PC Interfacing

Fourth Level

Lecture ONE

Regulated Design of Power Supply for Interfacing Circuit

1. Power Supply:-

A power supply is a hardware component that supplies power to an electrical device or load. The primary function of a power supply is to convert one form of electrical energy to another.

- **DC Power Supply:-**

The aim of a DC power supply is to provide the required level of DC power to the load using an AC supply at the input. DC power supplies usually have the following parts: Transformer, Rectifier, Smoothing, and Regulation as shown in figure 1.1, the purpose of these parts are explained in table 1.1.

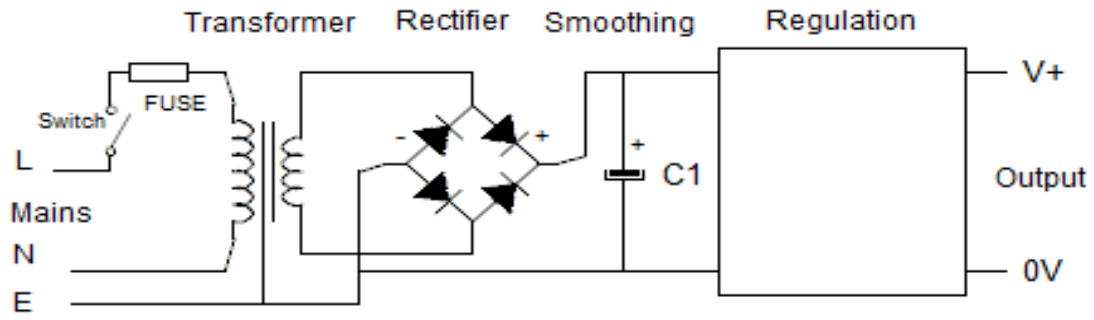


Fig. 1.1: typical design for DC power supply

Table 1.1: Parts of a DC power supply

Component or module	Purpose
Transformer	To change mains input voltage to provide voltage required
Rectifier	To convert AC to DC
Smoothing capacitor(s)	To reduce the amount of AC ripple on the DC voltage
Voltage regulation	To provide the required output voltage

- **DC Power Supply Design:**

Figure 1.2 shows a circuit of a dual DC power supply system. It provides +16V and -16V DC power supply with each rated at 1.8 A. The mains side of the power supply consists of a primary switch, an 110V/220V voltage selector, a primary fuse and a transformer. The transformer is of 50VA capacity with two independent primary windings that can be connected in series for 220V operation or in parallel for 110V operations. The fuse for the primary winding is a standard quick action 3A fuse. The fuses for the secondary windings are the resettable fuses. When the fuses are subject to a current overload, they rapidly switch from a low resistance state to a very high

resistance state. Once the fault condition has been removed, they automatically reset themselves within a short period of time, returning to the low resistance state.

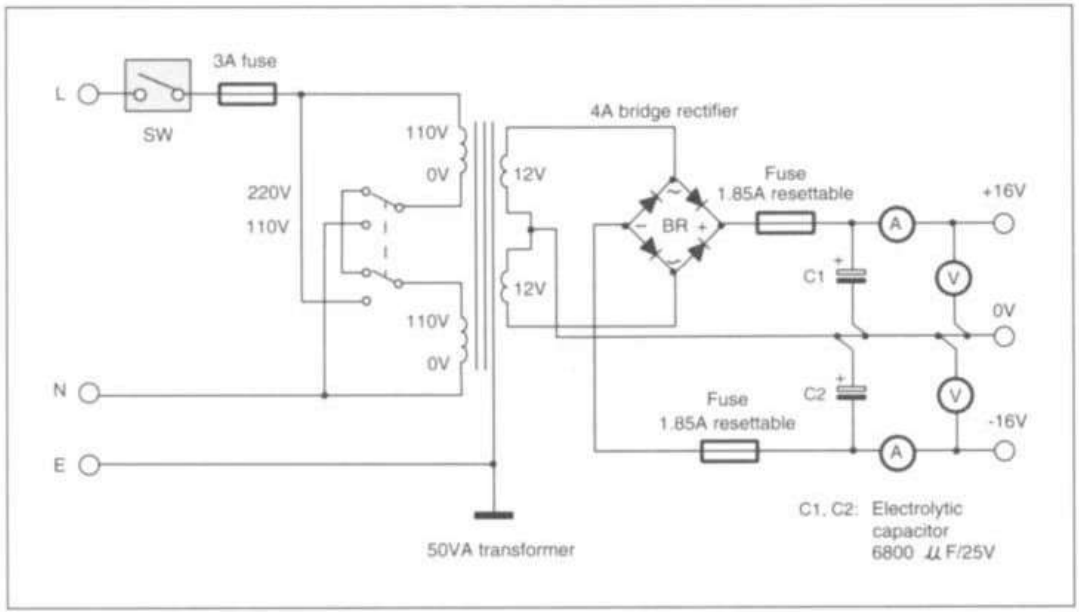


Fig. 1.2: +16V and -16V DC power supply

- **<u>+5V, -5V voltage supply :-</u>**

The simplest way of generating a fixed voltage is to use Zener diodes. The regulated voltage can vary from 2.4V to 75V using the BZX79 series diodes. The diodes in this series are rated at 500 mW and the tolerance of the stabilizing voltage is 5%. Figure 1.3 shows a circuit which converts a 16V DC voltage into 5.1V with a supply current of 20 mA.

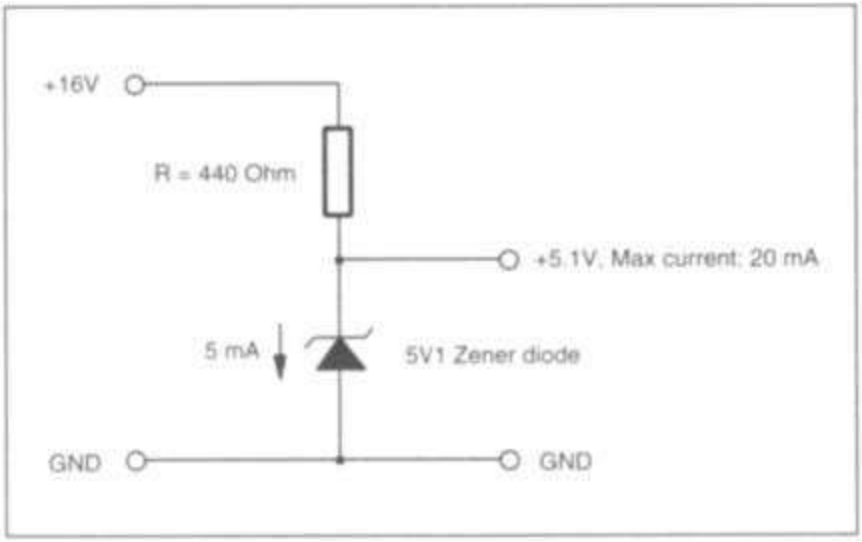


Fig. 1.3: +5V power supply using Zener diode

2. Voltage Regulator:-

Figure 1.4 shows a circuit using an L200C adjustable voltage regulator. It can supply a regulated voltage from 2.85 to 36V with an output current up to 2 A. It features current limiting, thermal shutdown and input over voltage protection up to 60V. The quiescent current is typically 4.2 mA.

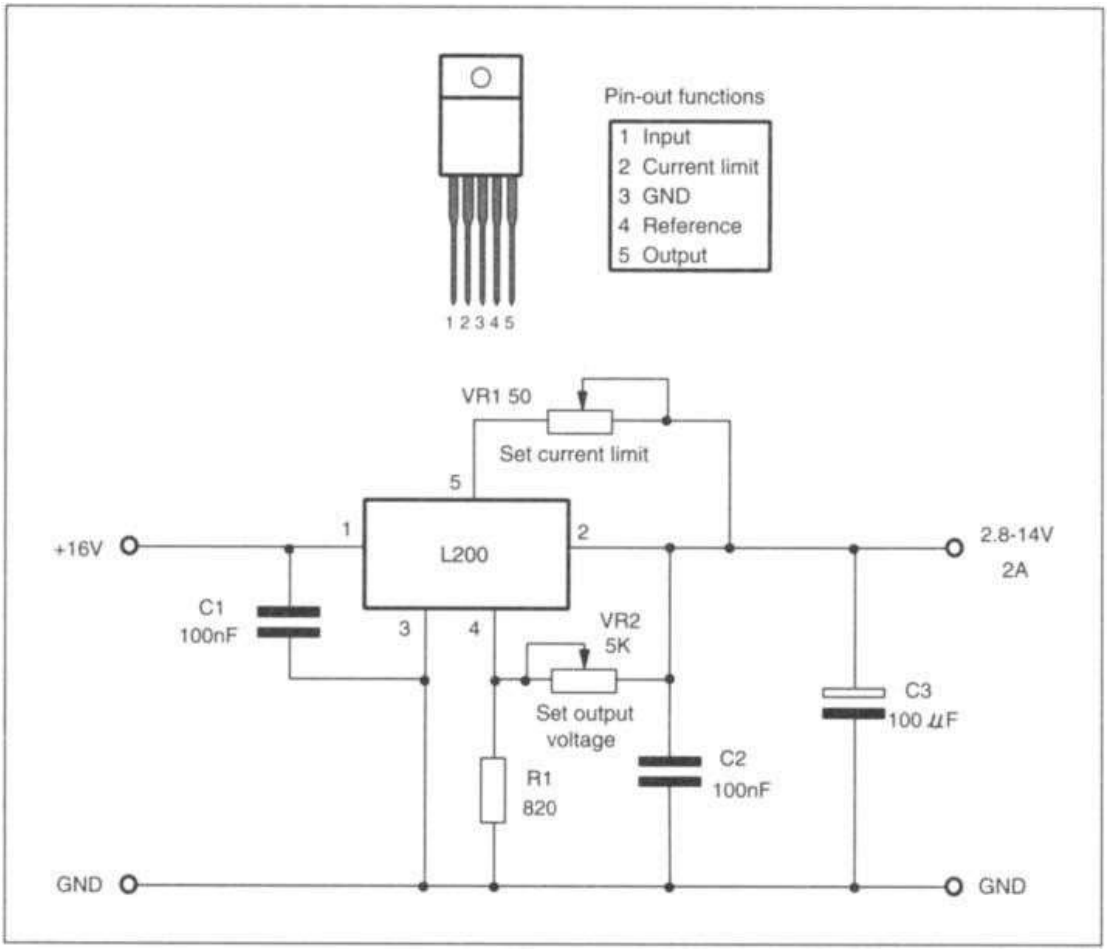


Fig.1.4: L200C adjustable voltage regulator

3. Voltage Converters:-

The circuit shown in Figure 1.5(a) is a voltage inverter which converts +5V voltage to-5V using an SI7660CJ voltage converter (Siliconix). The chip is able to generate a negative voltage output which is equal to the positive voltage input in the range 1.5V to 10V. Pin 7 should be tied to ground for a supply voltage below 3.5V. For supply voltages above 6.5V, a diode should be connected in series of the output. The output has an internal resistance of 70Ω. If a 10 mA current is drawn from the output, the voltage will be 4.3V. The quiescent current is 170µA and the maximum output current is 40 mA.

The circuit shown in Figure 1.5(b) converts a +5V voltage to +10V and-10V using a MAX680CPA voltage doubler and inverter (Maxim). The input voltage ranges from 2V to 6V. The internal resistances for the positive and negative output are 150 ~ and 90Ω respectively. If a 10 mA current is drawn from both outputs, the positive voltage falls to 7V and the negative voltage becomes -6.1V. The quiescent current of the device is typically 1 mA for a 5V power supply.

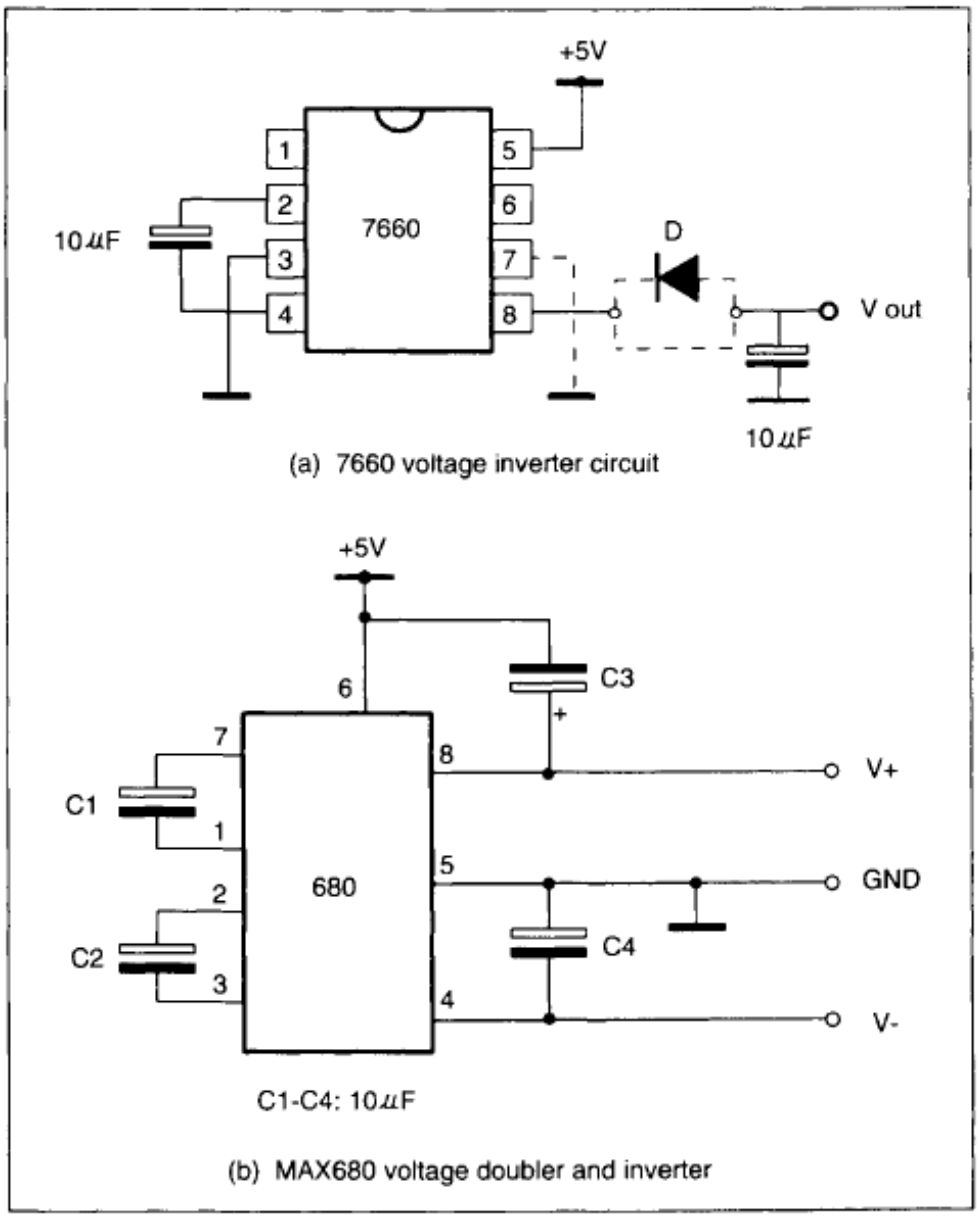


Fig.1.5: Voltage Converter Circuit.

4. Isolated voltage supply circuits:-

This circuit is used when a complete isolation between two circuits is required. NME and NMA series DC-to-DC converters are high efficiency voltage converters. The NME series operate from a 5V or 12V DC input and provide an isolated +5V,

12V or 15V output, depending on types. Up to 200 mA supply current is available from the 5V type, 84 mA from the 12V type and 67 mA from the 15V type. The NMA series provide dual +-5V, +-12V and +-15V DC supplies from a single 5V or 12V DC input. Up to 100 mA is available from the 5V type and 42 mA from the 15V type. The pin-out of the devices is shown in Figure 1.6.

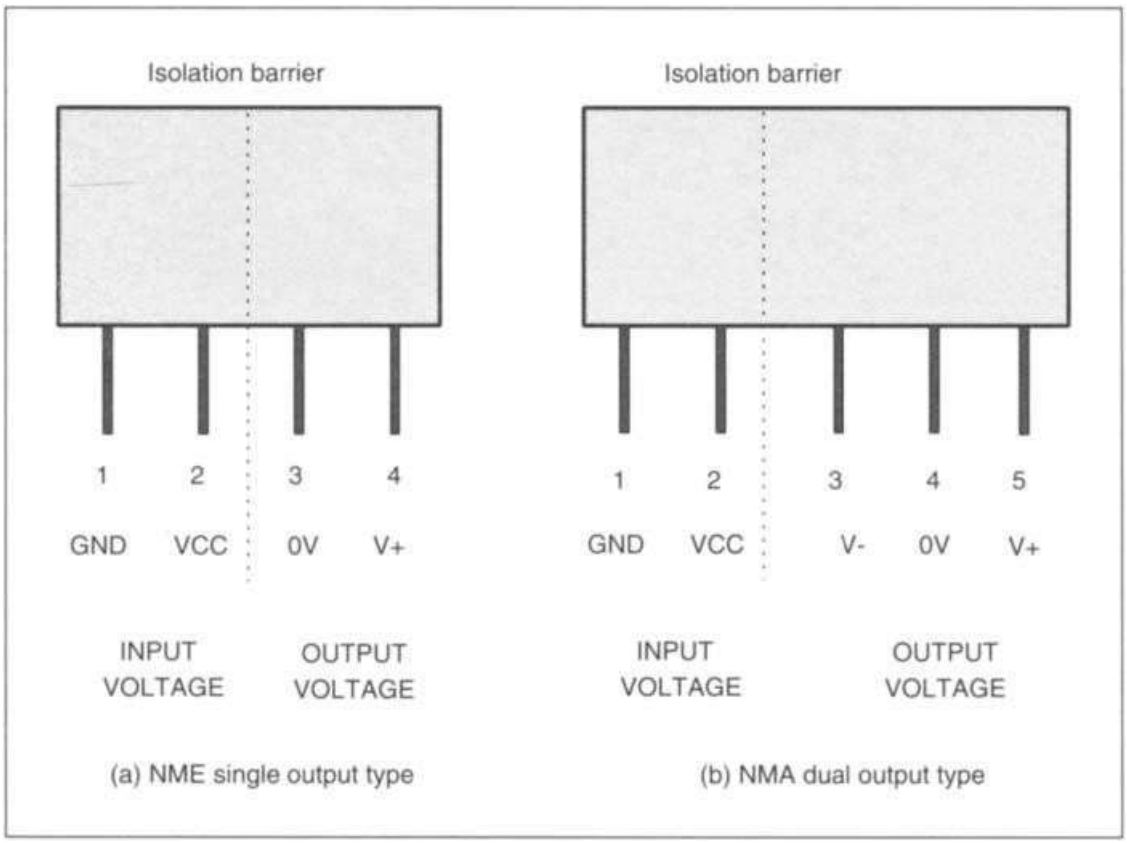


Fig.1.6: Isolated DC/DC converters

5. Digital signal generators:-

Figure 1.7(a) shows an eight-channel logic status generator circuit. It consists of eight single pole double throw (SPDT) switches and eight l k metal film resistors. When a switch is off, the status of the corresponding channel is high. When it is switched on, a logic low is generated. This logic generator suffers that the output signal is not 'clean' when it changes the status. When the switch changes position, the output signal does not change from one state to the other instantly. It consists of a number of oscillations within a very short period of time.

To solve this problem, a de-bouncing circuit is used. Figure 1.7(b) shows such a circuit using a Schmitt trigger inverter, 74LS14. When the switch is closed, the output gives logic 1. When the switch is open, the output gives logic 0.

Another logic generator is the toggle action switch. When a switch is pressed momentarily, the output changes status. The status is maintained until the switch is pressed again. Figure 1.7(c) gives such a circuit.

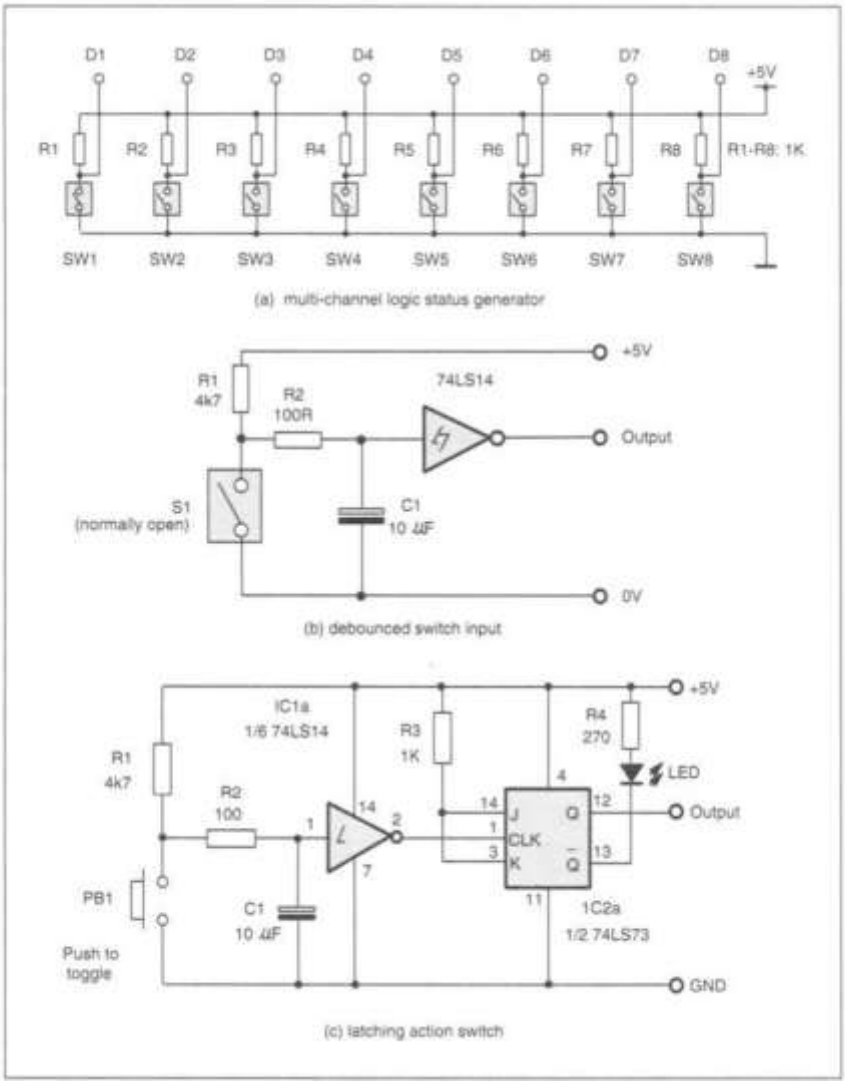


Fig.1.7: Logic status generator circuits

PC Interfacing

Fourth Level

Lecture TWO

Parallel (Centronic) Port Interface

1. Introduction:-

The Centronic, RS232 and game ports are the most common I/O ports that a modern computer has. Some notebook computers may not have a game port, but the Centronic and the RS232 ports are the universal features of all types of computers.

Originally, these ports were designed for specific applications. Centronic ports are used for connecting computers to printers; RS232 ports for connecting printers, modems and mice; and game ports for connecting joysticks. They can also be used for other interfacing applications. Peripheral devices designed for these ports not only provide the easiest way of connection to computers but also offer a universal hardware solution for all computers. Therefore, it would be very useful to understand how these ports work and how to make the best use of them.

