Design and Development of Daughter Board for USB-UART Communication between Raspberry Pi and PC

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***Abstract*- Development of real time applications using platforms such as Raspberry Pi often requires interfacing of different sensors and communication modules. They can be easily interfaced using RS232 port but now a days it is replaced by USB .Interfacing sensors and modules having only USB ports, some sort of port conversion is requiredthat can emulate a serial port providing a virtual COM through UART interface. This paper propose design & development of daughter board for USB to UART Communication to Raspberry Pi that provides communication with different embedded devices by the use of USB to UART Convertor Boards. With the help of these convertors, bidirectional data transmission is achieved. FT232RL & CP2102 IC's are used in the proposed daughter boards. A comparative analysis is presented between these boards in terms of cost, performance, reliability, packaging, required baud rate.**

Keywords: USB to UART, Raspberry Pi, FT232RL, CP2102

I. INTRODUCTION

Now day's modern systems do not support RS-232 ports and are replaced by USB ports. For development of real time applications, there is an urgent need for interfacing of different sensors and modules with the USB ports of PC. Embedded platforms such as Raspberry pi, Arduino have serial ports such as UART, SPI, and I2C. However most of traditional systems have UART interface. Certain amount of protocol conversion needs to be performed between UART and USB in order to perform serial communication with these systems. Design & Development of Daughter Board for USB to UART Communication between Raspberry Pi and PC is proposed in this paper since most of embedded devices have at least one UART (Universal Asynchronous Receiver and Transmitter) serial port. Many USB to UART convertors such as FT232RL, PL2303, MCP2200, and CP2102 are available in market [15]. A comparison is drawn in terms of cost, performance, availability and efficiency. In this paper, a proposal is made to design and develop USB to UART daughter board based on FT232RL or CP2102 IC's for the Raspberry Pi which is much cheaper, efficient and easy to handle comparative to other convertors. On the basis of QOS parameters of communication like transmission rate(baud rate), speed(in terms of bps), power consumption, cost, circuit complexity, availability and ease in handling, the performance of proposed solutions are evaluated for different file formats at different baud rates.

II. SYSTEM BLOCK DIAGRAM

Following block diagram shows the communication between Raspberry Pi and PC using USB to UART convertor daughter boards. In Fig1: connection between Host PC, the USB to UART Convertor Board and Raspberry Pi UART interface (UART_Rx, UART_Tx) for the serial communication is shown.

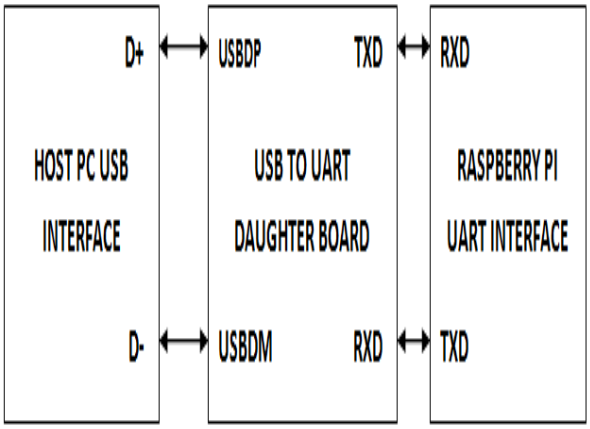

Fig 1: System Block Diagram

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III. SYSTEM ARCHITECTURE

A. USB

Universal Serial Bus (USB) is a bus communication standard used for connection, communication and for supplying power between PC's and various other embedded devices.

USB use 4 lines - Power, Ground and a twisted pair D +/- data lines using NRZI encoding. USB connectors are designed in a way that ground and power must be applied before signal connection [1]. USB port operates at 5volts [3]. Advantages of using USB port include a single interface for many devices and also automatic configuration .No external power supply is needed and devices can draw up to 500 mA from the PC [3].

B. UART

The Universal Asynchronous Receiver/Transmitter (UART) controller is the key component of the serial communications subsystem of a computer. In most microcontrollers, UART is also a common integrated feature. The UART takes bytes of data and transmits the individual bits in a sequential fashion. At the destination, a second UART re-assembles the bits into complete bytes [2]. UART is asynchronous so no clock signal is required but the transmitted data's structure consists of start and end to a message. Both ends of the link must operate with same baud rate. UART normally operates at 3.3V to 5V TTL levels.

