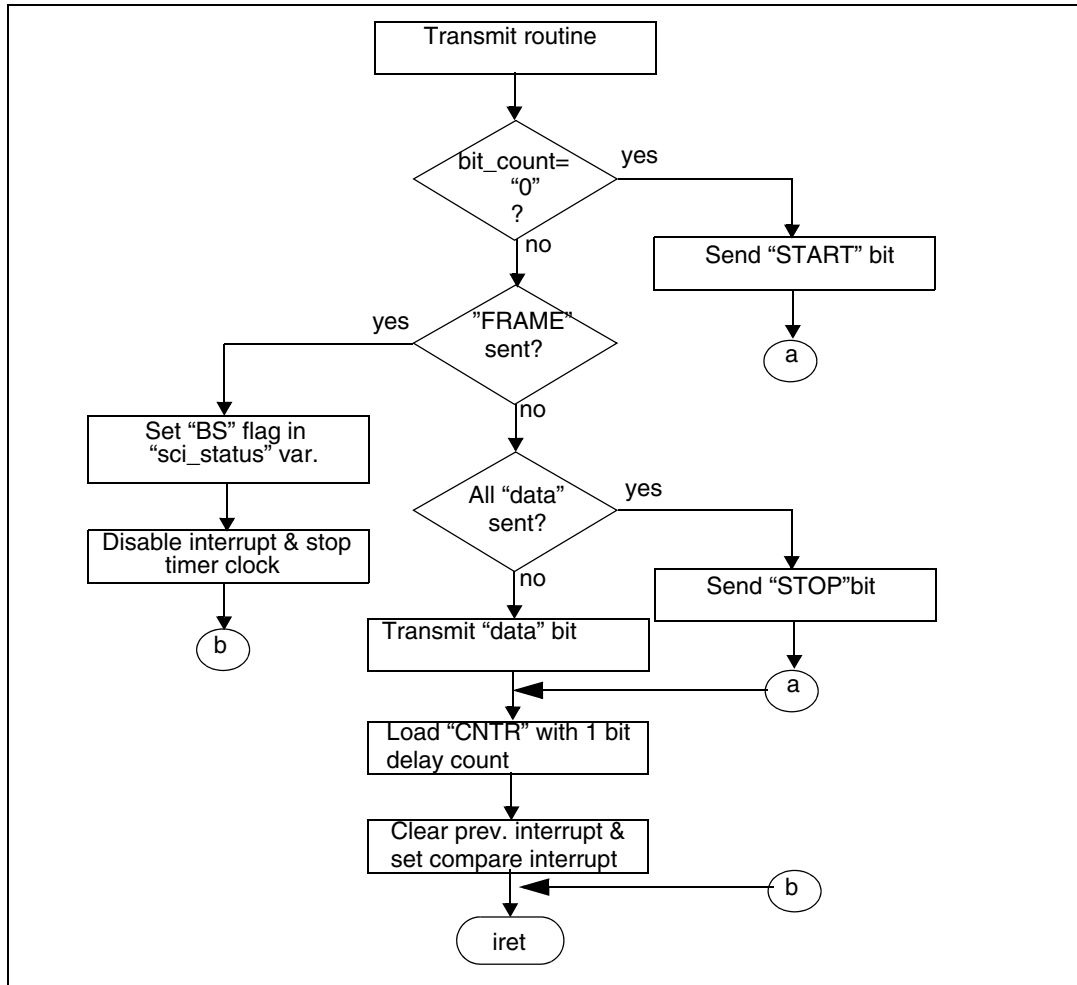


Figure 10. Output compare receive flow

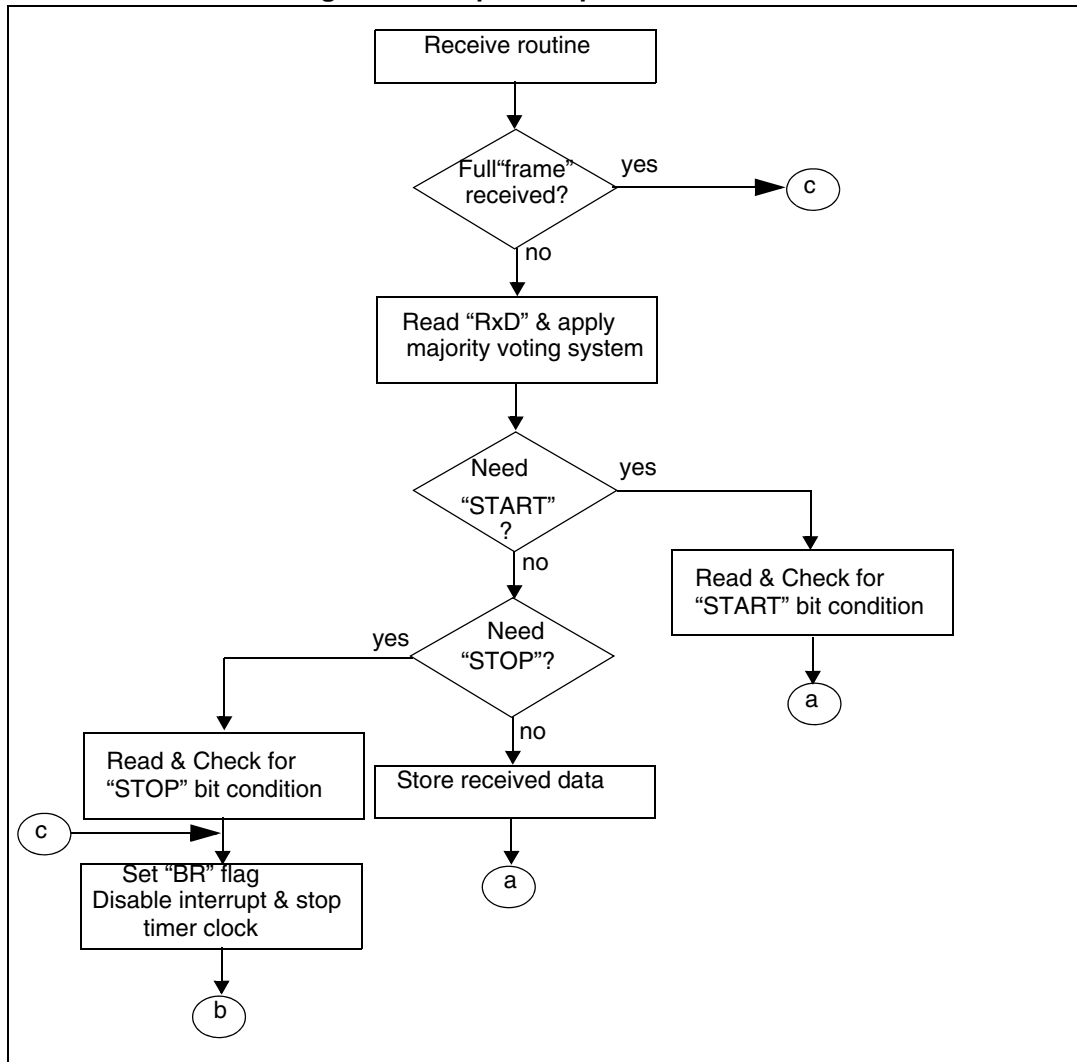
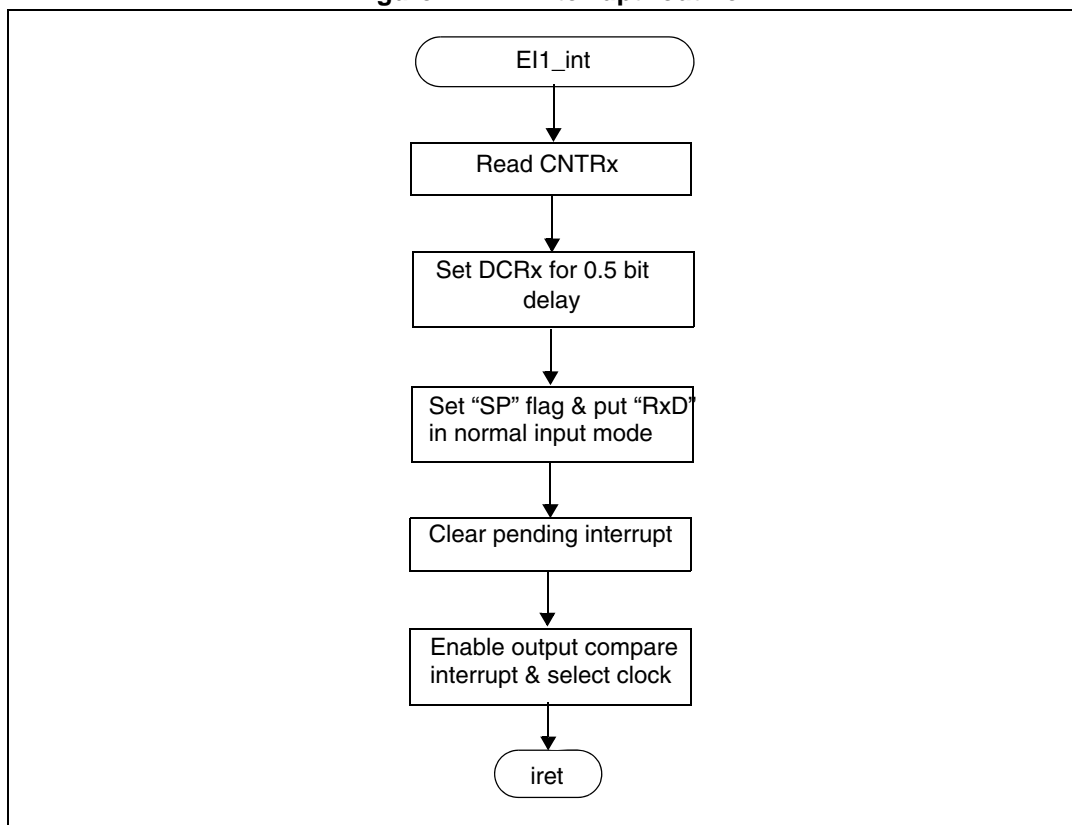


Figure 11. E11 interrupt routine



7 Test procedure

1. Connect both the communication and terminal equipment as shown in [Figure 4](#).
2. Open and configure the “Hyperterminal” application [Port, Baud rate, etc.].
3. Power on the ST7LITE0.
4. On the terminal, you should get “\$” as a starting character (If not, then check the link between the terminal and the ST7LITE0 and check the communication settings).
5. Press a key to send a character.
6. The same character should be returned by the ST7LITE0 (check the “Hyperterminal” window).
7. Continue by repeating the two previous steps.

8 Software

The complete software can be found on the ST internet website in a zipped file format. It is intended for use as an example only. It is up to you to adapt it to your specific application.

The source file is for guidance only. STMicroelectronics shall not be held liable for any direct, indirect or consequential damages with respect to any claims arising from use of this software.

9 Revision history

Table 2. Document revision history

Date	Revision	Changes
07-Nov-2003	1	Initial release.
29-Mar-2013	2	Revalidation Replaced 'ST7' by 'ST7LITE0' in the title and the <i>Introduction</i> , and added <i>Table 1: Applicable products and tools</i> .

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