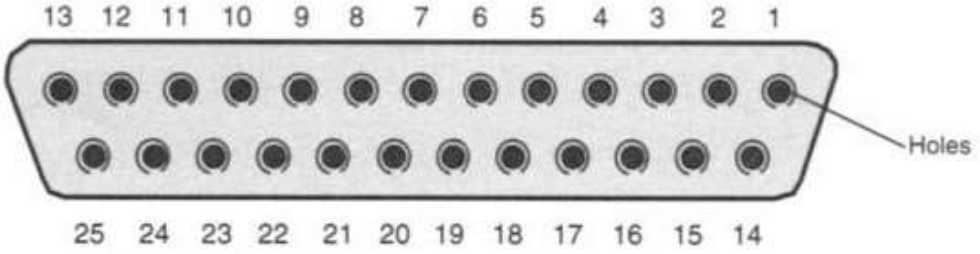
2. The Centronic Port :-

The Centronic port, also known as the printer port or the parallel port, is an industrial standard interface designed for connecting printers to a computer. A computer at least has one such a port installed. The port may come with the computer's mother-boards or with plug-in I/O cards. Adding more Centronic ports is easy and inexpensive. In total, four Centronic ports may be installed on a computer and they have logic names LPT1 to LPT4.

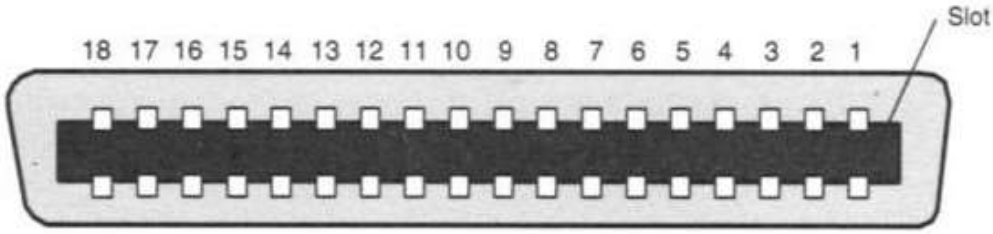
- **Mother boards have 1, adding more is easy and inexpensive using plug in I/O cards (Max.4)**
- **They have Logic name (LPT1 to LPT4)**
- **Work with distance < or= 5 meters**

3. Port connectors (Pin configuration) :-

The port connectors on a computer and on a printer are different. The one on the computer is a 25 pin D-type female connector (Figure 1.1(a)), and the latter is a 36-pin female Centronic-type connector (Figure 1.1(b)). The pin functions of the two connectors are shown in Figure 1.1. To connect a printer to a computer, a printer cable is used (Figure 1.2). The length of the cable must not exceed 5 meters. The Centronic interface is not for long distance operations.



(a) Centronic connector on a pc viewed from the back of the pc
Connector type: 25 pin female D-type

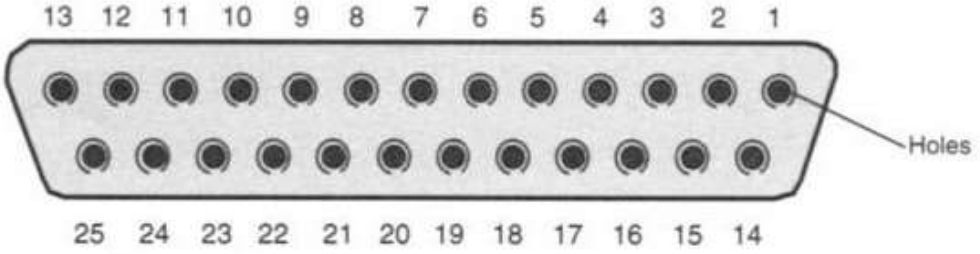


(b) Centronic connector on a printer viewed from the back of the printer
Connector type: 36 pin female Centronic-type

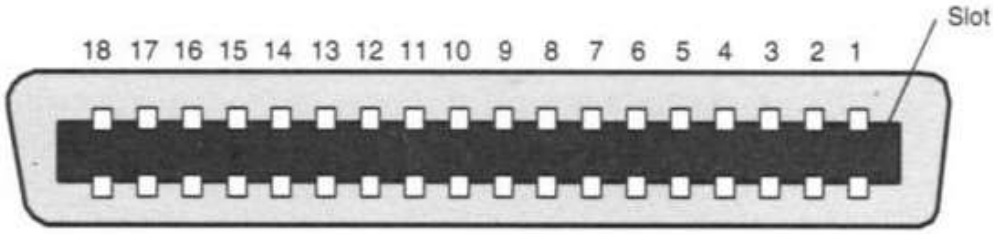
Pin functions of the Centronic port connectors

Connectors on pcs	Connectors on printers	Direction (for pc)	Name	Explanations
1	1	OUTPUT	$\overline{\text{STROBE}}$	low to strobe data into printer
2	2	OUTPUT	DB0	data bit 0
3	3	OUTPUT	DB1	data bit 1
4	4	OUTPUT	DB2	data bit 2
5	5	OUTPUT	DB3	data bit 3
6	6	OUTPUT	DB4	data bit 4
7	7	OUTPUT	DB5	data bit 5
8	8	OUTPUT	DB6	data bit 6
9	9	OUTPUT	DB7	data bit 7
10	10	INPUT	$\overline{\text{ACK}}$	low to indicate data received, printer ready
11	11	INPUT	BUSY	high to indicate printer busy
12	12	INPUT	PE	high to indicate printer paper empty
13	13	INPUT	SLCT	high to indicate printer on line
14	14	OUTPUT	$\overline{\text{LF/CR}}$	auto linefeed after carriage return
15	32	INPUT	$\overline{\text{ERROR}}$	low to indicating printer error
16	31	OUTPUT	$\overline{\text{INITIALIZE}}$	low to initialize printer
17	36	OUTPUT	$\overline{\text{SLIN}}$	low to select printer
18-25	19-30 and 33		GND	twisted-pair return Ground
	18,34		Unused	
	16		Logic GND	logic ground
	17		Chasis GND	chasis ground

Fig. 1.1: Pin-out of the Centronic port connectors on computers and printers



(a) Centronic connector on a pc viewed from the back of the pc
Connector type: 25 pin female D-type



(b) Centronic connector on a printer viewed from the back of the printer
Connector type: 36 pin female Centronic-type

Pin functions of the Centronic port connectors

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7	7	OUTPUT	DB5	data bit 5
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Fig. 1.1: Pin-out of the Centronic port connectors on computers and printers

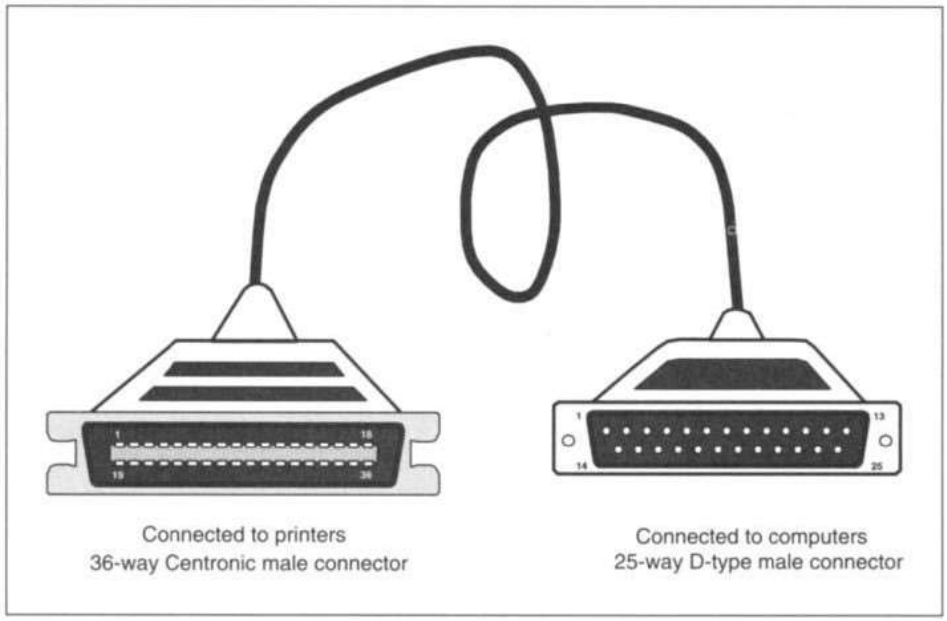


Fig. 1.2: The printer lead

4. Internal hardware organization :-

The circuit of a generic Centronic port inside a PC is shown in Figure 1.3. Eight-bit **data** is latched into IC1 by writing to a port having an address: base address+0. This operation is under the control of WRITE_DATA. The output forms **the Data group**. Data can be read into the computer from the same address via IC2 under the control of-READ_DATA. When reading data, the output from IC1 must be in high impedance state. This is achieved by making pin 1 (OUTPUT ENABLE) of IC1 high.

A 6-bit **control** is latched to IC3 by writing to base address+2. This operation is under the control of WRITE_CONTROL. Bit 0 to bit 3 are output to the port connector to form **the Control group**. Some of the lines are inverted by open-collector inverters (IC6 and IC7). All the output lines are pulled to +5V by 4k7 resistors. These bits can be read back into the computer at the same address via IC4a under the control of-READ_CONTROL. Bit 4 of the control byte enables the interrupt and bit 5 enables or disables the output of IC1. Five lines in the port connector (**the Status group**) can be read into the computer via IC4b under the control of-READ_STATUS. The address associated with this is base address +1. These inputs are pulled to +5V by 4k7 resistors and one of the lines is inverted.

In original, the output enable of IC1 is tied to ground to permanently enable the outputs. This is the unidirectional version of the Centronic port. From IBM PSI2, the output enable of IC1 is connected to bit 5 of the control register IC3 as shown in Figure 1.3 and the port becomes a bidirectional port. Each output line in the Data group is capable of sourcing 2.6 mA current with the voltage varying between 2.6 to 5V. Each can sink 24 mA. The lines in the Control group have a much smaller capacity to source and to sink current. They can only source 100 µA and sink 8 mA current. The rate of data transfer through the Centronic port is greater than 1 Mbyte/second.

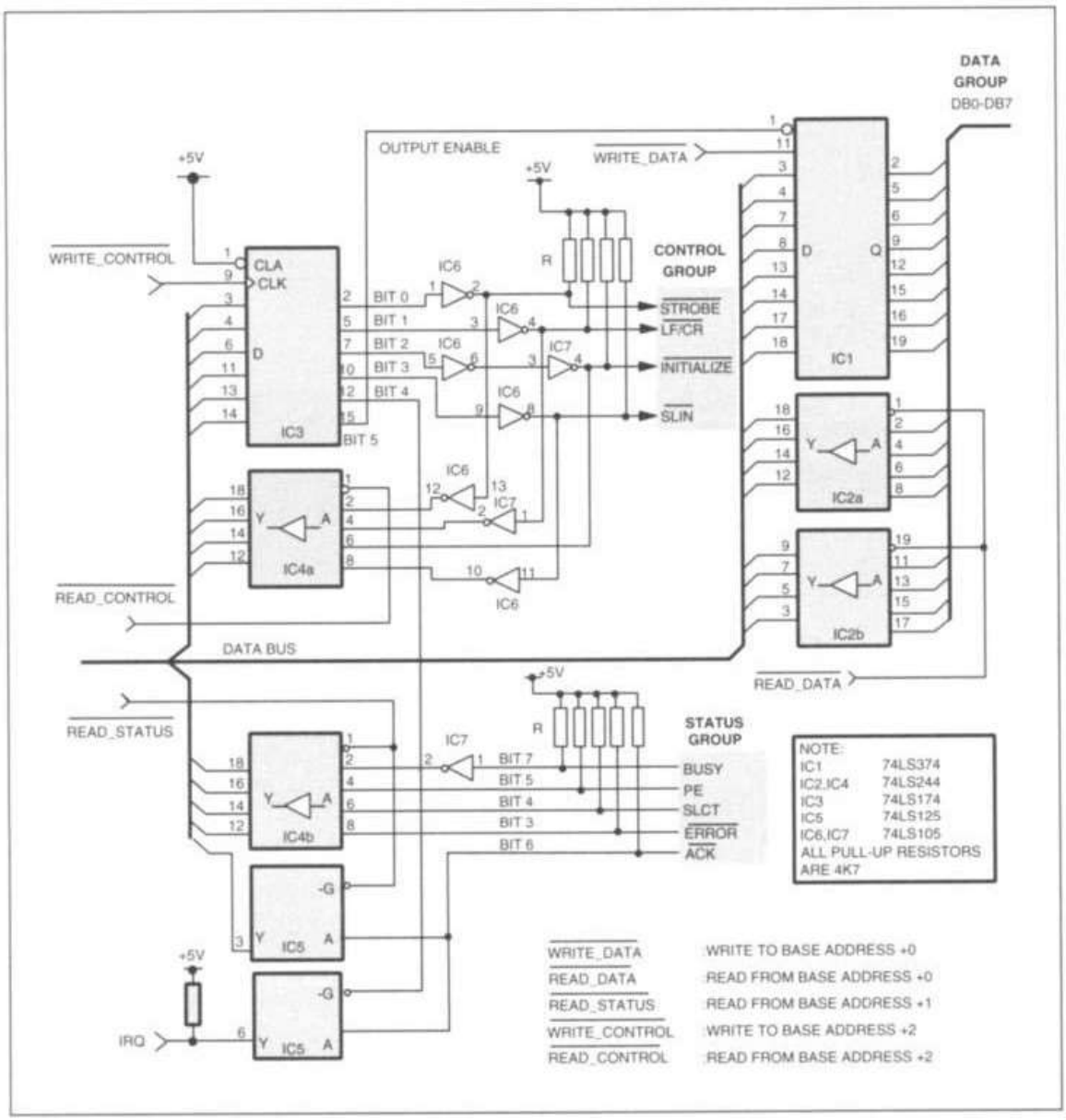


Fig. 1.3: Circuit diagram of the generic Centronic port

5. Groups (Data, Control and Status):-

The I/O lines in the port are organized into three groups, namely, the Data group, the Control and the Status group. Figure 1.4 gives the logic structure of the Centronic port.

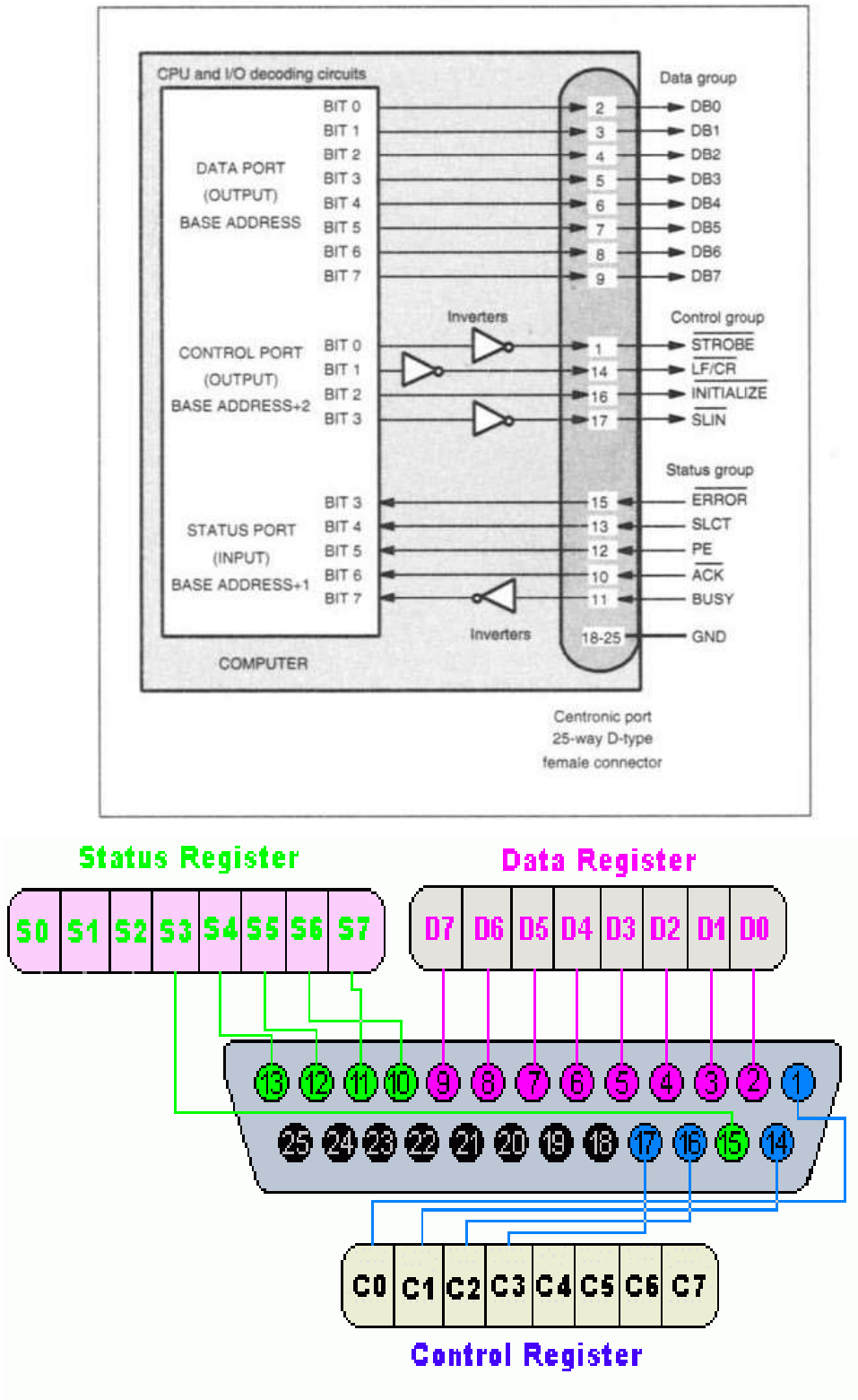


Fig. 1.3: the logic structure of the Centronic port on computers

The LPT base address

There are two ways to obtain the base address. One is to check the hardware configuration of your computer. The other is to find the addresses directly from the user's program by using the facilities provided by the computer's basic input output system (BIOS). When a computer is powered on or reset, the BIOS checks all the possible Centronic ports. If it finds one, it writes the addresses (a 2- byte word) of that port to two specific memory locations. The memory locations for LPT1 to LPT4 are listed as follows:

LPTI: 0000:0408h - 0000:0409h

LPT2: 0000:040Ah - 0000:040Bh

LPT3: 0000:040Ch - 0000:040Dh

LPT4: 0000:040Eh - 0000:040Fh

There is another useful memory location, 0000:4011h. It stores the total number of Centronic ports installed. The information is contained in bit 6 and bit 7.

bit 7=0, bit 6=0: no Centronic port installed

bit 7=0, bit 6=1: one Centronic port installed

bit 7=1, bit 6=0: two Centronic ports installed

bit 7=1, bit 6=1: three Centronic ports installed

The LPT base address
1-from the HW
2-directly from (BIOS), with memory locations are:
LPTI: 0000:0408h - 0000:0409h
LPT2: 0000:040Ah - 0000:040Bh
LPT3: 0000:040Ch - 0000:040Dh
LPT4: 0000:040Eh - 0000:040Fh

Software control
a. How to obtain the base address of LPT
-QBASIC
-TP6
-WINDOWS
b. How to Output & Input data via the LPT
1-Printer commands &BIOS interrupt routines
. QBASIC with instruction PRINT
. TP6 with instruction WRITELIN(LST)
.BIOS interrupt INT 17h
2-Direct I/O access

PC Interfacing

Fourth Level

Lecture Three

Serial (RS232) Port Interface

1. RS232 serial interface:-

The RS232 serial interface is an industrial standard bi-directional data communication interface. For computers, it is used for connecting printers, modems, mice, etc. The communication distance is 20 meters.

Unlike a parallel I/O port, which consists of a number of data lines and each time transmits a byte; the serial data transmission requires only one line. A byte is transmitted bit by bit. This reduces data lines between devices. It reduces the rate of data transfer too; maximum data rates may be up to 20 kbps.

2. Serial data transmission:-

A serial data format includes four parts: a start bit (1 bit), serial data bits (5, 6, 7 or 8 bits), parity check bit (1 bit) and stop bits (1 or 1.5 bit). Figure 1.6 shows a typical serial data format. When no data is sent, the data line is at logic high. This is called the waiting stage.

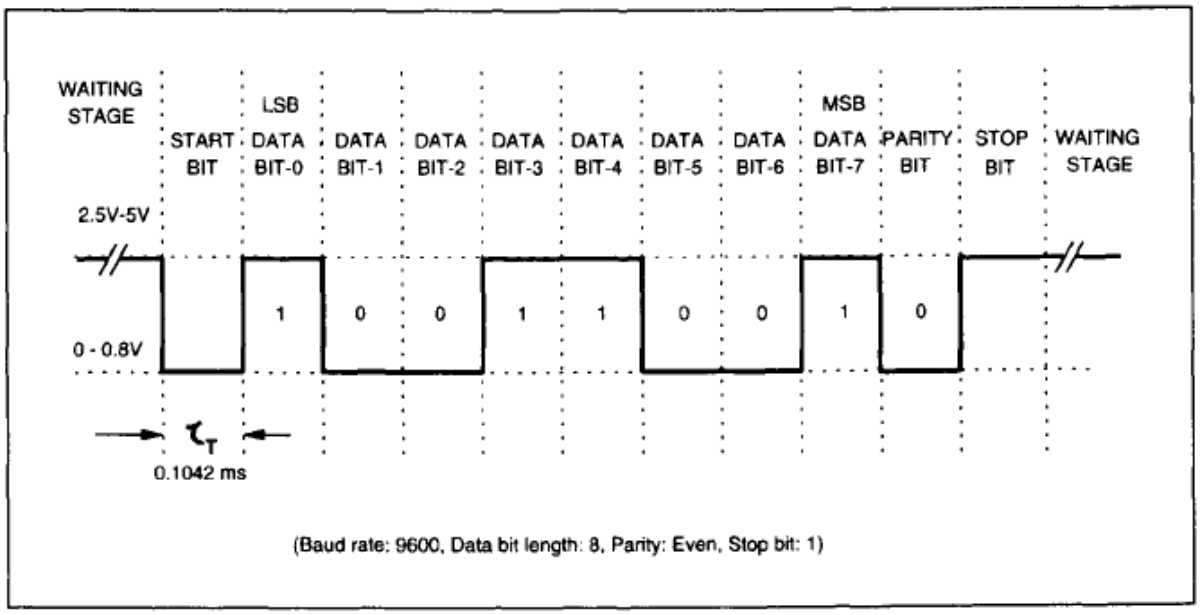


Fig. 1.6: the format of a serial data transmission produced by the UARTs

The beginning of a data transmission is indicated by pulling the line to the logic low state for 1 bit time. This bit is the start bit. The data bits are then sent out one after another. The number of the data bits can be 6, 7 or 8. Following the data bits comes the parity bit which is used to check transmission errors occurred during the data transmission. The parity check can be ODD, EVEN or NONE. The odd and even parities indicate that the total number of ones ('1') in the transmitted serial data is an odd number or an even number. It is only reliable to detect single-bit errors. Errors

occurred to several bits cannot be detected. The last bits are the stop bits, which pull the data line to the high state for at least 1 bit time to indicate the end of the data transmission. The number of the stop bits can be 1, 1.5 and 2 bits.

The rate at which the data bits are sent is measured by the baud rate. The standard baud rates for an RS232 serial port are 110, 150, 300, 600, 1200, 2400, 4800, 9600 and 19200. Knowing the baud rate, the number of bytes to be transmitted per second can be calculated. For example, if a serial data has 8 data bits, no parity check and 1 stop bit, the total length of serial data bits is 10. The transfer rate for characters is the baud rate divided by 10. A baud rate of 9600 will transfer 960 characters per second.

A specially designed electronic device which generates and receives the asynchronous serial data is called the Universal Asynchronous Receiver/Transmitter (UART). The serial data transmission format is generated by the transmitting UART.

The Universal Asynchronous Receiver / Transmitter (UART) controller is the key component of the serial communications of a computer. The UART takes bytes of data and transmits the individual bits in a sequential fashion. At the destination, a second UART reassembles the bits into complete byte.