C. Raspberry Pi

Raspberry pi can be termed as small computer that provides complete functionality as our desktop does. Raspberry Pi has Broadcom SOC BCM2835, 512Mb RAM and. It works at 700MHz clock and operates on 3.3. Volts. This platform is extremely useful for development of handheld devices. Raspberry Pi provides support for various operating systems such as Debian, Arch Linux. Open source Debian OS is ported on SD card using Win32 Disk Manager software[16].In this paper communication between PC amd Raspberry Pi is implemented with the help of USB to UART convertor boards that results in a very cost friendly option.

IV. SYSTEM DESIGN

USB to UART Daughter Boards Design

FT232RL & CP2102 are preferred IC bridges for designing of daughter boards for Raspberry Pi. In this section designing of these boards has been discussed:

A. FT232RL Based Convertor Board

The FT232RL is a USB to serial UART IC provided by FTDI and used for asynchronous serial data transfer. It is available in 28-pin SSOP and 32pin QFN packaging with transfer rate capability from 300 to 3Mbauds at TTL levels with operating voltage of 5V at 15mA current consumption. IC does not require any specific USB firmware programming with entire USB protocol handling on chip itself. Because of FTDI's virtual com port drivers [9], no USB driver development is needed. This IC has the capability of low USB bandwidth consumption. FT232 has support for all operating systems such as Windows, Linux, and Mac [8]. Complete BOM for designing of this board is mentioned as per [8][14].

SCHEMATIC DIAGRAM:

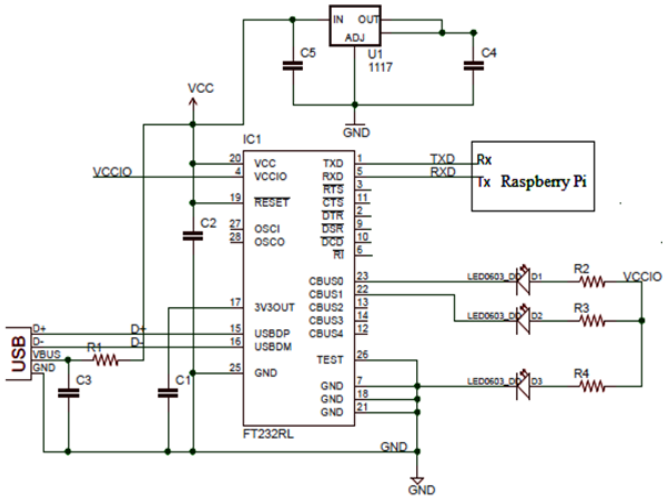

Fig 2: FT232RL Daughter Board Schematic Diagram[12]

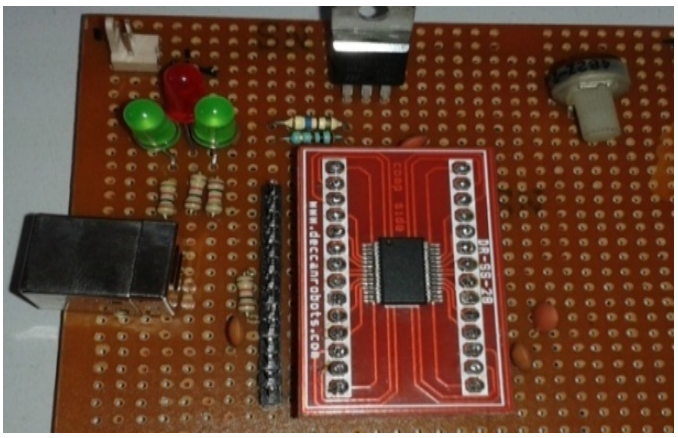

Fig3: FT232 Daughter Board Implementation Circuit

Board is connected between PC and Raspberry Pi UART interface in following manner:

Architectural Block Diagram

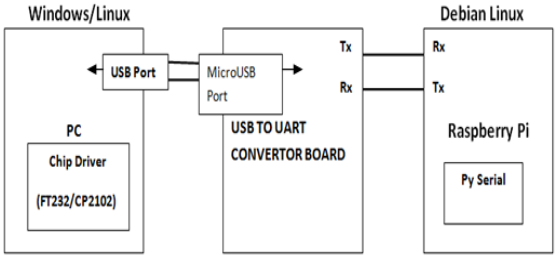

Fig4: Architectural Connection Diagram

As depicted in fig4: USB cable is used to connect PC and Convertor's microUSB connector. After plugging, the installed FTDI driver on either windows or Linux system causes convertor board to appear as a COM port on the computer. The baud rate and other parameters for the port can be set just as it is done for a serial port in Control Panel > System > Device Manager > Ports (COM & LPT).