The UARTS have a TTL voltage level. In order to achieve a long distance communication, the TTL voltage level is converted to higher voltage level (logic 0 = -12 to - 3V, logic 1 = +3V to +12V). This is achieved by using dedicated RS232 drivers/receivers. All drivers/receivers have an inverting action.

UART is responsible for sending and receiving a sequence of bits. At the output of a UART these bits are usually represented by logic level voltages. These bits can become RS232.

RS232 specifies voltage levels. Notice that some of these voltage levels are negative, and they can also reach ±15V.

A microcontroller UART cannot generate such voltages levels by itself. This is done with help of an additional component: RS232 line driver. A classic example of an RS232 line driver is MAX232. This IC has a charge pump, which generates ±10V from +5V.

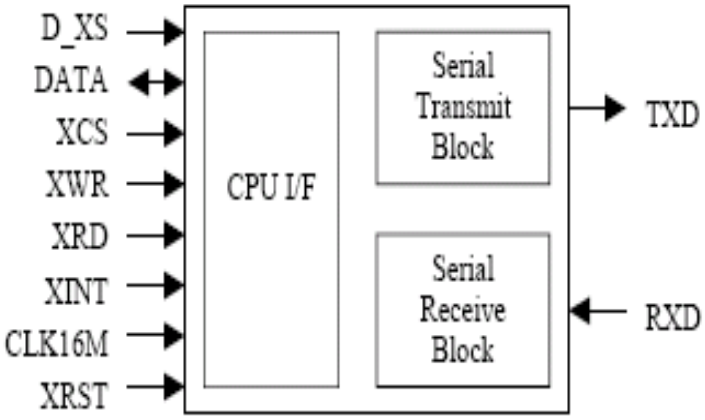
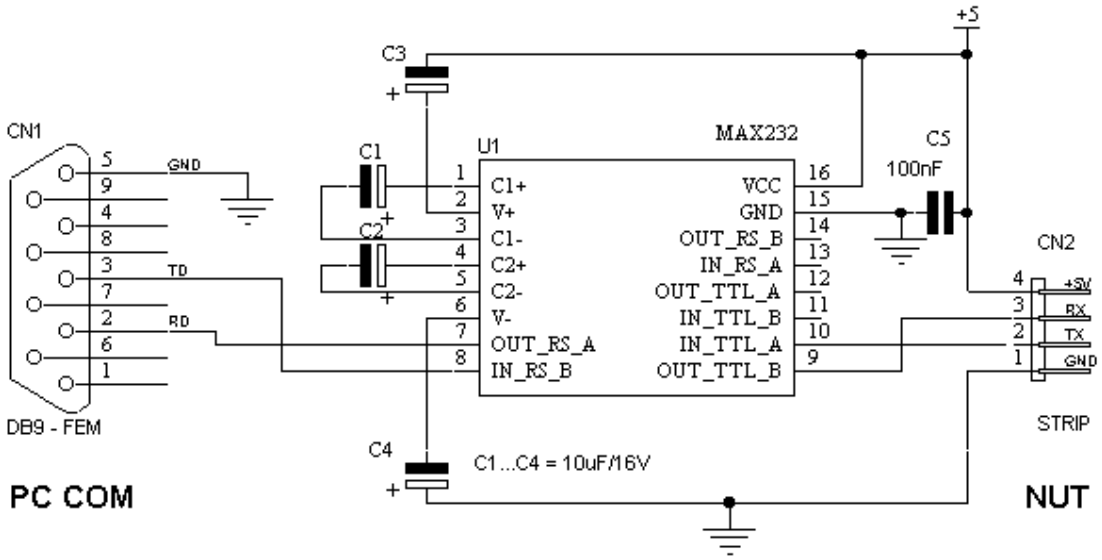
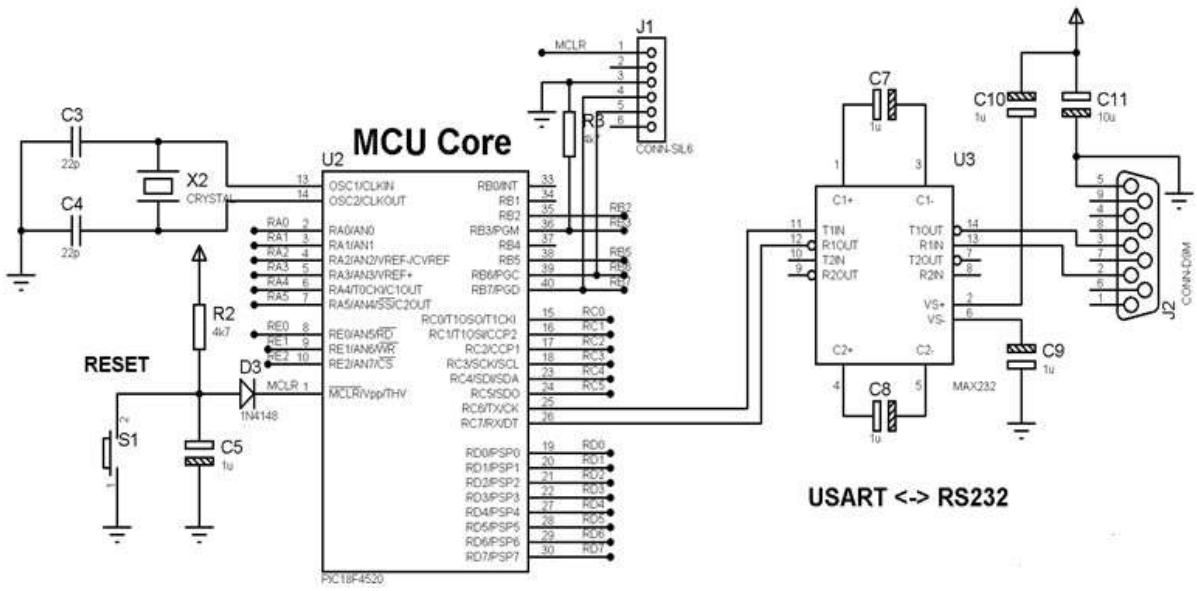


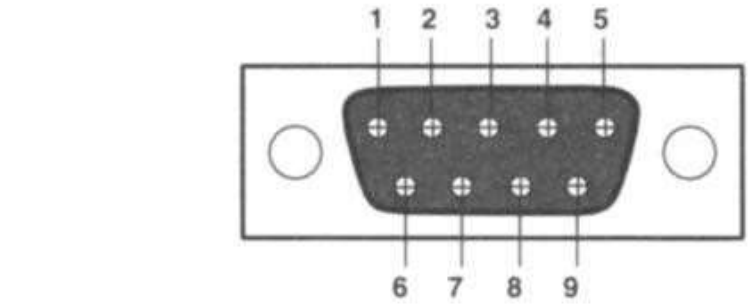
Figure 1. Basic UART block diagram.



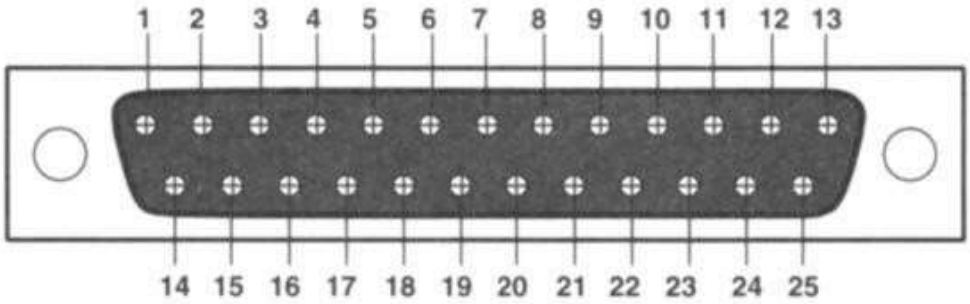


3. RS232 port connector and connections:-

A standard RS232 interface is a 25-pin interface housed in a 25-pin or a 9-pin D-type male connector. Figure 1.7 gives the pin-out and functions of connectors.



(a) 9-pin male socket viewed from the back of the computer



(b) 25-pin male socket viewed from the back of the computer

Pin functions of the RS232 connectors

25 PIN	9 PIN	NAME	DIRECTION (FOR PCS)	DESCRIPTION
1		Prot	-	Protective ground
2	3	TD	OUTPUT	Transmit data
3	2	RD	INPUT	Receive data
4	7	RTS	OUTPUT	Request to send
5	8	CTS	INPUT	Clear to send
6	6	DSR	INPUT	Data set ready
7	5	GND	-	Signal ground (common)
8	1	DCD	INPUT	Data carrier detedt
20	4	DTR	OUTPUT	Data terminal ready
22	9	RI	INPUT	Ring indicator
23		DSRD	I/O	Data signal rate detector

Fig. 1.7: pin-out and function of the RS232 connectors and computers

Table 1.2

Prot	Protective ground. It is connected to the metal screening of the cable and the chassis of the equipment.
GND	Ground line. It provides a common voltage reference for all signals.
TD	Transmitting Data. Serial data is transmitted on this line. It is an output line from the computer.
RD	Receiving Data. Serial data is received from the line. It is an input line to the computer.
RTS	Request To Send. It is a handshake line and indicates that a transmitting device is ready to send data. It is an output from the computer. If handshake is not required, it can be used as an output.
CTS	Clear To Send. It is a handshake line from which a receiving device tells a transmitting device that it is ready to receive data. It is an input to the computer. If handshake is not used, it could be used as an input.
DTR	Data Terminal Ready. It is a handshake line and indicates that a transmitting device is ready. It is an output from the computer. If handshake is not used, it can be used as another output.
DSR	Data Set Ready. It is a handshake line from which a receiving device tells the transmitting device that the data set is ready. It is an input to the computer. If handshake is not used, it can be used as another input.

Two types of RS232 link between a computer and an external device are shown in Figure 1.8. The arrows show the direction of data flow. Figure 1.8(a) is known as the null modem. Figure 1.8(b) shows a connection using only three lines. One line is for transmitting data and the other for receiving data. The connection is arranged so that the transmitting line of the first device is connected to the receiving line of the second device.

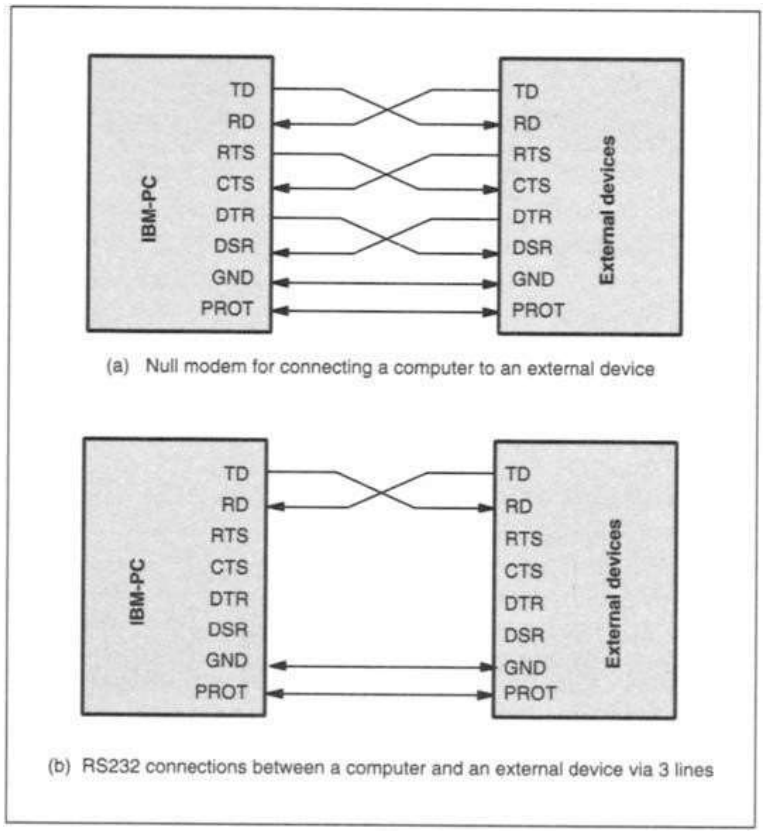


Fig. 1.8: RS232 connections between a PC and an external device

4. Internal hardware organization:-

A computer can have up to four RS232 interfaces installed. They are labeled COM1 to COM4. Each COM port is associated with a UART inside the computer.

RS232 driver/receivers

The RS232 output control signals (-RTS and -DTR) and input status signals (-CTS,-DSR) are processed by the UART in an inverted form. The serial data signal S_{IN} and S_{OUT} are in a non-inverting form. The UART produces the TT'L/CMOs voltage levels only. RS232 line drivers/receivers are connected between the UART and the RS232 connector. The drivers convert the TTL voltage to the RS232 voltage level and the receivers convert the RS232 level to the TTL level. All the drivers/receivers have inverting action. The logic structure of the RS232 port is shown in Figure 1.10.

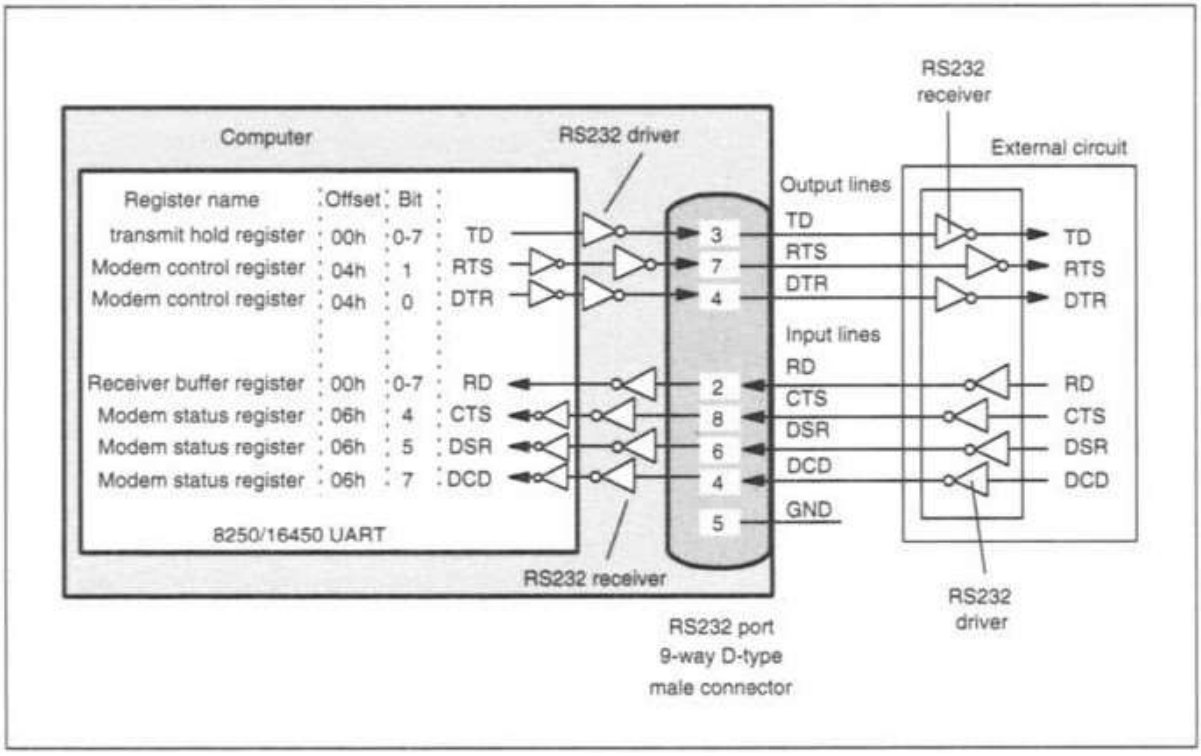


Figure 1.10 Logic structure of the RS232 port

Base addresses of COM ports

The base addresses of COM1 to COM4 are summarized below.

COMI: 3F8h

COM2: 2F8h

COM3: 3E8h

COM4: 2E8h

When a computer is switched on or reset, the BIOS checks all possible RS232 addresses. If it finds an installed one, it writes the base address (a 2-byte word) into specific memory locations. By reading these locations, the base address can be obtained. The memory locations for COM1 to COM4 are listed below.

COM1: 0000:0400h - 0000:0401h

COM2: 0000:0402h - 0000:0403h

COM3: 0000:0404h - 0000:0405h

COM4: 0000:0406h - 0000:0407h

Another useful one-byte memory location is 0000:4011h. It stores the total number of COMs installed. The information is contained in bit 3, bit 2 and bit 1 of the byte.

bit 3=0, bit 2=0, bit 1=0 → no COM port installed

bit 3=0, bit 2=0, bit 1=1→ one COM port installed

bit 3=0, bit 2=1, bit 1=0 → two COM ports installed

bit 3=0, bit 2=1, bit 1=1 → three COM ports installed

bit 3=1, bit 2=0, bit 1=0 → four COM ports installed

Software control

a. How to obtain the base address of COM port

-QBASIC

-TP6

-WINDOWS

b. How to transmit and receive serial data

-Printer commands &BIOS interrupt calls

PC Interfacing

Fourth Level Lecture Four

Experiment board design and Expanding the Centronic

By

Omar Al-farouk Al- dulaimi

1. Centronic experimental board:-

Figure 2.18 shows the circuit diagram of the Centronic experimental board.

DB0 to DB7 of the data port of the Centronic port are fed into the inputs of 74LS244 Schmitt trigger buffers (IC2) via eight 100 Ω resistors (RL2, eight-way resistor array). The outputs of the buffers are connected to an eight-way detachable screw terminal. Each line is also connected to a low current LED via a 3.3K resistor.

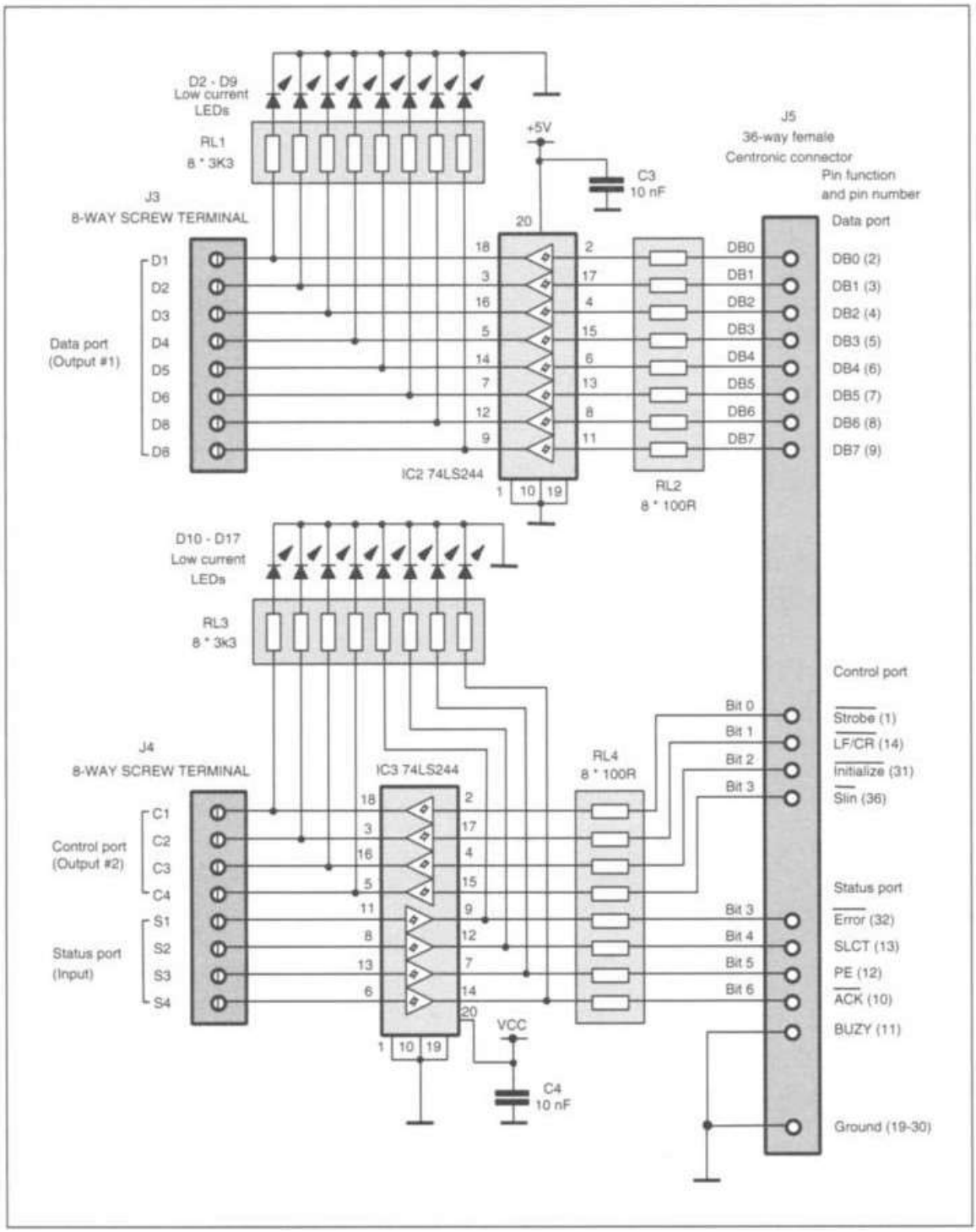


Fig. 2.18: Circuit of the Centronic experimental board

When a line has a logic high state, the corresponding LED illuminates. The four output lines of the control port are connected in the same way as for the data port. Four inputs are connected to the inputs of four Schmitt trigger buffers of IC3. The outputs of the buffers are connected to the four input lines of the status port via four 100Ω resistors. The status port has five input lines, but only four of them are connected this way. The logic status of these lines is monitored by LEDs.

The fifth input line of the status port (the BUZY input) is connected permanently to the ground. This is a very useful feature if high level printer control commands are used to control the board. This indicates that the Centronic experimental board is always ready to receive data.

The power supply incorporates a 1A +5V 7805 fixed voltage regulator (see Figure 2.19). Power is fed to the board via a power connector SK1. SW1 controls the on/off of the power. A 1A fuse is used on the board to limit the total current. The on/off status is indicated by an LED. The input unregulated power supply and the regulated +5V DC are both connected to a four-way screw terminal (J1). The components utilized on the board are listed in Table 2.1.

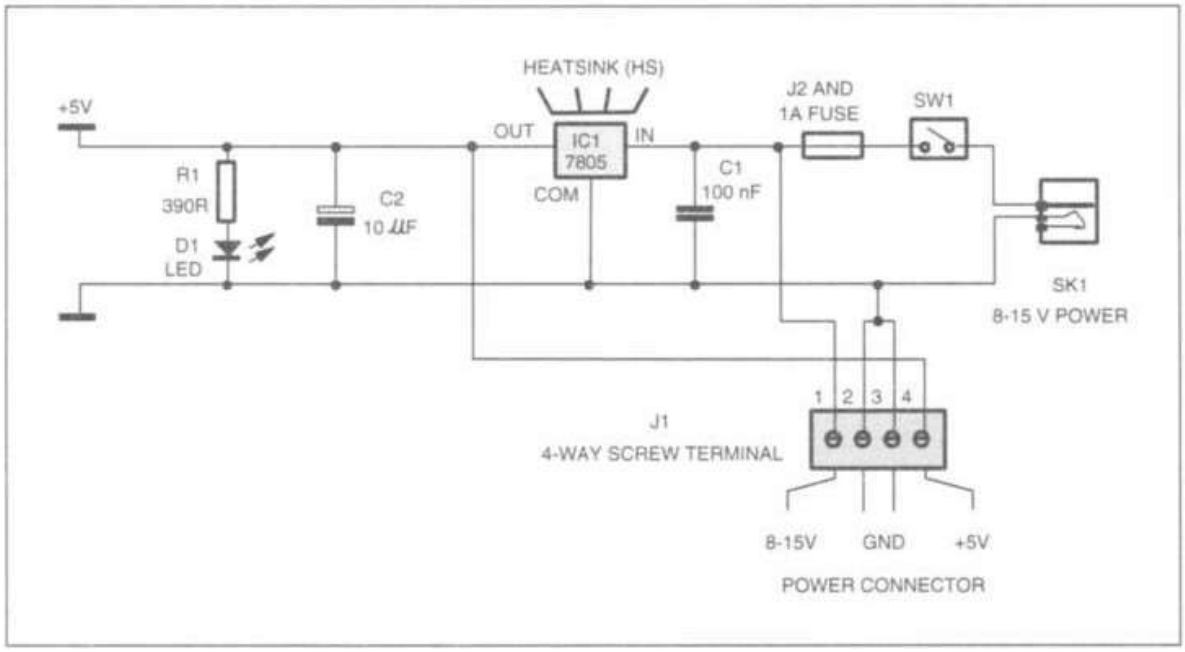


Fig. 2.19: Power Supply Circuit for the three interfacing boards

Table 2.1

Resistors (all 1% 0.25W metal film resistors)	
R1	390R
RL1, RL3	3.3K eight-way resistor array
RL2, RL4	100R eight-way resistor array
Capacitors	
C1, C3, C4	100 nF
C2	10 µF
Semiconductors	
IC1	7805 1A +5V voltage regulator
IC2, IC3	74LS244
D1	5mm green LED
D2–D17	Low power 3 mm red LEDs
Connectors	
J1	Four-way detachable screw terminal block set
J2	Fuse holder
J3, J4	Eight-way detachable screw terminal block set
J5	36-way female Centronic type connector
SK1	2.5 mm male power connector
Others	
SW1	PCB mounting miniature SPDT switch
Fuse	1A 25 mm length
Heat sink	(5 deg/watts)
PCB boards	
Holders for 3mm LEDs	
PCB pilar & screws	

In many applications, the number of I/O lines provided by the Centronic, RS232 and game port is not enough. Expansion of the I/O lines is required.

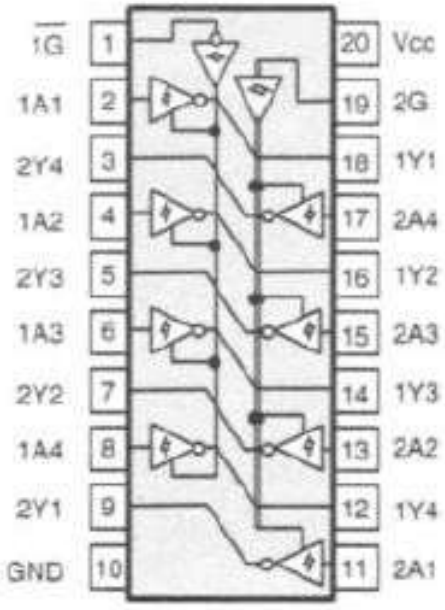
2. Expanding the Centronic port:

One method for expanding I/O lines of the port is to use the 74LS TTL or 4000 CMOS series logic chips. The other is to use dedicated peripheral programmable interface (PPI) chips such as the 8255, 8155 or others. Using the logic chips is simple and economical. The disadvantage is that the hardware is not configurable. Using interface chips makes the expansion configurable. For example, the 8255 PPI provides 24 I/O lines which are arranged in three groups, A, B and C. Each group has eight I/O lines and can be configured as an input or an output port.

(a) Reading 8- bits data:

Figure 4.1 shows an experimental circuit to allow the Centronic port to read 8-bit data using a 74LS241 octal buffer. The pin-out of the 74LS241 is shown in Figure 4.1. When pin 1 is taken low, the four buffers on the left hand side are enabled (the outputs follow the inputs). Otherwise the outputs are in the high the impedance state. When pin 19 goes high the four buffers on the right hand side are enabled. If pins 1 and 19 are connected together to form a data selection line (DSL), by putting it low and then high, you can read the four bits connected to the buffers on the left and then the other four bits connected to the buffers on the right in turns. Operating in such a manner, 8-bit data can be read into the computer via only four lines. The DSL line can be controlled by bit 0 of the data port.

Octal buffer used to read 4 bits and other 4 bits are in high impedance state. The DSL line connected to the both low and high signal to read 4 bits lower data and 4 bits upper data in turns via four data lines. The DSL can be controlled by D0 line to read byte data in two consecutive readings.



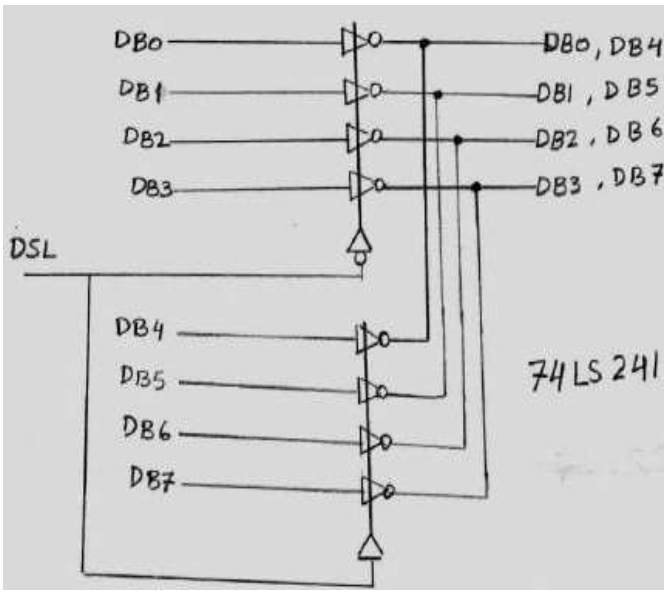


Fig. 4.1: The pin-out of the 74LS241

Figure 4.1 also shows how the 74LS241 is connected to the Centronic experimental board. Eight-bit input data is loaded into a computer in two consecutive

readings. When SEL is low, bit 0 to bit 3 of the input data are read into the computer. When SEL is high, bit 4 to bit 7 are read into the computer.

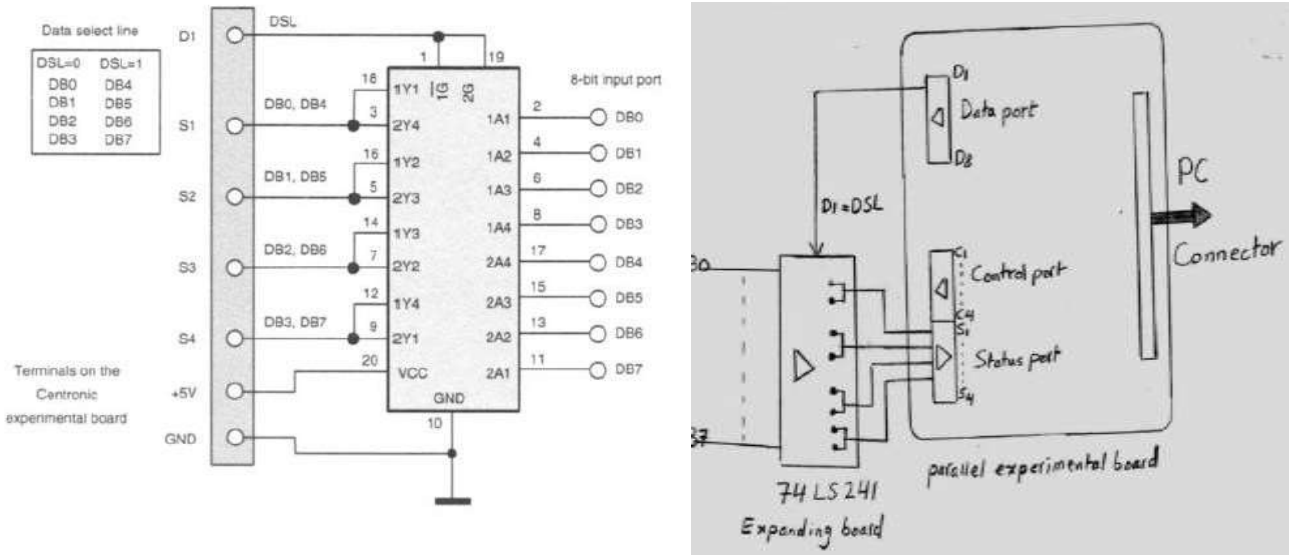


Fig. 4.1: The connection between 74LS241 and the Centronic experimental board.

(b) Expanding Outputs:

The way to expand output lines are to use latches such as the 74LS373 or 74LS374 ICs. The pin-out and an experimental circuit using the 74LS374 are shown in Figure 4.2. The inputs to the 74LS374 are connected to bit 0 to bit 7 of the DATA port. Latching data into the IC is controlled by the CLK. The CLK pin is controlled by one output line of the CONTROL port. In Figure 4.2, D1 to D8 and C1 are terminals on the Centronic experimental board.

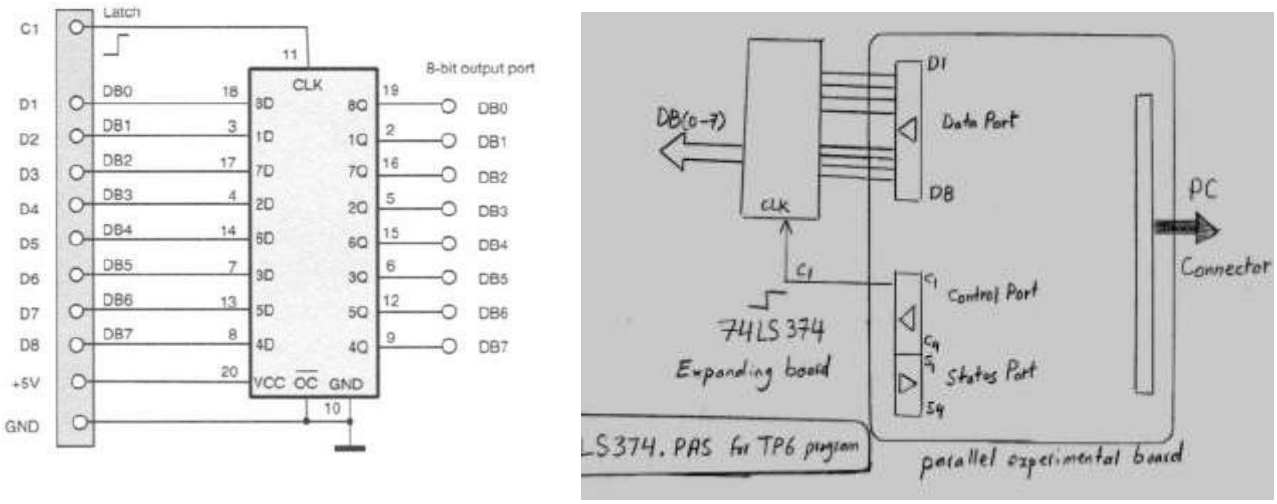


Fig. 4.2: connection between 74LS374 and the Centronic experimental board

The modes of the 8255 are configured by writing an 8-bit control word to the control register. The bit function of this control word is shown below:

bit 7 (mode set flag) always 1

bit 6, Bit 5 (mode selection bits) 00=Mode 1, 01=Mode 2, lx=Mode 3

bit 4 (mode of port A) 1=input, 0=output

bit 3 (mode of upper half of C) 1=input, 0-output

bit 2 (mode selection for Mode 3) 1-Mode 1, 0-Mode 0

bit 1 (Mode of port B) 1=input, 0=output

bit 0 (Mode of lower half of C) l=input, 0-output

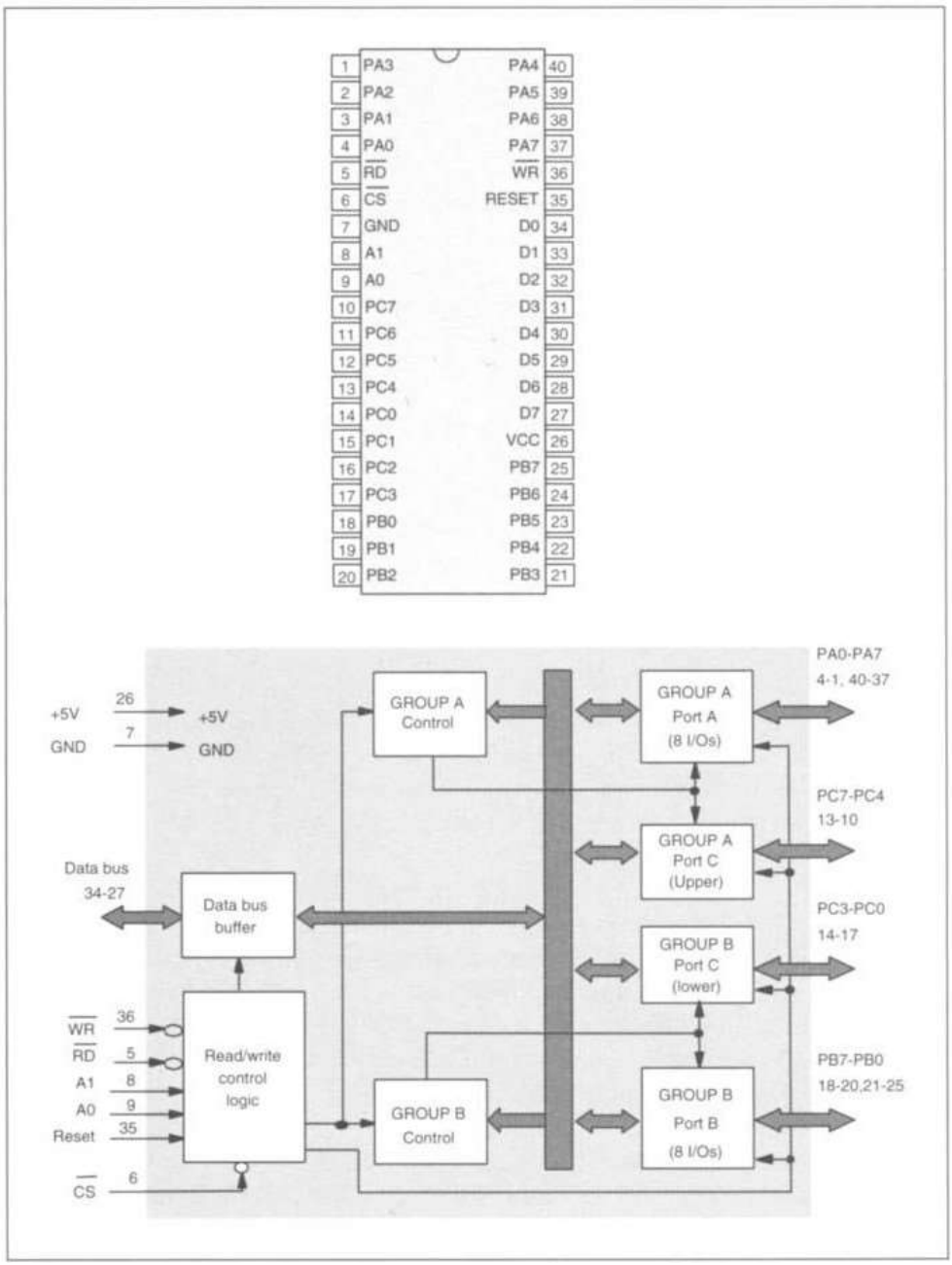


Fig. 4.4: pin out and internal block diagram of the 8255

PC Interfacing

Fourth Level Lecture Five

Experiment board design and Expanding the RS232

By

Omar Al-farouk Al- dulaimi

1. Serial RS232 experimental board:-

The circuit diagram of the RS232 experimental board is given in Figure 2.20.

The three outputs of the RS232 port of a PC (TD, RTS and DTR) are fed into the MAX238 RS232-TTL driver/receiver (IC3, Maxim), where the RS232 voltage level is converted to TTL level. The outputs from the IC3 are fed into Schmitt trigger buffers 74LS244 (IC2), the outputs from which are connected to three screw terminals (J3). The logic status of each line is monitored by low current LEDs. The four input signals (RD, DSR, DCD and CTS) are fed into the 74LS244 buffers. The outputs from the buffer are fed into IC3 where the TTL voltage level is converted into the RS232 level. Their logic status is monitored by LEDs. The power supply system is the same as that for the Centronic experimental board. The MAX238 is an RS232/TTL receiver/transmitter; it's requiring only a single +5V supply. The two on-chip charge pump voltage converters generate +10 V and -10 V power supplies from a single +5 V supply. The IC contains eight voltage level converters, four of which convert the TTL/CMOS level into the RS232 level, and four of which convert the RS232 voltage level into the TTL/CMOS level. It requires five external 1µF capacitors. The components utilized on the board are listed in Table 2.2.

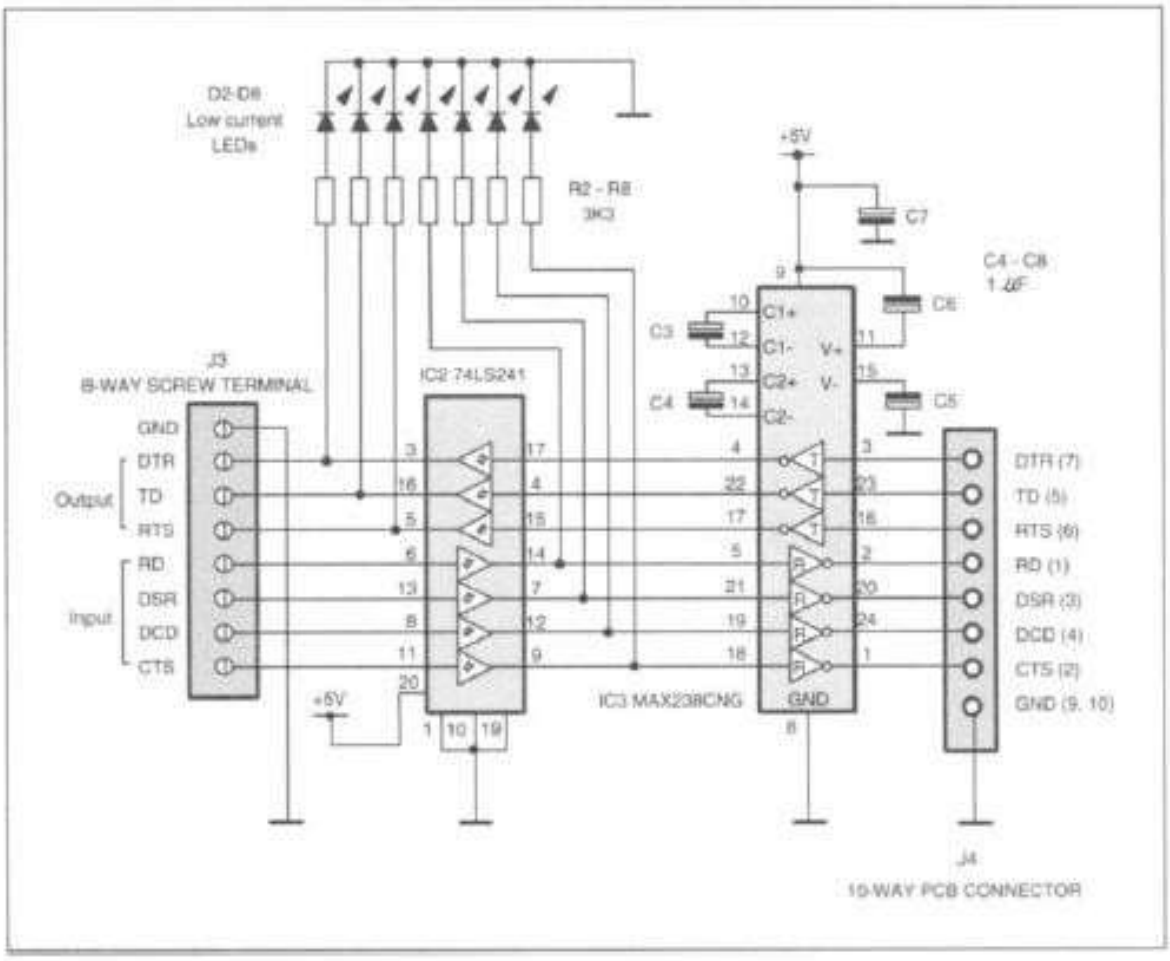


Figure 2.20 Circuit diagram of the RS232 experimental board

Table 2.2

Resistors (all 1% 0.25W metal film resistors)	
R1	390R
R2-R8	3.3K
Capacitors	
C1	100 nF
C2	10 µF
C3-C7	1 µF
Semiconductors	
IC1	7805 1A +5V voltage regulator
IC2	74LS244
IC3	MAX238CNG
D1	5mm green LED
D2-D8	Low power 3mm red LEDs
Connectors	
J1	Four-way detachable screw terminal block set
J2	Fuse holder
J3	Eight-way detachable screw terminal block set
J4	Ten-way PCB connector set
SK1	2.5mm male power connector
Others	
SW1	PCB mounting miniature SPDT switch
Fuse	1A 25mm length
Heat sink	(5 deg/watts)
PCB boards	
Holders for 3mm LEDs	
PCB pilar & screws	
9 pin female D-type connector and housing	
1m 9 core digital signal cable	

2. <u>RS232/TTL line translators:</u>

The simplest way of converting the RS232 voltage level to the TTL voltage level is to use **voltage clamp** circuits as shown in Figure 4.5(a). The circuit consists of one resistor and a +5.1V Zener diode. When the input RS232 status is high, the output is +5 V when the status is low, the output voltage is -0.6V. **Another TTL/RS232** transceiver circuit is shown in Figure 4.5(b). The circuit does not require any external power supplies. It 'steals' the power from the RS232 port. It has an inverting action.

The TTL/RS232 transceivers ICs are widely used. The MAX232 and the MAX238 are two examples. Both ICs require a signal rail +5V power supply. The MAX232 contains an on-board dual charge-pump DC-DC voltage converter, two RS232 drivers and two RS232 receivers. The dual charge-pumps convert the +5 V supply voltage to +10V and -10V. Care should be taken not to load V+ and V- to a point that it violates the minimum RS232 (RS232C, V_{min} = 3V) voltage level. The supply current of the MAX232 is 4 mA when the outputs have no load. The MAX238 has similar electrical characteristics and has four drivers and four receivers.