B. CP2102 Based Convertor Board

The CP2102/9 is a USB to UART Bridge Controller provided by Silicon Labs that includes a USB 2.0 full speed function controller, USB transceiver, asynchronous serial data bus (UART), EEPROM, with full modem control signals in a very compact QFN-28 package [1]. It does not require any external USB components. It contains an On-chip voltage regulator and provides 3.3 V output.

SCHEMATIC DIAGRAM

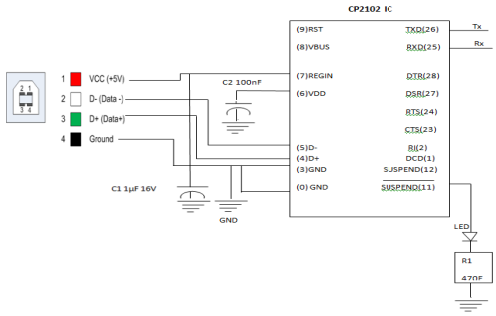

Fig5: CP2102 Daughter Board Schematic Diagram[12]

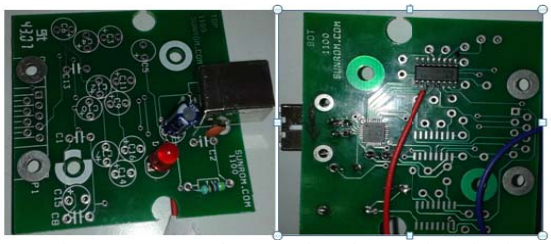

Fig6: CP2102 Daughter Board Implementation Circuit

As available for FT232RL, CP2102 drivers are also available for different OS and these needs to be installed onto PC. When it is plugged, a virtual COM port establishes for carrying out further serial communication as mentioned in fig4.

V. SYSTEM IMPLEMENTATION

Designed daughter boards are used to provide serial communication between Raspberry Pi & Pc as per steps given below:

A. Serial Port Setup in Raspberry Pi:

(i) PySerial Installation

To use serial port of Raspberry Pi, PySerial library need to be installed in following manner:

$ sudo python apt-get install python-serial

Serial communication of raspberry pi need to be set before start as by default UART for Raspberry Pi is set for console operations. Changes need to be done in startup file to disable default console operations.To perform this open etc/inittabfile in nano editor

$ sudonano /etc/inittab

Erase or comment line

#To:23:respawn:/sbin/getty –L ttyAMA0 115200 vt100

(ii)Package Installation for Serial Setup:

After disabling console operations, Raspberry Pi serial UART is to be configured for user interaction. To achieve this task some packages need to be installed as per the following list:

Python, Python-dev, Libipeg-dev, Libfreetype6-dev,python-setuptools,python pip, RPi.GPIO, Python Serial,Nose,Cmd2 [6][10][11].

VI. PROPOSED ALGORITHM

Performance implementation is carried out to achieve derived results as per thefollowing proposed methodology:

STEP1: Connect interface board (USB to UART) as per block diag. in fig.1

STEP2: Open Serial Port for Tx/Rx at their respective ends and configure ports for desired baud rates at both ends.

STEP3: Select file to be transferred at one end and to be received at other end.

STEP4: Execute send and receive python codes at different ends.

STEP5: In respective python codes, calculate file transmission time, bps (bits per second), baud rates for different file formats (text, image, pdf, audio)

VII. PERFORMANCE ANALYSIS AND TESTING

The performance of both thedesigned FT232RL and CP2102 daughter boards is analyzed for quality of service(QoS) parameters of communication like transmission rate (baud rate), transmission speed (in terms of bps), power consumption, cost, circuit complexity, availability and ease in handling. For different file formats, file sizes, baud rates and file transmission times, graphs have been plotted for both the convertor boards. Baud rates are taken from 9600 to 38400. File formats of types: text, pdf, audio, image of sizes varying from 50Kb to 300Kb are chosen for analysis, however higher baud rates and more file formats may be selected. Communication between both transmitter and receiver ends is obtained by running python codes at respective ends.