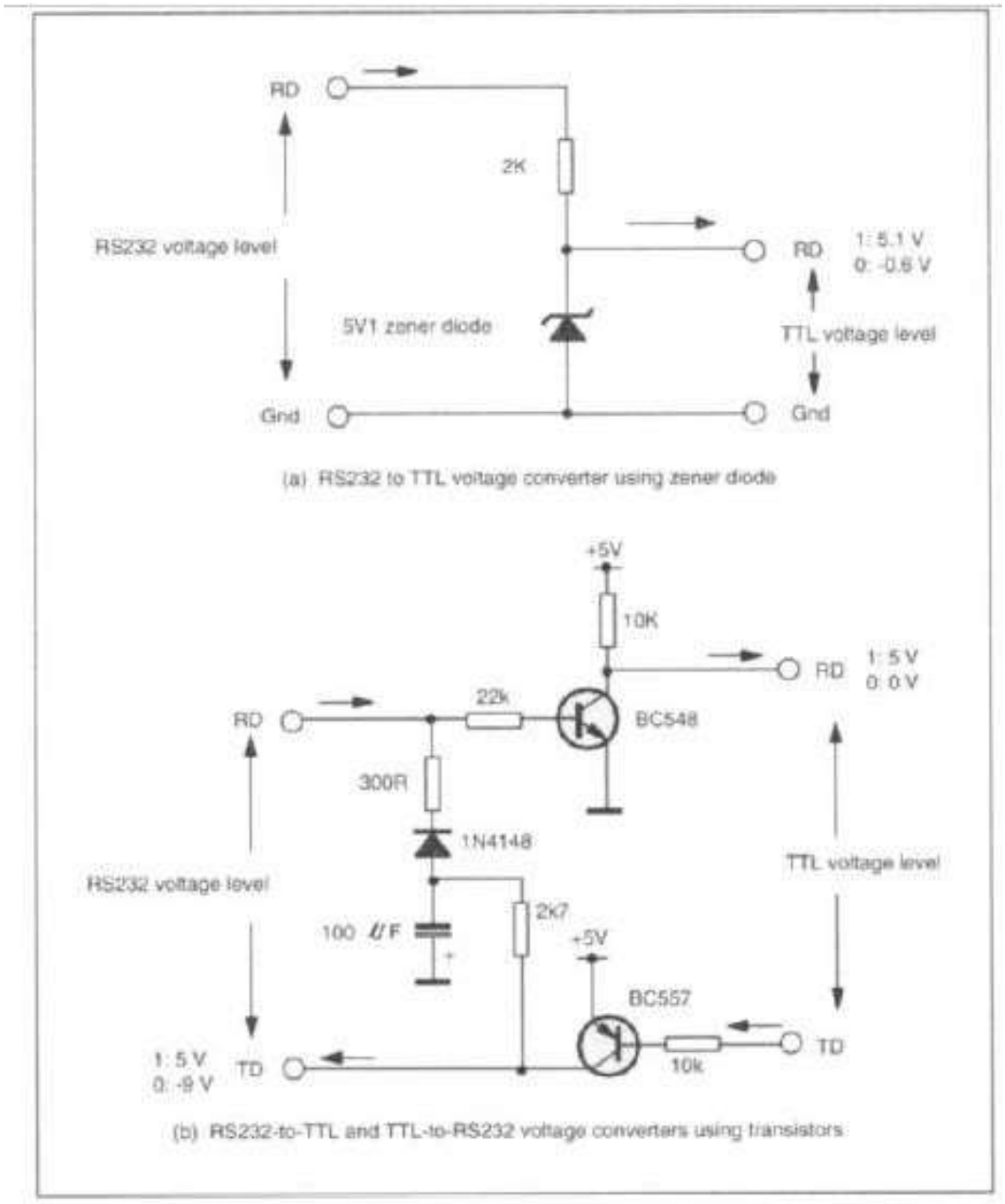


Figure 4.5 TTL/RS232 voltage converter circuits

3. Expanding the RS232 port (using UARTs):-

The CDP6402 is a Universal Asynchronous Receiver/Transmitter for interfacing to asynchronous serial data channels. Serial data format is programmable. It can have 5, 6, 7, or 8 bit length. The parity check can be odd, even or none. Stop bits can be 1, 1.5 or 2. The IC requires a power supply voltage 4 to 10 volts. The pin-out and the internal block diagram are shown in Figure 4.8. Pin 21 is the Master Reset (MR), which should be at the logic low state in normal operations. Pins 35 through 39 control the serial data format. To enable the control pins, pin 34 (Control Register Load, CRL) must be at logic high. A high level on pin 35 (Parity Inhibit, PI) inhibits parity generation and check. It also forces the Parity Error (PE, pin 13) pin to stay low. When PI is low, a high level on Even Parity Enable (EPE, pin 39) selects even parity. A low level on EPE pin selects odd parity. Pin 36 (Stop Bit Select) high selects 1.5 stop bits for 5 character format and 2 stop bits for other data lengths. If it is low, 1 stop bit is selected. Pins 37 (Character Length Selected, CLS2) and 38 (CLS1) select the data length: CLS1=0, CLS2=0 for 5 bits; CLS1=1, CLS2=0 for 6; CLS1=0, CLS2=1 for 7 and CLS1=1 and CLS2=1 for 8.

Pins 17 (Receiver Register Clock) and 40 (Transmitter Register Clock) are the clock inputs for the receiver and transmitter. They are normally connected together. Pin 20 (Receiver Register Input, RRI) is the serial data input. The received data is stored in the receiver buffer registers which are accessed via pins 5 to 12 (Receiver Buffer Registers). Pin 4 (Receiver Register Disable, RRD) should be low. When data is successfully received and loaded into the receiver buffer registers, pin 19 (Data Received) goes from low to high. It can be set to low by making pin 18 (-Data Received Reset) low. Pins 13 (Parity Error), 14 (Framing Error) 15 (Overrun Error) give the status of errors occurring during a data transmission and they are all high active. To enable these status outputs, pin 16 (Status Flag Disable, SFD) should be low.

Pin 25 (Transmitter Register Output, TRO) is the serial data output. Data to be sent is written into the transmit buffer registers via pins 26 to 33 (Transmitter Buffer Registers). When pin 23 (-Transmitter Buffer Register Load,-TBRL) goes low, the data is loaded into the transmitter buffer registers and when it goes from low to high, it

loads the data into the transmitter register and initiates the serial data transmission. Pin 22 is Transmitter Buffer Register Empty. A high level on this indicates that transmitter buffer register has transferred data into the transmitter register and is ready for new data. Pin 24 is Transmitter Register Empty. A high level on this pin indicates the completion of a serial data transmission.

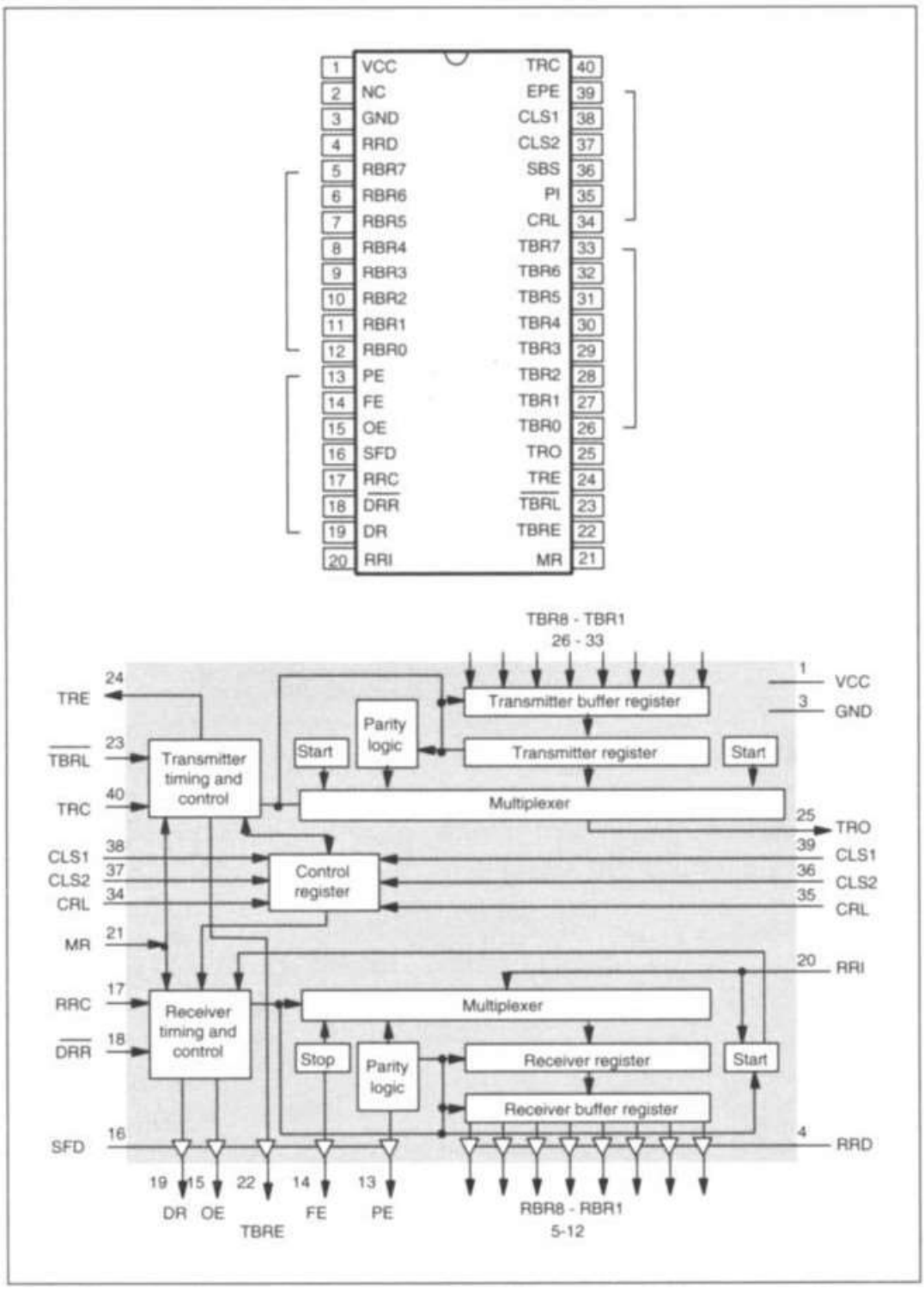


Figure 4.8 Pin-out and internal block diagram of the 6402 UART

An experimental circuit of the 6402 connected to the RS232 experimental board is shown in Figure 4.10. RRI, TRO and -TBRL of the 6402 are connected to TD, RD and DTR terminals on the experimental board. The clock input to the UART is generated by a circuit using a CD4060 and a 2.4576 MHz crystal. From pins 7 of the CD4060, a clock signal at 153.6 kHz is generated, giving a baud rate of 9600. Pin 18 (-DRR) is pulled to logic low. This causes the 6402 to receive serial data continuously.

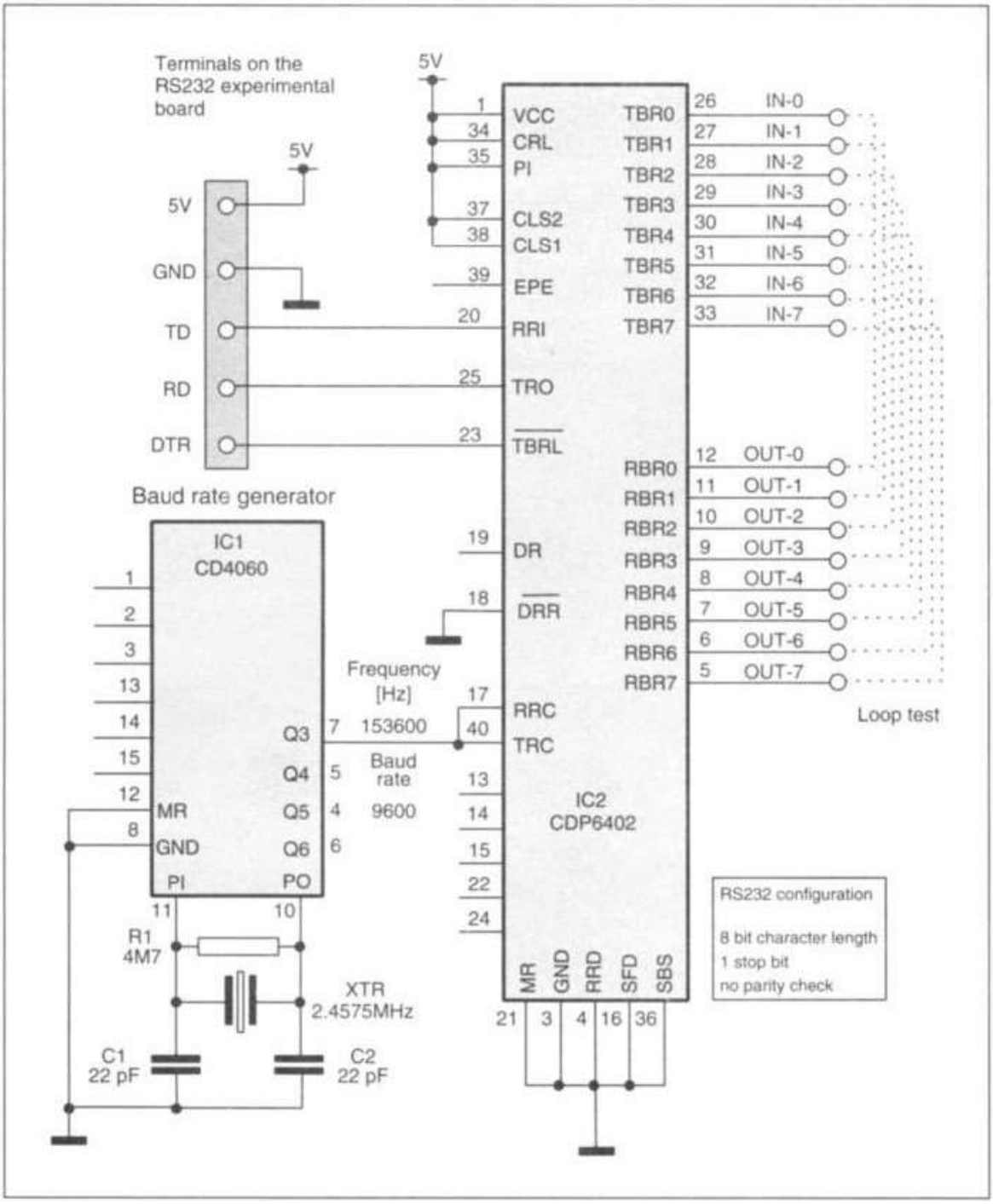


Figure 4.10 Experimental circuit diagram of the 6402 UART

PC Interfacing

Fourth Level Lecture Six

Serial to Parallel and Parallel to Serial Interface

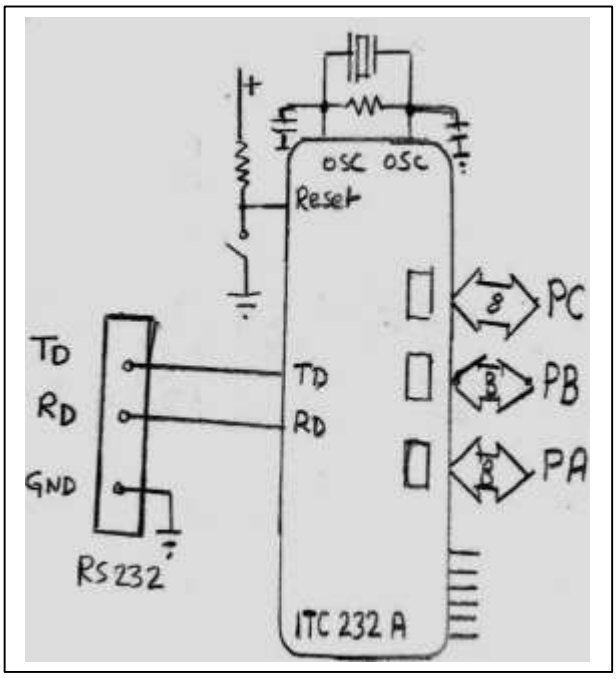
By

Omar Al-farouk Al- dulaimi

1. New Concepts for RS232 (ITC 232-A):-

ITC232-A is a new peripheral chip which is designed for easy interfacing with the RS232 port on computers. It is connected to the RS232 port via three lines, TD, RD and ground. The IC has a powerful built-in control command set and translator it to machine code. Users can input command from keyboard, the IC decodes the command & perform the action. This is advantageous over other I/O interfacing schemes. Firstly, there is no need for users to learn low-level languages and hardware controls. Secondly, there is no need to compile the instructions.

The ITC232-A has a 40-pin. The device requires a +5V power supply and consumes 50 mA. The RS232 serial I/O command port operates with a baud rate from 300 to 115, 200. The IC has 24 I/O lines arranged in three ports A, B and C. They can be configured individually as input or output. Bits 4 to 7 of ports A, B and C can be used to drive 3PH stepper motors of speed range 10 to 4000 steps per second. Bits 0 to 3 of ports A, B and C can be used to measure resistance or capacitance. The device offers a pulse-width modulated output with a frequency range from 10 Hz to 10 kHz and a duty cycle range from 1 to 100%. The ITC232-A can be connected to the RS232 experimental board as shown in Figure 4.11. The full instruction set and application notes are available from the manufacturer.



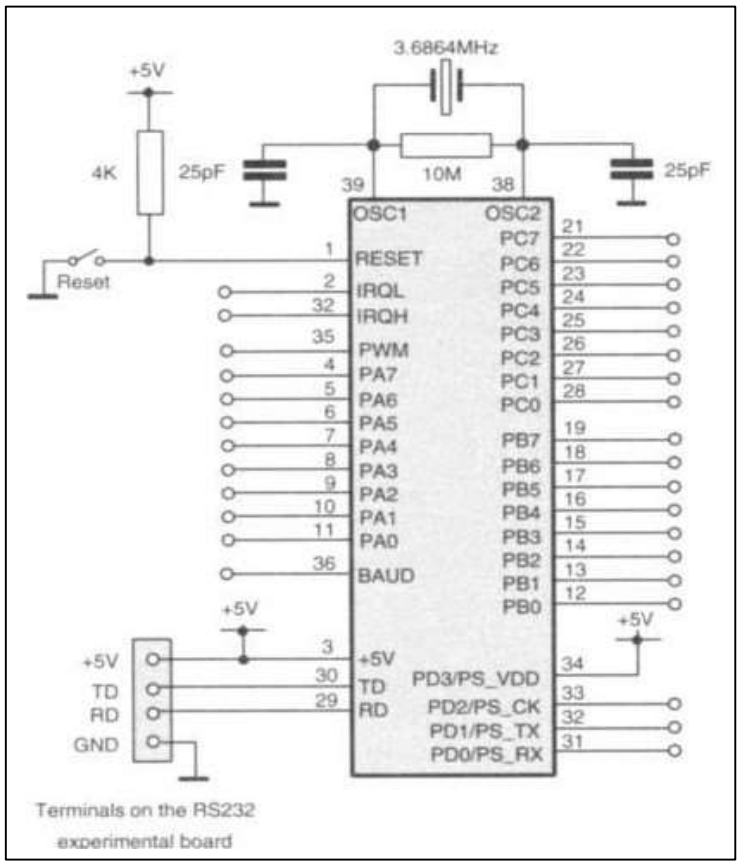


Figure 4.11: the internal block diagram and an application of the ITC232-A

2. Serial to Parallel Interface:-

By using serial-in and parallel-out shift registers such as the 74LS164s, two output lines from a computer can generate an unlimited number of outputs. Figure 4.12(a) shows how a 74LS164 is used to generate eight output lines from two output lines of a PC. The 74LS164 has two serial data inputs, pins 1 and 2 (A and B) and eight shift register outputs (Qa to Qh). At transition, the serial data bit presented at the inputs A and B is shift to Qa. In the same time the value on Qa is shift to Qb, Qb to Qc, etc. After eight clock cycles, the 8-bit byte can be loaded into the outputs of the shift register. A logic low at pin 9 (-CLEAR) sets the eight outputs low. The maximum input clock frequency is 25 MHz. Several 74LS164s can be used to generate more outputs. The connection of the circuit to the RS232 experimental board is given in Figure 4.12(a). We can see that RTS is connected to the serial data in (pins 1 and 2) and DTR connected to the CLOCK (pin 8).

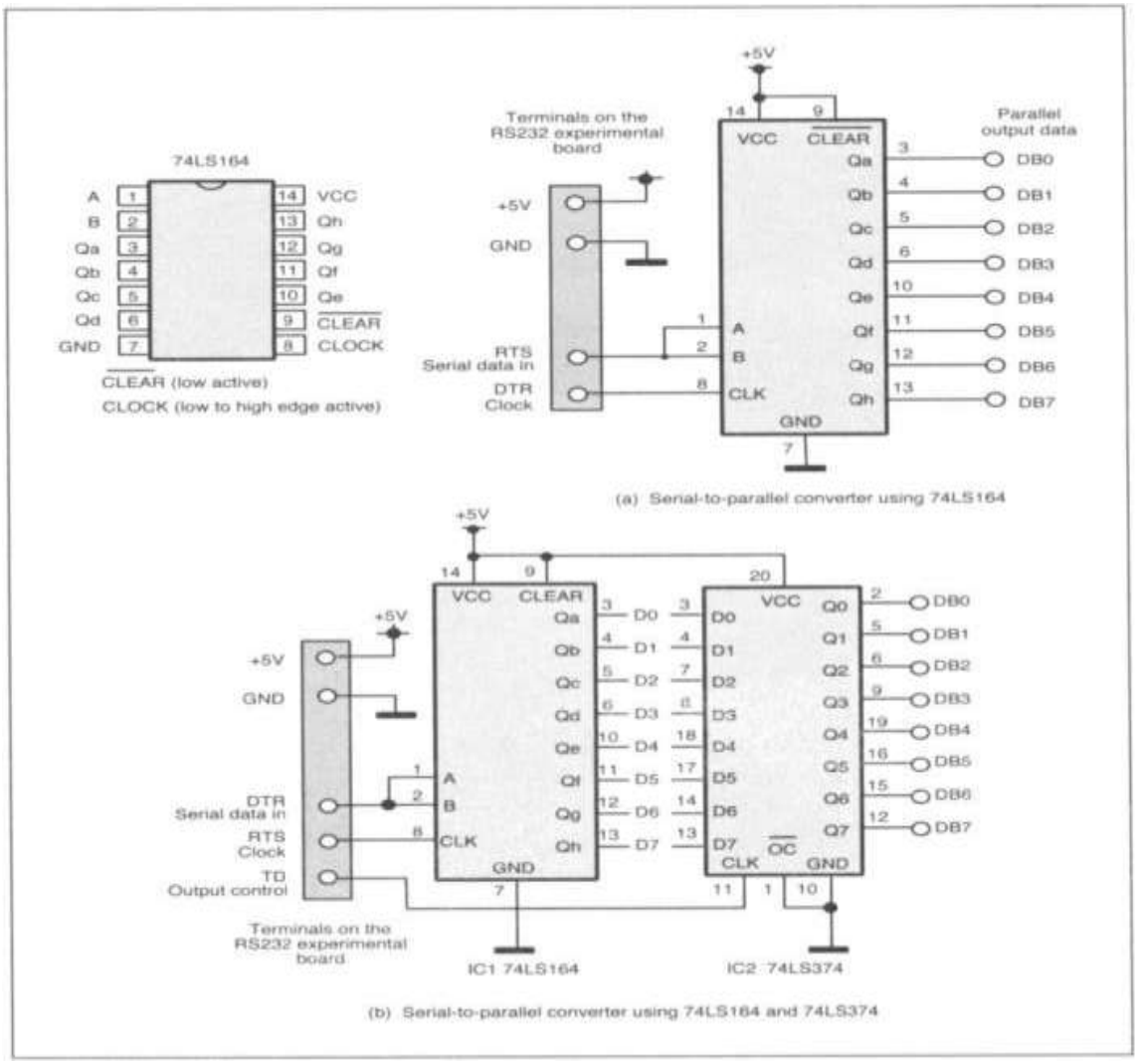


Figure 4.12: Serial to Parallel convertor circuits using 74LS164 and 74LS374

There are two problems associated with the serial-to-parallel interface. One is the data transfer rate. A Pentium computer can output clock signal at a frequency in the range from 0.1 MHz to 1 MHz. The more outputs you have in the circuit, the slower the loading speed is. This is not a problem for low and medium speed interfacing applications. The other problem is that during data loading, the output same times changes randomly. To solve this, data latches such as the 74LS374 can be used (see Figure 4.12(b)). After all data bits are loaded into the shift registers, they are loaded into the 74LS374 by applying a low-to-high signal to the CLOCK of the 74LS374 (pin 11). The circuit, however, requires another output line from the computer. For the RS232 port, TD line can be used. These circuits can be also used for the Centronic port. The three lines could be the output lines of the data port or the control port.

3. Parallel to Serial Interface:-

Using a parallel-in and serial-out shift register such as the CD4021, the number of inputs to a computer can be expanded. It requires two output lines from the computer (one to load parallel data and one to shift the data) and one input line to the computer to read data. Figure 4.13 shows a circuit for inputting eight bits of data. The pin-out of the CD4021 is also shown in Figure 4.13.

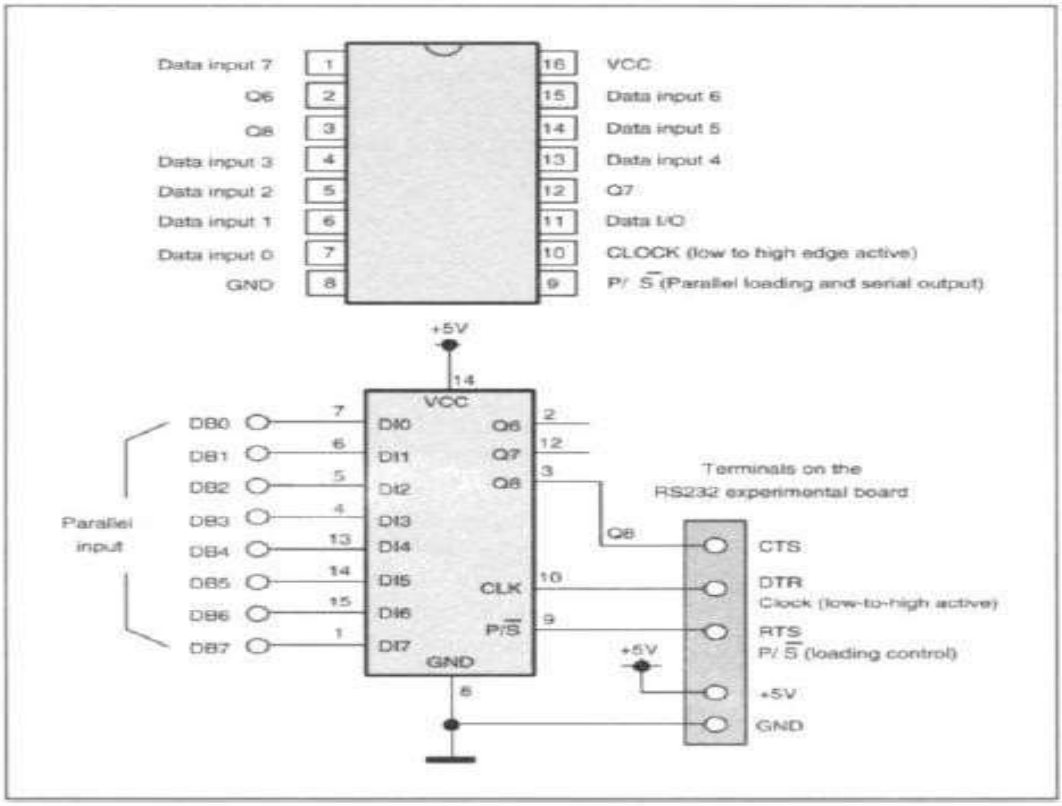


Figure 4.13 Parallel-to-serial converter using a CD4021 shift register

The IC has a CLOCK input (pin 10), a parallel-in/serial-in control input (P/-S, pin 9), a serial data I/O (pin 11), eight parallel data inputs (D0 to D7) and three serial data outputs (Q6 to Q8).

In operation, 8-bit data is present at the inputs. Then P/-S goes from low to high to load the 8-bit data into the internal register (parallel-in operation). Next, P/-S is brought low to terminate the parallel-in operation and to start the serial-out operation. At transition, the input data bits are shift out. After eight clock cycles, the 8-bit data is serially transmitted. The connection of the IC to the RS232 experimental board is shown in Figure 4.13. CLOCK is connected to terminal DTR. P/-S control is connected to terminal RTS. Output Q8 is connected to CTS terminal. This circuit can be used with the Centronic port as well. Again there is a problem associated with the data transfer rate. It can be used only for medium to low speed interfacing applications.

PC Interfacing

Fourth Level Lecture Six

Serial to Parallel and Parallel to Serial Interface

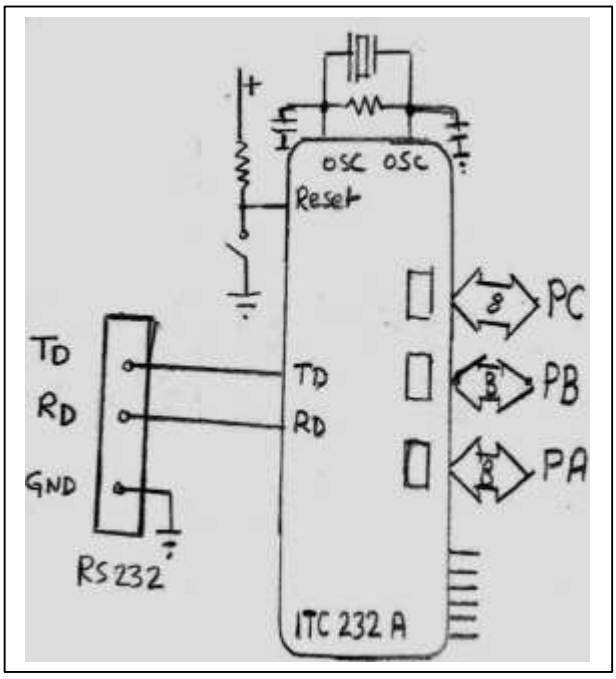
By

Omar Al-farouk Al- dulaimi

1. New Concepts for RS232 (ITC 232-A):-

ITC232-A is a new peripheral chip which is designed for easy interfacing with the RS232 port on computers. It is connected to the RS232 port via three lines, TD, RD and ground. The IC has a powerful built-in control command set and translator it to machine code. Users can input command from keyboard, the IC decodes the command & perform the action. This is advantageous over other I/O interfacing schemes. Firstly, there is no need for users to learn low-level languages and hardware controls. Secondly, there is no need to compile the instructions.

The ITC232-A has a 40-pin. The device requires a +5V power supply and consumes 50 mA. The RS232 serial I/O command port operates with a baud rate from 300 to 115, 200. The IC has 24 I/O lines arranged in three ports A, B and C. They can be configured individually as input or output. Bits 4 to 7 of ports A, B and C can be used to drive 3PH stepper motors of speed range 10 to 4000 steps per second. Bits 0 to 3 of ports A, B and C can be used to measure resistance or capacitance. The device offers a pulse-width modulated output with a frequency range from 10 Hz to 10 kHz and a duty cycle range from 1 to 100%. The ITC232-A can be connected to the RS232 experimental board as shown in Figure 4.11. The full instruction set and application notes are available from the manufacturer.



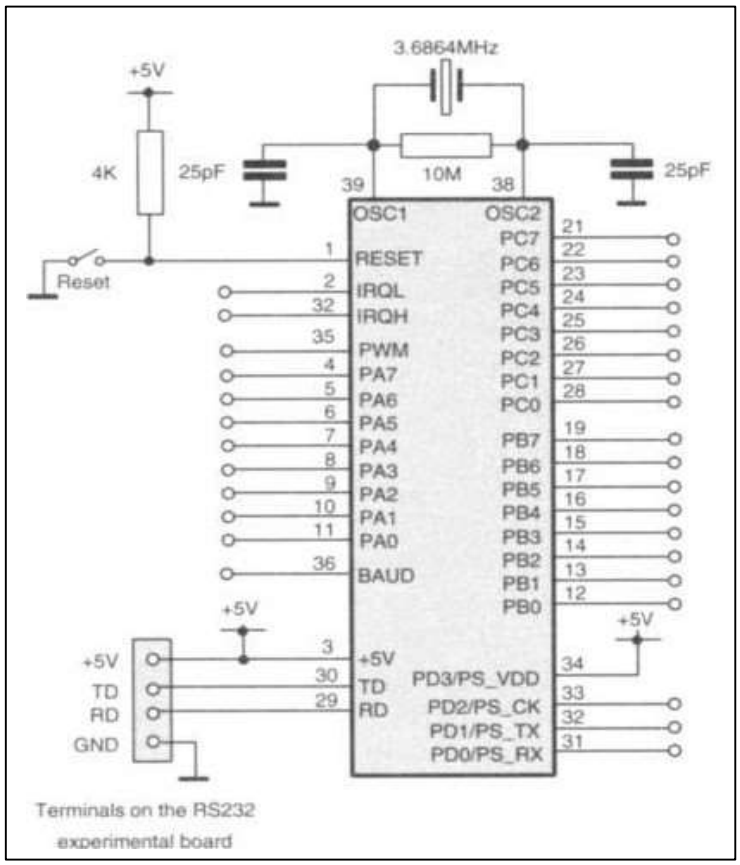


Figure 4.11: the internal block diagram and an application of the ITC232-A

2. Serial to Parallel Interface:-

By using serial-in and parallel-out shift registers such as the 74LS164s, two output lines from a computer can generate an unlimited number of outputs. Figure 4.12(a) shows how a 74LS164 is used to generate eight output lines from two output lines of a PC. The 74LS164 has two serial data inputs, pins 1 and 2 (A and B) and eight shift register outputs (Qa to Qh). At transition, the serial data bit presented at the inputs A and B is shift to Qa. In the same time the value on Qa is shift to Qb, Qb to Qc, etc. After eight clock cycles, the 8-bit byte can be loaded into the outputs of the shift register. A logic low at pin 9 (-CLEAR) sets the eight outputs low. The maximum input clock frequency is 25 MHz. Several 74LS164s can be used to generate more outputs. The connection of the circuit to the RS232 experimental board is given in Figure 4.12(a). We can see that RTS is connected to the serial data in (pins 1 and 2) and DTR connected to the CLOCK (pin 8).

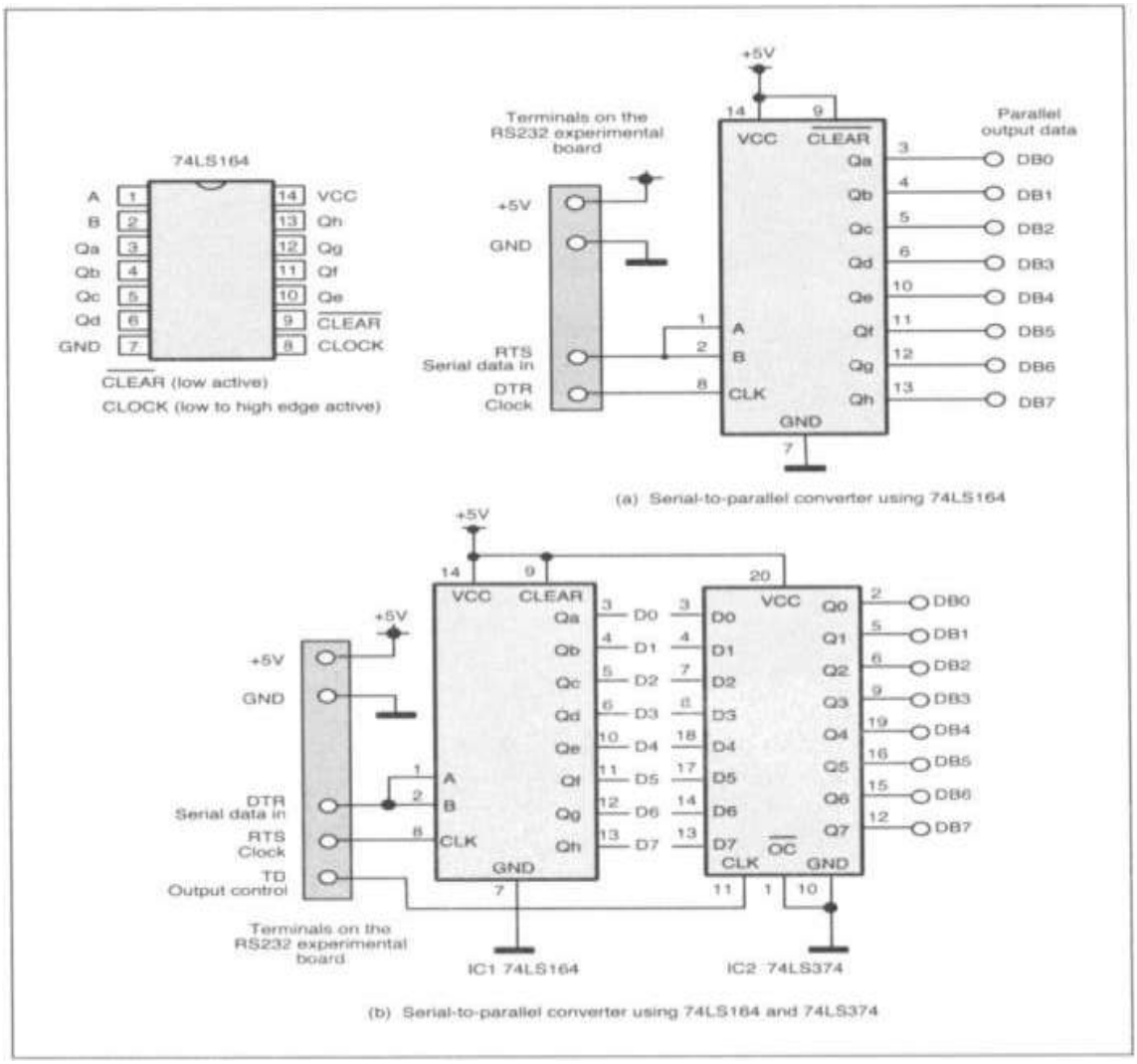


Figure 4.12: Serial to Parallel convertor circuits using 74LS164 and 74LS374

There are two problems associated with the serial-to-parallel interface. One is the data transfer rate. A Pentium computer can output clock signal at a frequency in the range from 0.1 MHz to 1 MHz. The more outputs you have in the circuit, the slower the loading speed is. This is not a problem for low and medium speed interfacing applications. The other problem is that during data loading, the output same times changes randomly. To solve this, data latches such as the 74LS374 can be used (see Figure 4.12(b)). After all data bits are loaded into the shift registers, they are loaded into the 74LS374 by applying a low-to-high signal to the CLOCK of the 74LS374 (pin 11). The circuit, however, requires another output line from the computer. For the RS232 port, TD line can be used. These circuits can be also used for the Centronic port. The three lines could be the output lines of the data port or the control port.

3. Parallel to Serial Interface:-

Using a parallel-in and serial-out shift register such as the CD4021, the number of inputs to a computer can be expanded. It requires two output lines from the computer (one to load parallel data and one to shift the data) and one input line to the computer to read data. Figure 4.13 shows a circuit for inputting eight bits of data. The pin-out of the CD4021 is also shown in Figure 4.13.

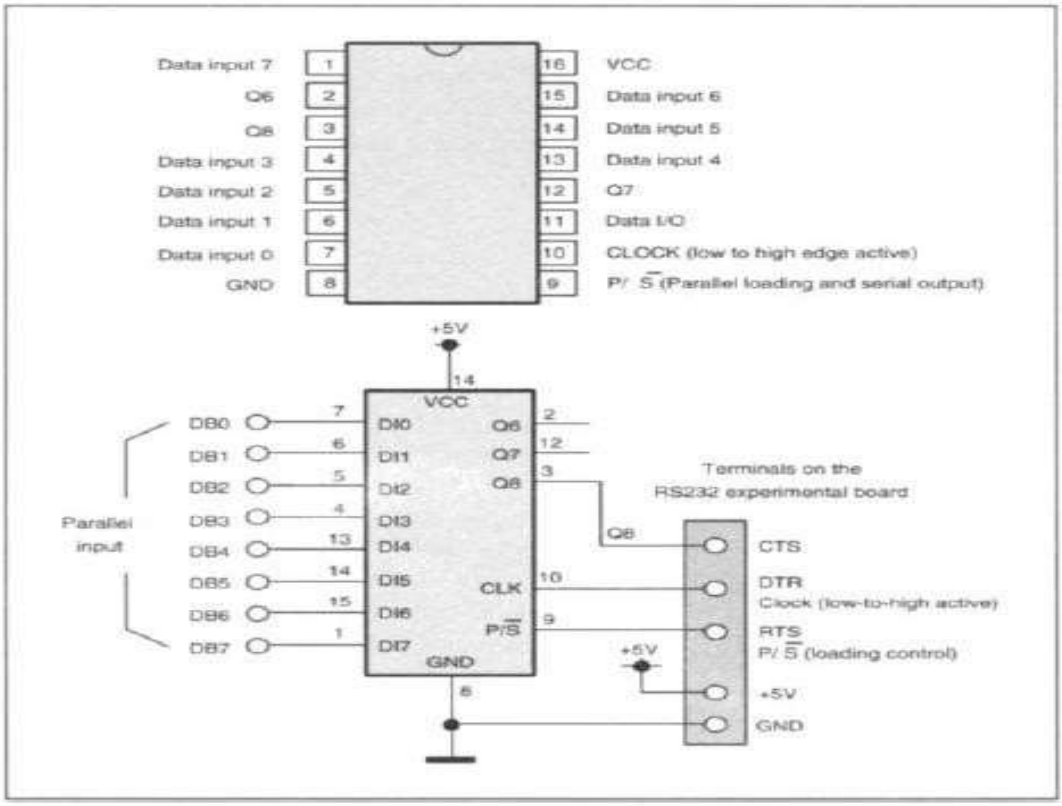


Figure 4.13 Parallel-to-serial converter using a CD4021 shift register

The IC has a CLOCK input (pin 10), a parallel-in/serial-in control input (P/-S, pin 9), a serial data I/O (pin 11), eight parallel data inputs (D0 to D7) and three serial data outputs (Q6 to Q8).

In operation, 8-bit data is present at the inputs. Then P/-S goes from low to high to load the 8-bit data into the internal register (parallel-in operation). Next, P/-S is brought low to terminate the parallel-in operation and to start the serial-out operation. At transition, the input data bits are shift out. After eight clock cycles, the 8-bit data is serially transmitted. The connection of the IC to the RS232 experimental board is shown in Figure 4.13. CLOCK is connected to terminal DTR. P/-S control is connected to terminal RTS. Output Q8 is connected to CTS terminal. This circuit can be used with the Centronic port as well. Again there is a problem associated with the data transfer rate. It can be used only for medium to low speed interfacing applications.

PC Interfacing

Fourth Level

Lecture Eight

RS232 to PIC Microcontroller Interface

By

Omar Al-farouk Al- dulaimi

Why do we need to learn Microcontrollers?

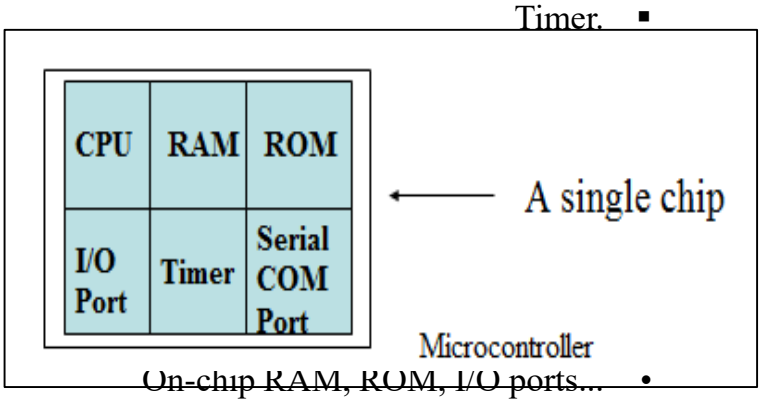
It's not an exaggeration if we say that, today there is no electronic gadget on the earth which is designed without a Microcontroller. Ex: communication devices, digital entertainment, portable devices etc… Not believable???

- Personal information products: Cell phone, pager, watch, pocket recorder, calculator
- Laptop components: mouse, keyboard, modem, sound card, battery charger.
- Home appliances: door lock, alarm clock, thermostat, air conditioner, TV remote, refrigerator, exercise equipment, washer/dryer, microwave oven.
- Industrial equipment: Temperature/pressure controllers, Counters, timers.
- Toys: video games, cars, dolls, etc.

So, a good designer should always know what type of controller he/she is using, their architecture, advantages, disadvantages, ways to reduce production costs and product reliability etc….

Components of a microcontroller:

- CPU: Central Processing Unit.
- I/O: Input /Output.
- Bus: Address bus & Data bus.
- Memory: RAM & ROM.
- Timer.

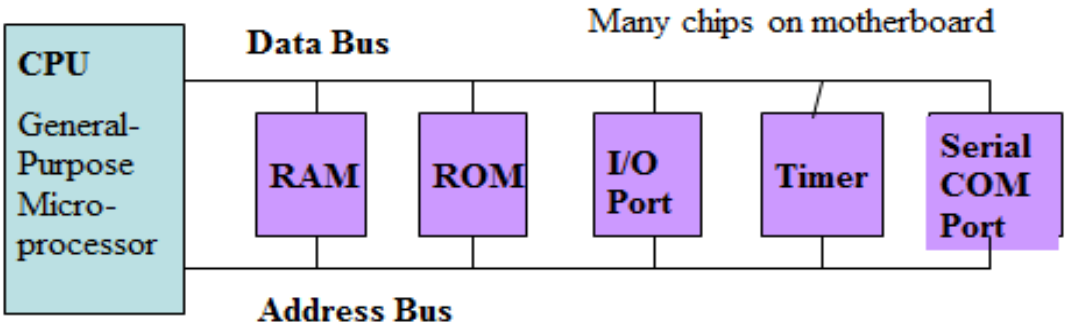


- On-chip RAM, ROM, I/O ports...

A single chip computer or A CPU with all the peripherals like RAM, ROM, I/O Ports, Timers, ADCs etc... on the same chip. For ex: Motorola's 6811, Intel's 8051, Zilog's Z8 and PIC 16X etc…

General-purpose microprocessor:

- CPU for Computers.
- Commonly no RAM, ROM, I/O on CPU chip itself. For ex: Intel's 8086, 8088, 80386, 80486 and Pentium, Motorola's 68000, 68010, 68020 and 68030.



A CPU built into a single chip is called a microprocessor. It is a general-purpose device. The microprocessor contains arithmetic and logic unit (ALU), Instruction decoder and control unit, Instruction register, Program counter (PC), clock circuit (internal or external), reset circuit (internal or external) and registers. But the microprocessor has no on chip I/O Ports, Timers, Memory etc. For example, Intel 8085 is an 8-bit microprocessor and Intel 8086/8088 a 16-bit microprocessor. The block diagram of the Microprocessor is shown in Fig.1.

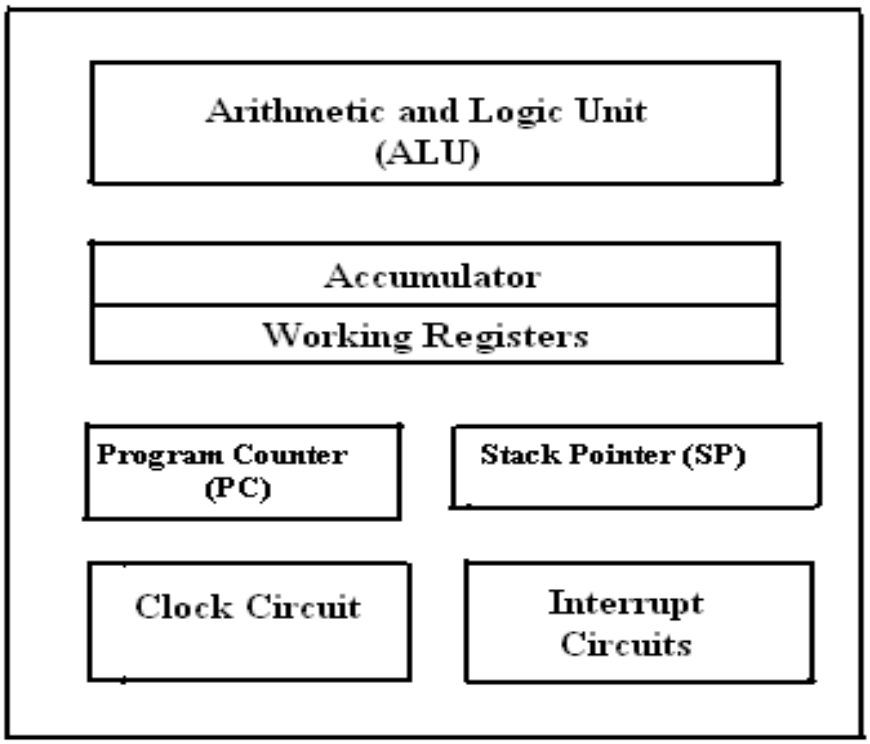


Fig.1 Block diagram of a Microprocessor.