FT232RL& CP2102 DAUGHTER BOARD

A. Bits per second and Baud rate for different file formats.

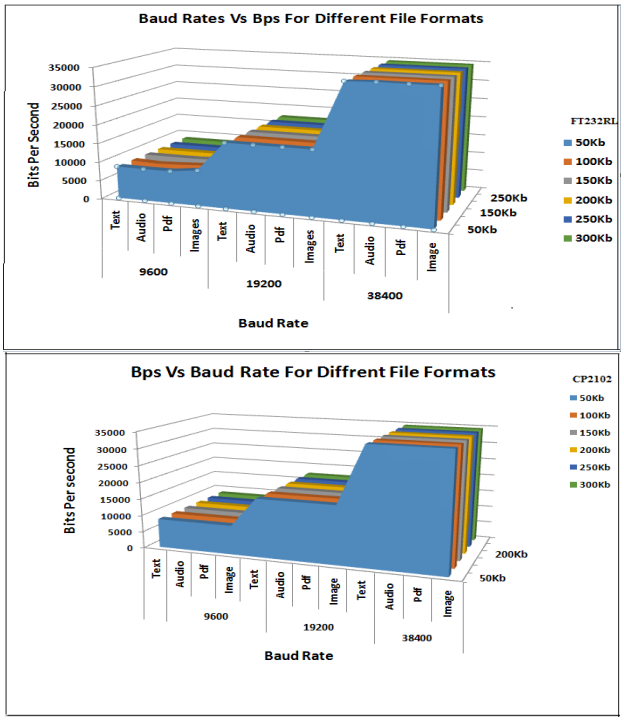

Fig7: Baud Rate Vs BPS for different file sizes

Graph shows thatfor both FT232 and CP2102 daughter boards, as the baud rate increases, for all file formats data transmit and receive rates (bits per second) remains same irrespective of file formats.

B. Transfer time for different file sizes at different Baud Rates

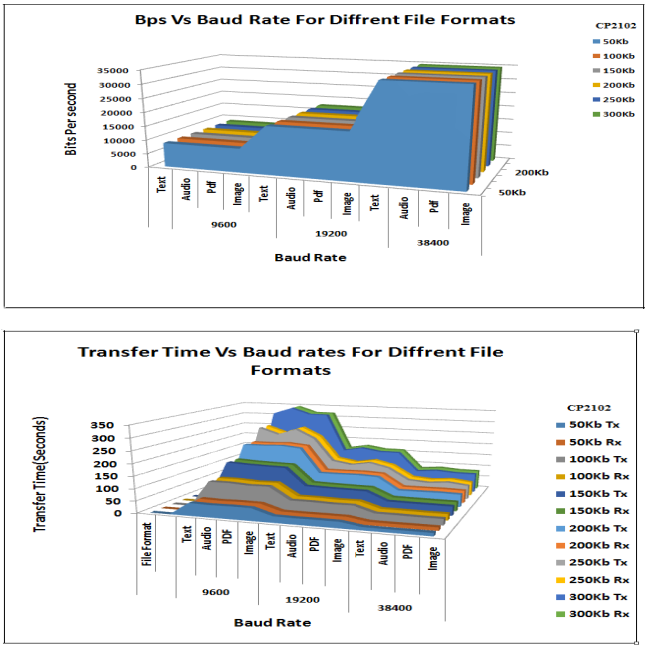

Fig8:Transfer Time Vs Baud Rates for Different File Formats

Graph show that as the baud rate increases, transfer /receive time reduces irrespective of file formats in both FT232 and CP2102 daughter boards. Slight variation in transmission time is seen in graph for different file formats due to slight variation in the file sizes.

VIII. RESULTS AND CONCLUSION

Comparative analysis of FT232 & CP2102 daughter boards shows that performances of both are inline to each other as depicted in performance graphs sited above as per fig[7,8,9]. Either of them can be chosen for intended usage. However characteristics table shows benefits and limitations of both IC's. As per table[1], though CP2102 offers less advantage but it is easy to implement and cost effective than its counterpart FT232.On the other hand,FT232 provides additional benefits like support for nonstandard baud rates, security dongle feature , clock availability which may be used to drive additional circuitry that may be useful in implementing more features in daughter board.

TABLE I [12]: FT232 & CP2102 IC Comparison Table

Parameters	FT232RL	CP2102
Packaging	SSOP -28 Pin	QFN-28 Pin
Operating Voltage	5V IC	3-3.6V
Solderability	Hand Solder able	Difficult to hand solder.
Usage	Most widely used	Less Used
Voltage Regulator	External	On chip available
Availability	Wide	Less
Typ. current consumption	15mA	20mA
Approx. Cost	Rs 225	Rs 150
Baud Support	300 to 3M, Non standard baud rates supported	300 To 1M
External components	Extra components	No extra components
Additional Features	Security Dongle Feature, USB Compliance Certification, RS-422/485 Support	Not available.
Clock Options	6/12/24/48MHz	Not available

IX. FUTURE WORK

Performance analysis and its results shows that either convertor board can be opt for implementation. This implementation will be used for accessing raspberry pi heedlessly using virtual com ports or PuttY applications on PC's for much easier working environment.

X. ACKNOWLEDGMENT

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