Microcontroller:

a highly integrated single chip, which consists of on chip A microcontroller is Memory), Access (RandomRAMUnit),Processing(CentralCPU I/O Memory),Only Read Programmable(ErasableEPROM/PROM/ROM (input/output) – serial and parallel, timers, interrupt controller. For example, Intel 8051 is 8-bit microcontroller and Intel 8096 is 16-bit microcontroller. The block diagram of Microcontroller is shown in Fig.2.

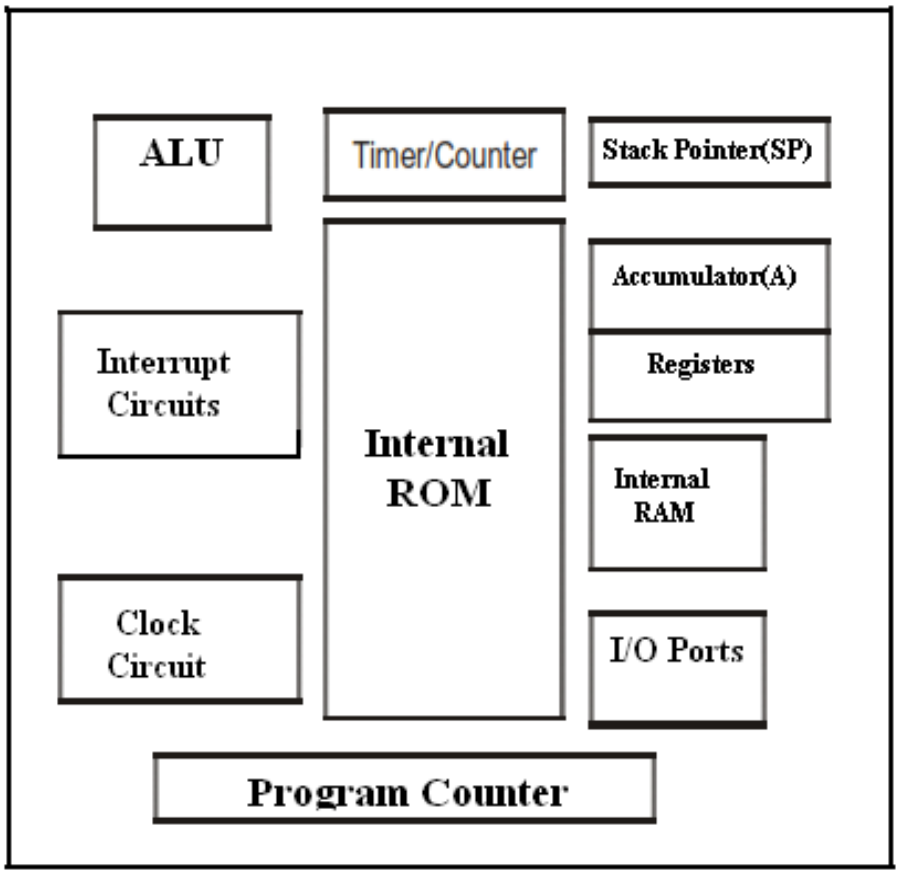
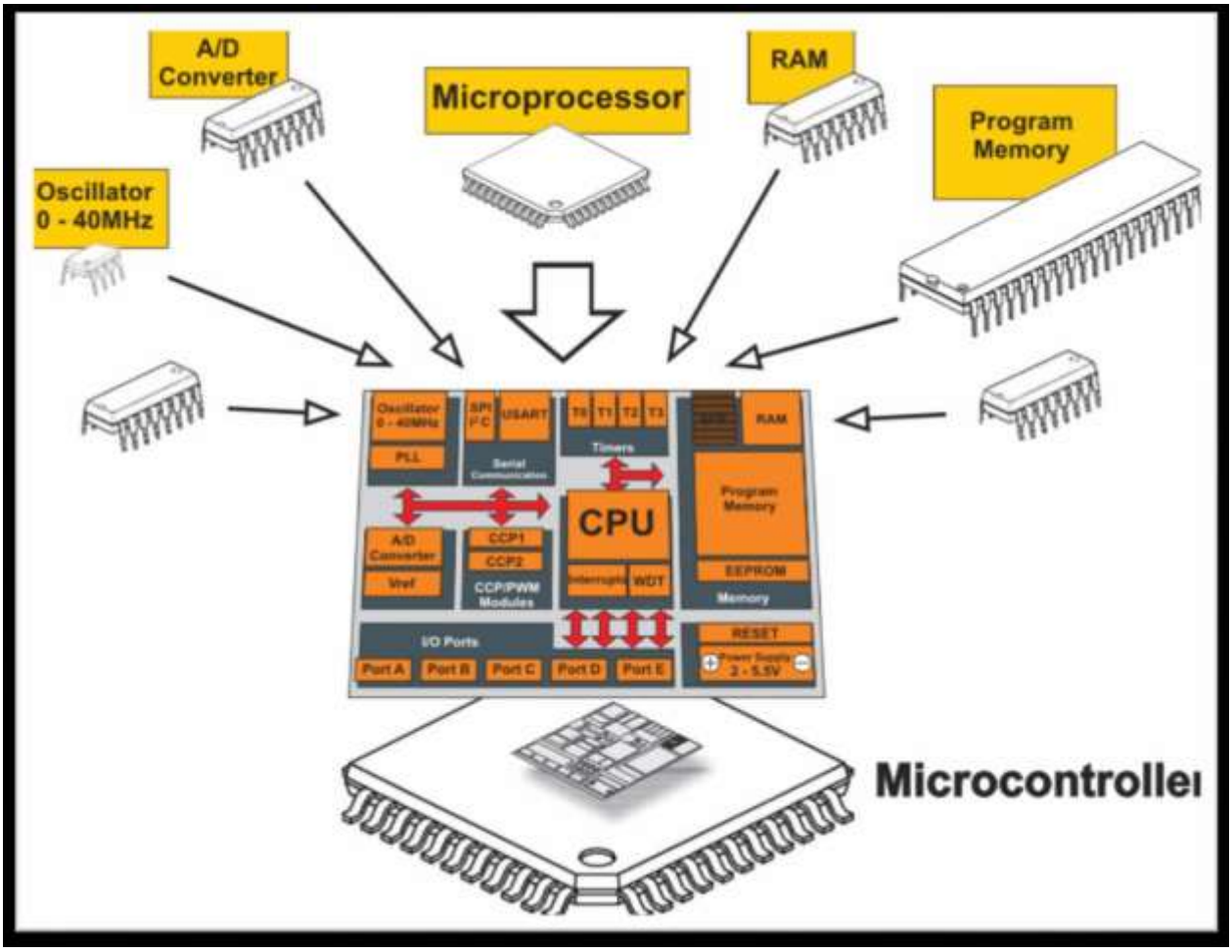


Fig.2. Block Diagram of a Microcontroller.

Difference between a Microprocessor and Microcontroller

Essentially these two devices are similar, but with a little bit of difference. A CPU which is the heart of these devices needs a host of external devices to make it communicate with real-world. These devices which are independent circuits, work in harmony with the CPU, to make one system. In a Computer these devices are attached to the CPU, using hard-wired connections. This makes the system more flexible, which means you can add more memory, change capacity of hard drives, add or remove CD-ROMs, sound cards etc.

A microcontroller on the other hand is made up of most of these devices built exactly within the same package. So, microcontroller will therefore contain, the CPU, RAM, ROM, Timers, I/O etc. all packed within one integrated circuit. This facilitates the development process, as well as reduce the requirements of external components, however this also means you cannot change, the number and type of integrated devices.



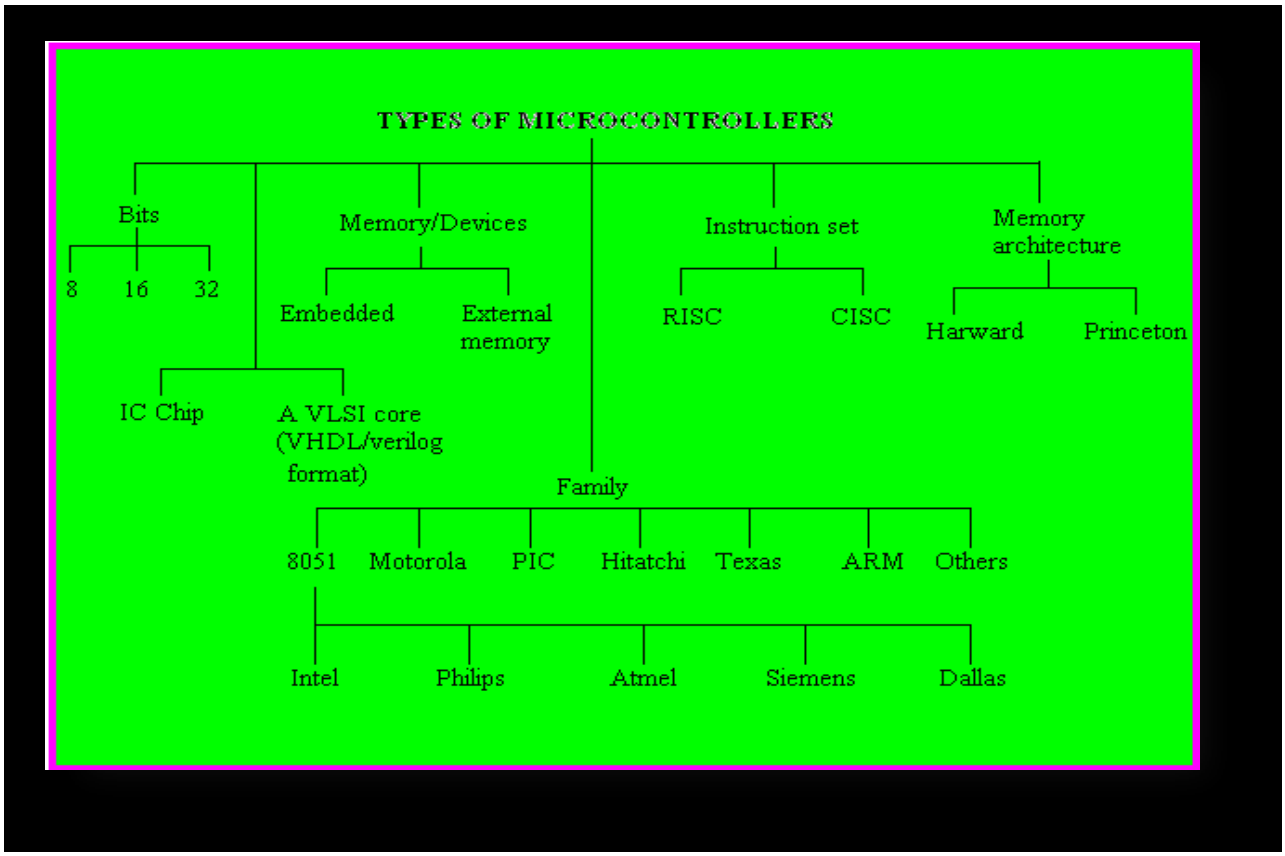
Distinguish between Microprocessor and Microcontroller

Microprocessor	Microcontroller
CPU is stand-alone, RAM, ROM, I/O, timer are separate.	CPU, RAM, ROM, I/O and timer are all on a single chip.
Designer can decide on the amount of ROM, RAM and I/O ports.	Fixed amount of on-chip ROM, RAM, I/O ports.
General-purpose.	Single-purpose.
High processing power	Low processing power
Typically 32/64 – bit	Typically 8/16 bit
High power consumption.	Low power consumption

Evolution of Microcontrollers:

In the year 1976, Motorola designed a Microprocessor chip called 6801 which replaced its earlier chip 6800 with certain add-on chips to make a computer. This paved the way for the new revolution in the history of chip design and gave birth to a new entity called "Microcontroller". Later the Intel company produced its first Microcontroller 8048 with a CPU and 1K bytes of EPROM, 64 Bytes of RAM an 8-Bit Timer and 27 I/O pins in 1976. Then followed the most popular controller 8051 in the year 1980 with 4K bytes of ROM, 128 Bytes of RAM, a serial port, two 16-bit Timers, and 32 I/O pins. The 8051 family has many additions and improvements over the years and remains a most acclaimed tool for today's circuit designers. INTEL introduced a 16 bit microcontroller 8096 in the year 1982. Later INTEL introduced 80c196 series of 16-bit Microcontrollers for mainly industrial applications. Microchip, another company has introduced an 8-bit Microcontroller PIC 16C64 in the year 1985.The 32-bit microcontrollers have been developed by IBM and Motorola. MPC 505 is a 32-bit RISC controller of Motorola. The 403 GA is a 32 -bit RISC embedded controller of IBM.

In recent times ARM Company (Advanced RISC machines) has developed and introduced 32 bit controllers for high-end application devices like mobiles, IPods etc...



Microcontrollers from different manufacturers

- Atmel
- ARM
- Intel
  - 8-bit
    - 8XC42
    - MCS48
    - MCS51
    - 8xC251
  - 16-bit
    - MCS96
    - MXS296
- National Semiconductor
  - COP8
- **Microchip** ←
  - **12-bit instruction PIC**
  - **14-bit instruction PIC**
    - **PIC16F84**
  - **16-bit instruction PIC**
- NEC
- Motorola
  - 8-bit
    - 68HC05
    - 68HC08
    - 68HC11
  - 16-bit
    - 68HC12
    - 68HC16
  - 32-bit
    - 683xx
- Texas Instruments
  - TMS370
  - MSP430
- Zilog
  - Z8
  - Z86E02

Why there are too many different Microcontrollers?

PIC Microcontrollers:

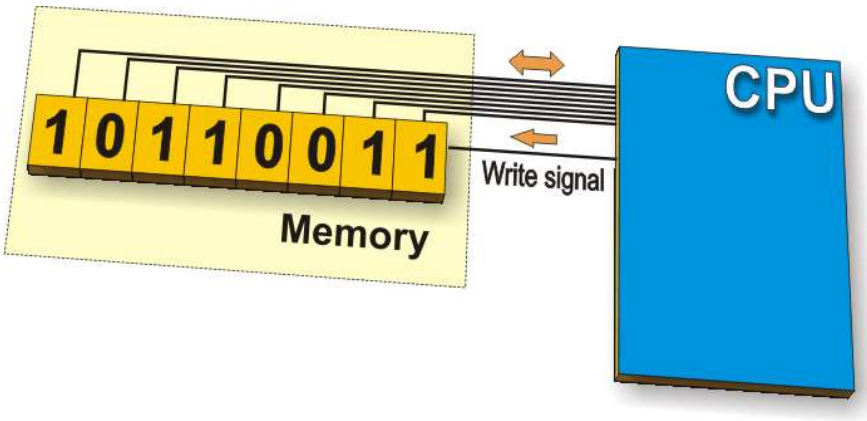
- PIC – "Peripheral Interface Controller" made by Microchip Technology.
- Most popular by industry developers and hobbyists.
  - Low cost.
  - Availability.
  - Extensive application.
  - Serial programming.

Advantages of PIC:

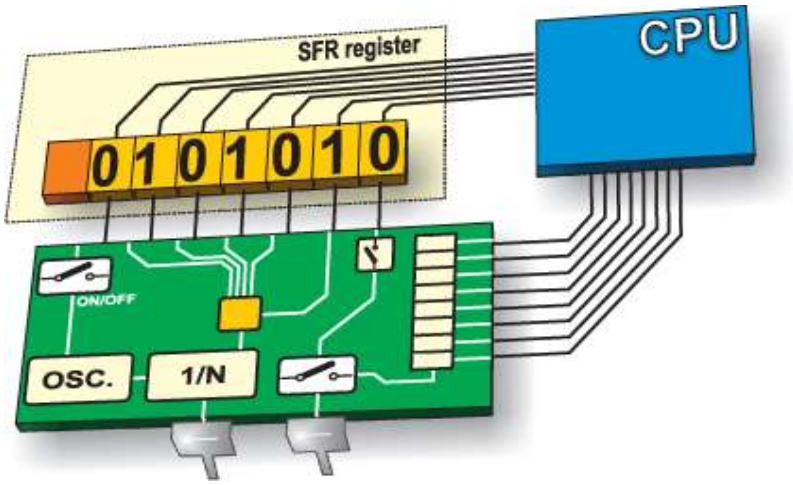
- 30 to 100 times faster than other µCs (program memory is integrated to the chip).
- Smaller size (on-board memory).
- Easy to program, reusable and inexpensive.

Internal Units description:-

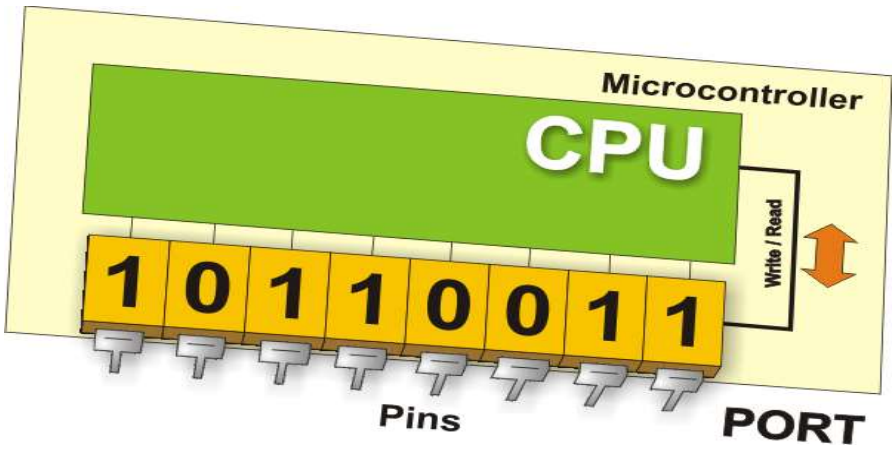
- **Register:** An electronic circuit which can memorize the state of one byte.



- **SFR (Special Function Register):** Registers whose function is predetermined by the manufacturer of the microcontroller Examples are timers, A/D converter, oscillators, etc.

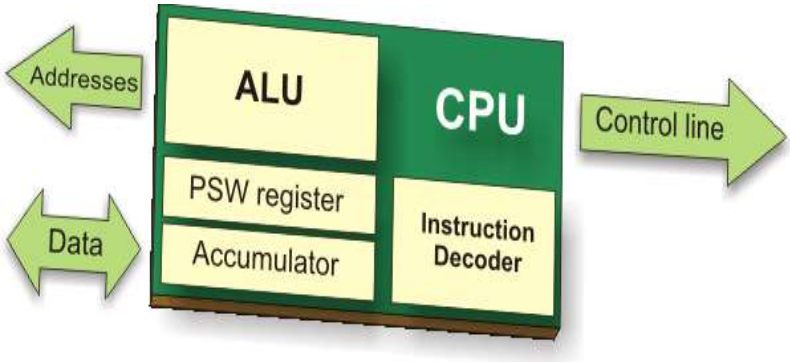


- **Input / Output Ports:** Microcontroller has one or more registers (called ports) connected to the microcontroller pins. Can change a pin function as you wish.

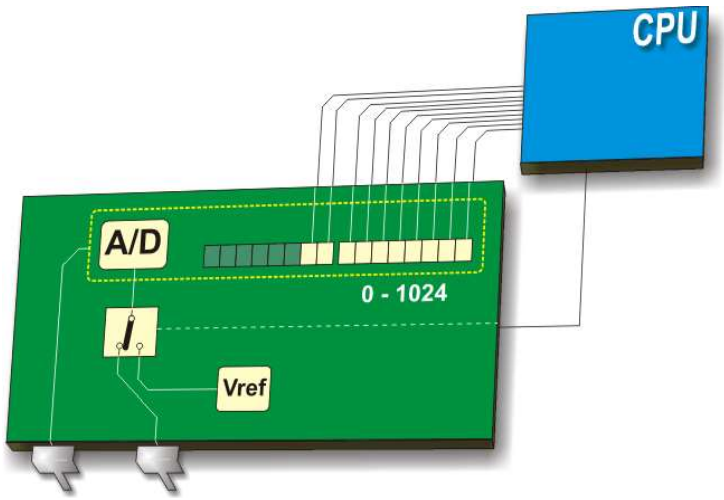


- **Memory Unit:** Memory is part of the microcontroller used for data storage. Types (RAM, ROM).

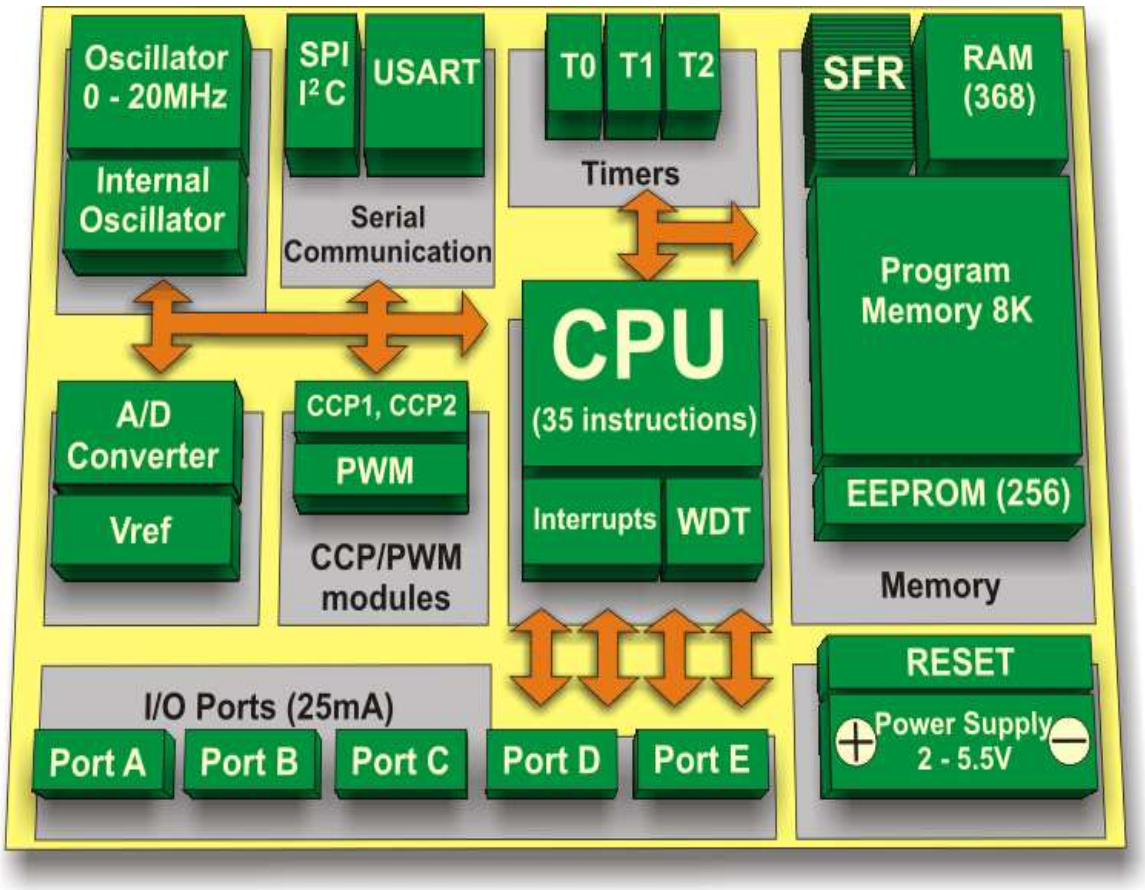
- **INTERRUPT**: Most programs use interrupts in their regular execution. The signal which informs the central processor unit about such an event is called an INTERRUPT.
- **Central Processor Unit (CPU)**: which contains instruction decoder, accumulator and ALU.

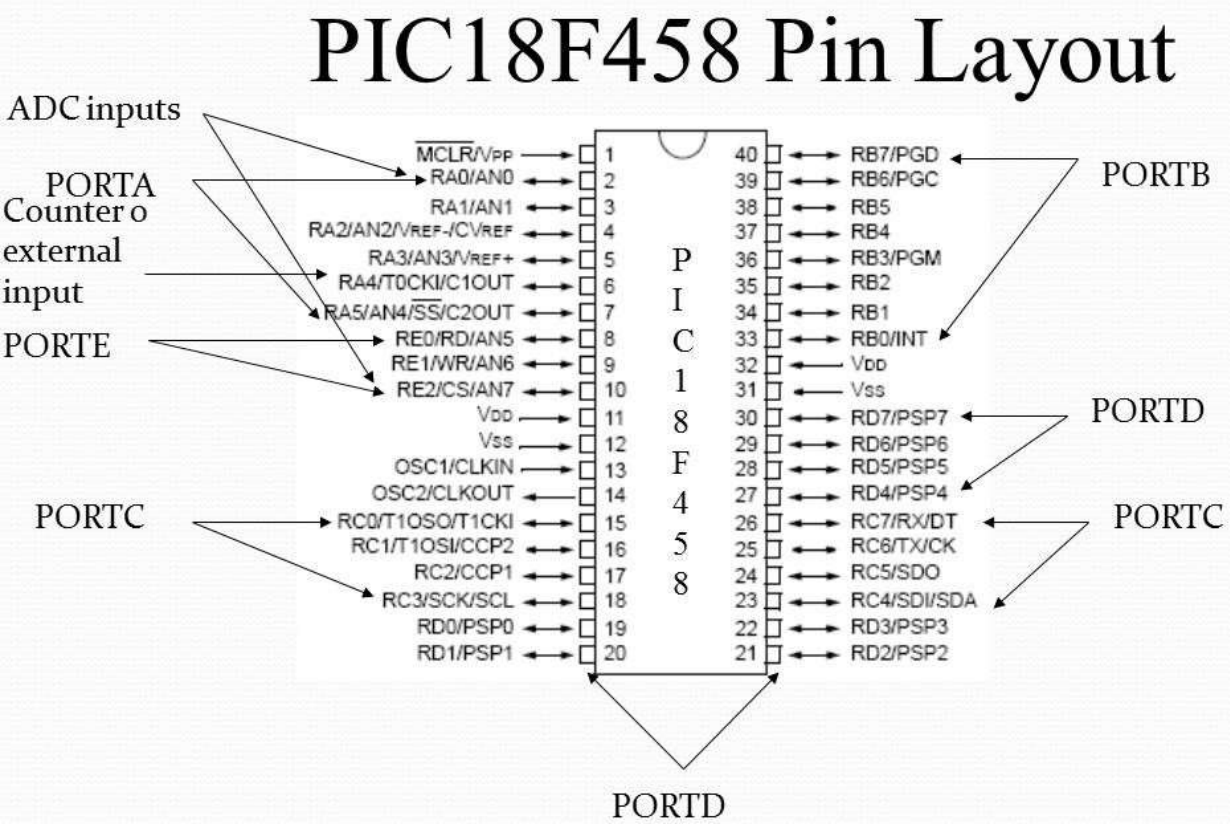


- **A/D converter**: converts continuous signals to discrete digital numbers or convert an analogue value into a binary number and passes it to the CPU for further processing.

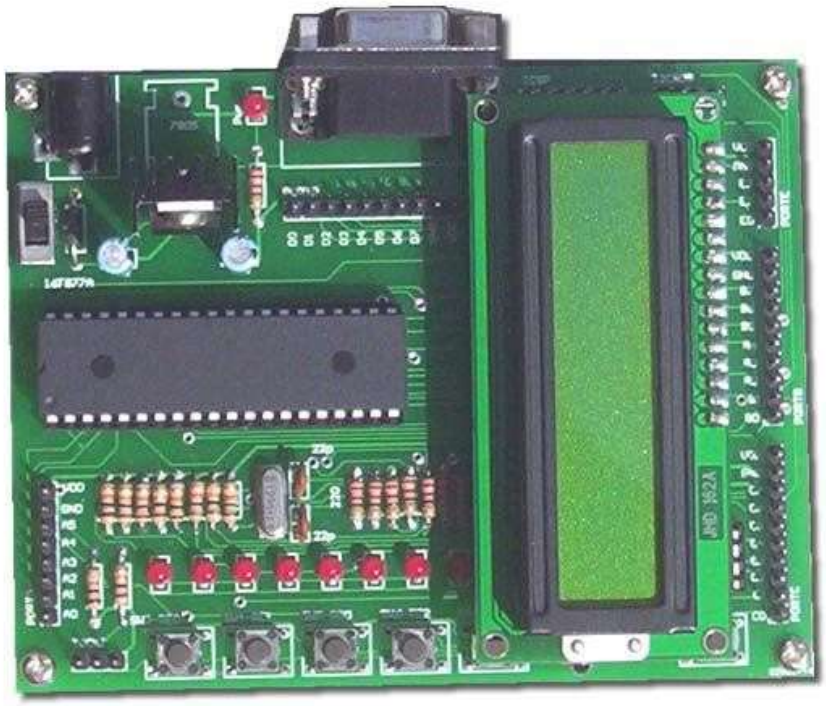


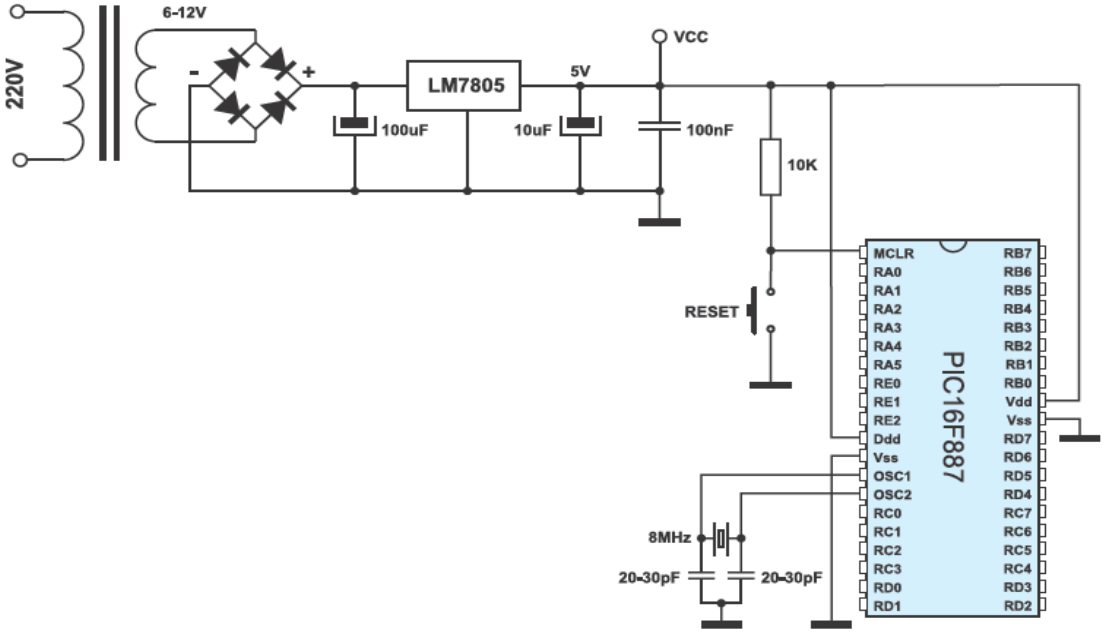
- **Bus:** the bus consists of 8, 16 or more wires. There are two types of buses: address and data bus.
- **UART (Universal Asynchronous Receiver/Transmitter).**
- **Oscillator**.
- **Power supply circuit**.
- **Timers/Counters**.





In order to do various experiments with PIC microcontroller it is advisable to have a development board. In case you don't have a development board available, you can make a simple board using bread-board or vero board.




6-12V
220V
-
+
LM7805
5V
VCC
100uF
10uF
100nF
10K
RESET
8MHz
20-30pF
20-30pF
PIC16F887
MCLR
RA0
RA1
RA2
RA3
RA4
RA5
RE0
RE1
RE2
Ddd
Vss
OSC1
OSC2
RC0
RC1
RC2
RC3
RD0
RD1
RB7
RB6
RB5
RB4
RB3
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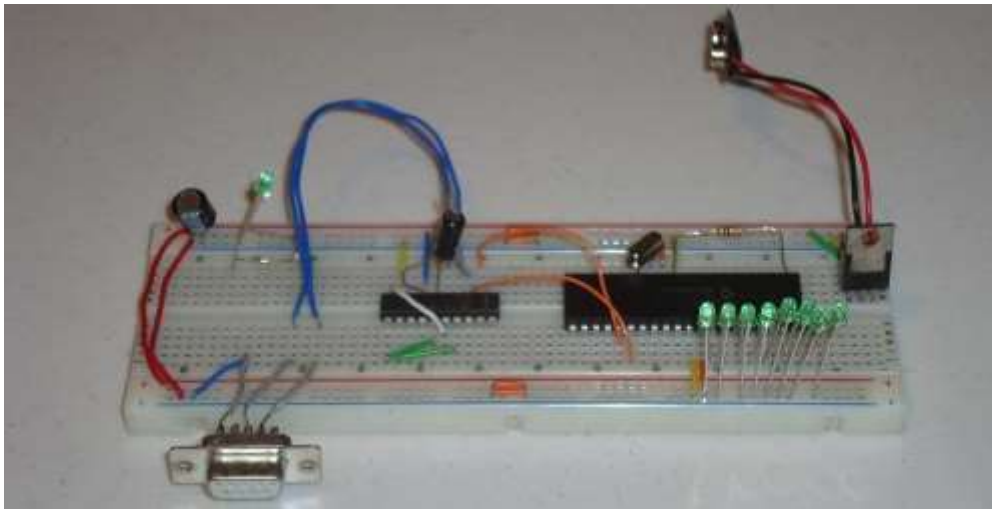
RC6
RC5
RC4
RD3
RD2



UART (Universal Asynchronous Receiver and Transmitter) PORTC.6, 7:

The board contains a standard universal Serial Asynchronous Receiver and Transmitter. Many devices use this protocol to communicate with other devices. The communication needs two wires, one for transmission and one for receiving data. PCs and some other devices, use a level translator, to redefine the standard signals for logical 0 and 1. This is done so, to minimize noise interference as well as prolong communication distance. To use these signals, they must be converted back to TTL level logic. The PIC board contains RS232 level converter which converts these signals to TTL level, and to transmission levels while sending data. Most PIC microcontrollers contain an internal hardware to manage this communication, so that software development becomes easy. PORTC.6 and PORTC.7 are configured as hardware USART communication pins.

NOTE: since the PORTC is also connected to LEDs, if LEDs are enabled receiving data from USART is interfered. It is therefore mandatory to disable, LEDs while using UASRT.

RS232 Communication with PIC Microcontroller

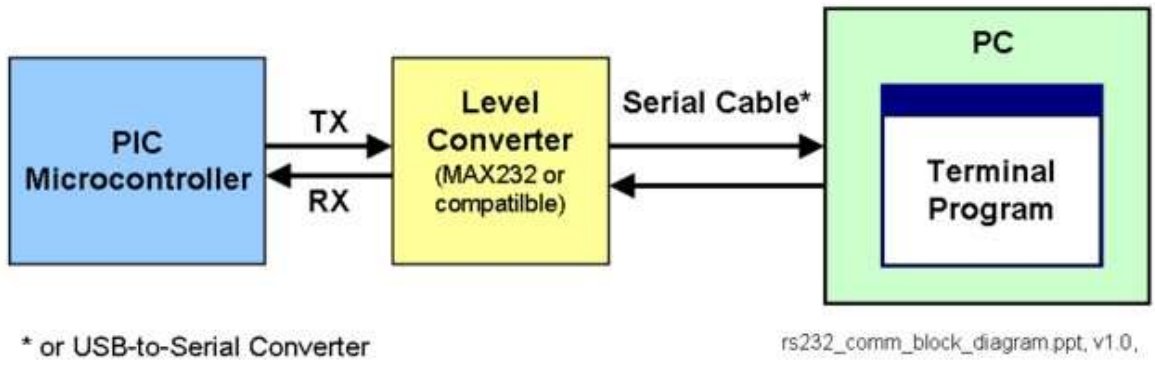
This paragraph shows how to do a simple communication via a RS232 interface with a PIC microcontroller. RS232 is a standard for a serial communication interface which allows sending and receiving data via at least three wires. With the RS232 interface it is possible to setup a connection between a microcontroller and a PC (via PC's COM port) or between two microcontrollers. So, we will show how to link a PIC microcontroller to a standard PC. On the PC we will use a program to send and receive data.

Note that modern PCs don't have a serial port so you need to get a USB to serial converter. They are available at low cost.

Fig. USB to Serial Converter

Block Diagram

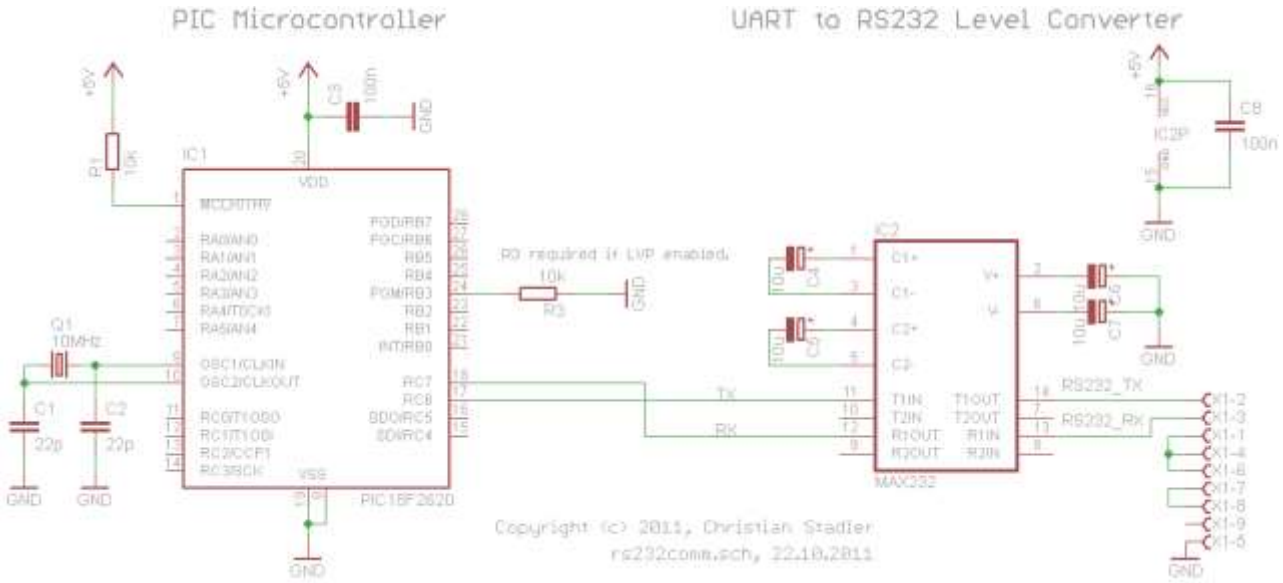
The following block diagram shows the whole setup:



For serial communication the line used to transmit data is called TX and the line used to receive data is called RX. The level converter is required to translate the voltage level of the microcontroller to RS232 voltage level. The microcontroller operates at TTL level (0V = logic 0, +5V logic 1) whereas RS232 uses around +/-12V. A very famous RS232 level converter is the MAX232 chip.

Hardware

In the schematic below a PIC microcontroller is connected to the RS232 level converter chip. A PIC18F2620 microcontroller is used, but it will also work with any other microcontroller which has a built-in UART.



The PIC usually is running at 10 MHz,

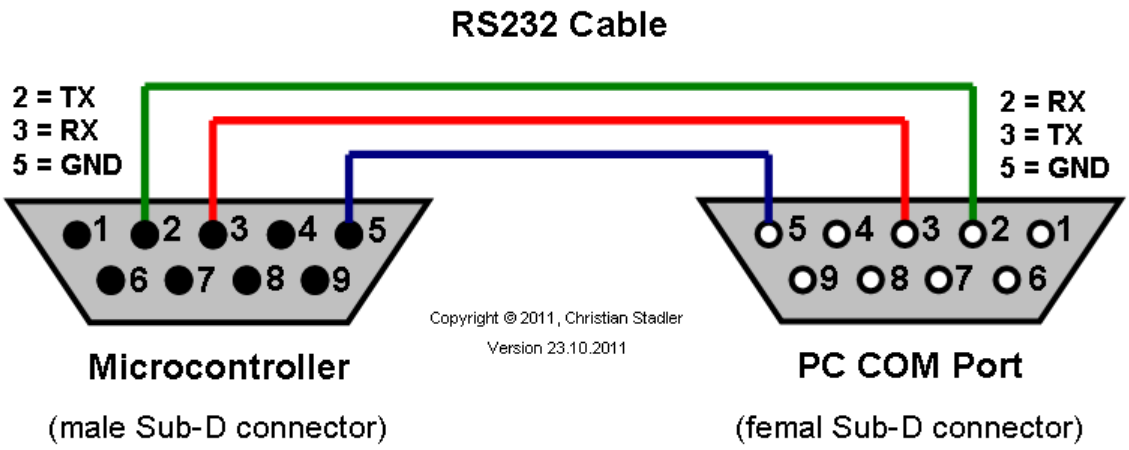
In order to properly communicate it is very important that the communication devices should have the same Baud rate usually 9600.

The RS232 level converter uses the famous MAX232 chip, but any other MAX232 compatible chip will also work. It just requires 4 capacitors to do its job. These external capacitors are required for the charge pump inside the chip which generates the required voltage levels.

The connections on the DB9 connector pins 1, 4, 6, 7, 8 and 9 are not used.

RS232 Cable

To connect the above circuit to the PC we need a RS232 cable. The below picture shows the necessary connections.



Hardware Picture:

Below a picture of the hardware setup.

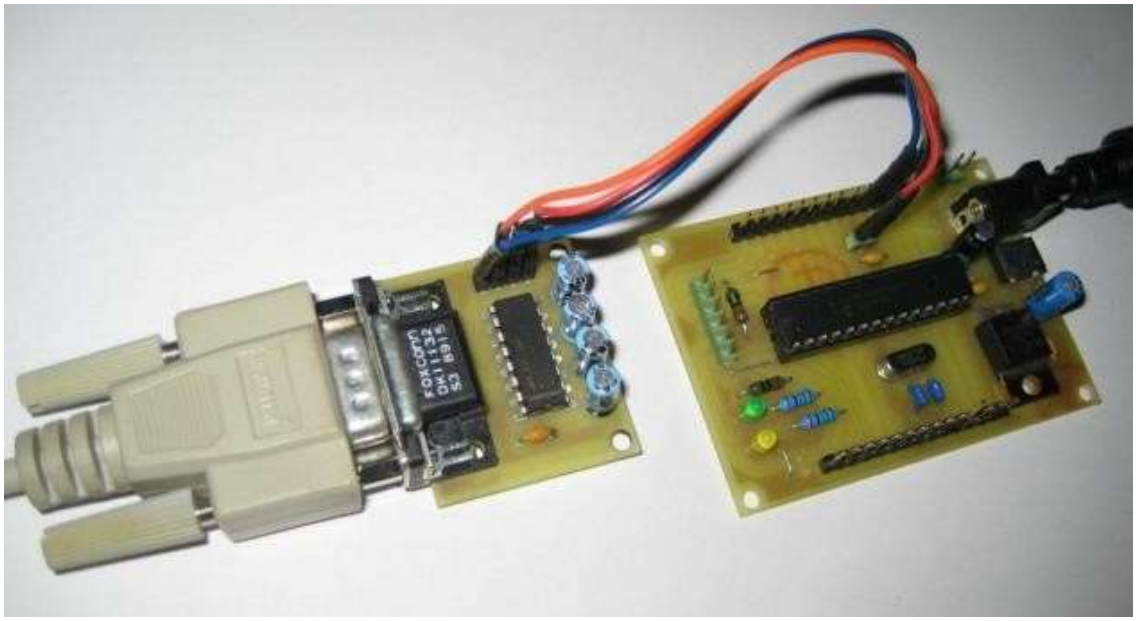


Fig. Serial Port Connected

Software

Now since the hardware is ready we have to write the software for the PIC microcontroller. The different compiler vendors provide different ways to setup the UART in the PIC.

PC Interfacing

Fourth Level

Lecture Nine

USB to PIC Microcontroller Interface

By

Omar Al-farouk Al- dulaimi

Universal Serial Bus (USB):

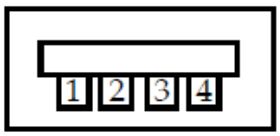
USB (Universal Serial Bus) is the most popular connection used to connect a computer to devices such as digital cameras, printers, scanners, and external hard drives. USB is a cross-platform technology that is supported by most of the major operating systems. On Windows, it can be used with Windows 98 and higher. USB is a hot-swappable technology, meaning that USB devices can be added and removed without having to restart the computer. USB is also "plug and play". When you connect a USB device to your PC, Windows should detect the device and even install the drivers needed to use it. There are many versions of USB. The original version of USB, USB 1.0, only supported speeds of up to 11 Mbps and was used mostly to connect keyboards and mice. The second version of USB, which is known as USB 2.0, supports speeds of up to 480 Mbps. The third version of USB, which is known as USB 3.0, supports speeds of 5 Gbps. The last version of USB, which is known as USB 3.1, supports speeds of up 10 Gbps.

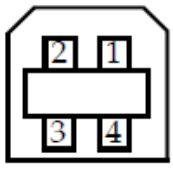
- Allows access of up to 127 different connections via a 4 wire serial connection.
- This interface is ideal for keyboards, sound cards, modems, etc.
- Sound cards can derive their power from an external (no-PC) power supply.
- Cable lengths are limited to 5 meters (for the full-speed interface).
- Maximum power is given by 100mA x 5V.

USB Connector:

It has 4 pins:

- 5 v
- -Data
- +Data
- Ground





Pin #	Signal
1	5.0V
2	-Data
3	+Data
4	GND

The +/-Data signals are 180 degrees out of phase.

Biphase signals: when +data are at 5.0V, -data are at zero volts and vice versa.

Physical Interface:

Full Duplex: data transmission can occur in both directions at the same time

Half Duplex: data transmission can go in only one direction at a time

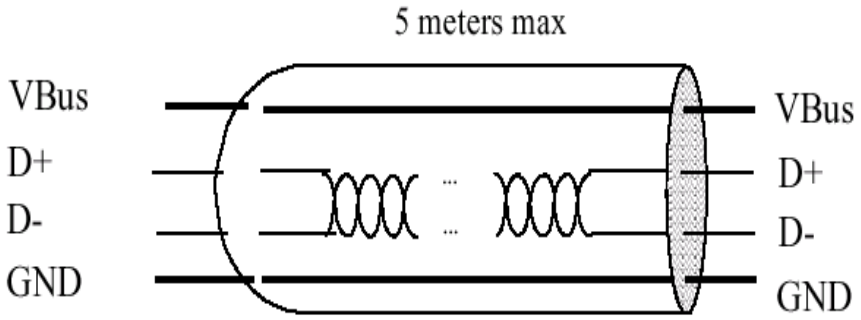


Figure 4-2. USB Cable

USB to PIC interfacing:-

It's a low cost USB interface Board that provides very good interface to your computer and it can be used to control various devices like DC Motor, Stepper motor, Servo, relay switch etc. A small program communicates with the hardware to issue commands to set the pins of the Microcontroller. USB controlling is better than that of parallel and RS232 ports. Rather laptops now days don't come with parallel and RS232 ports.

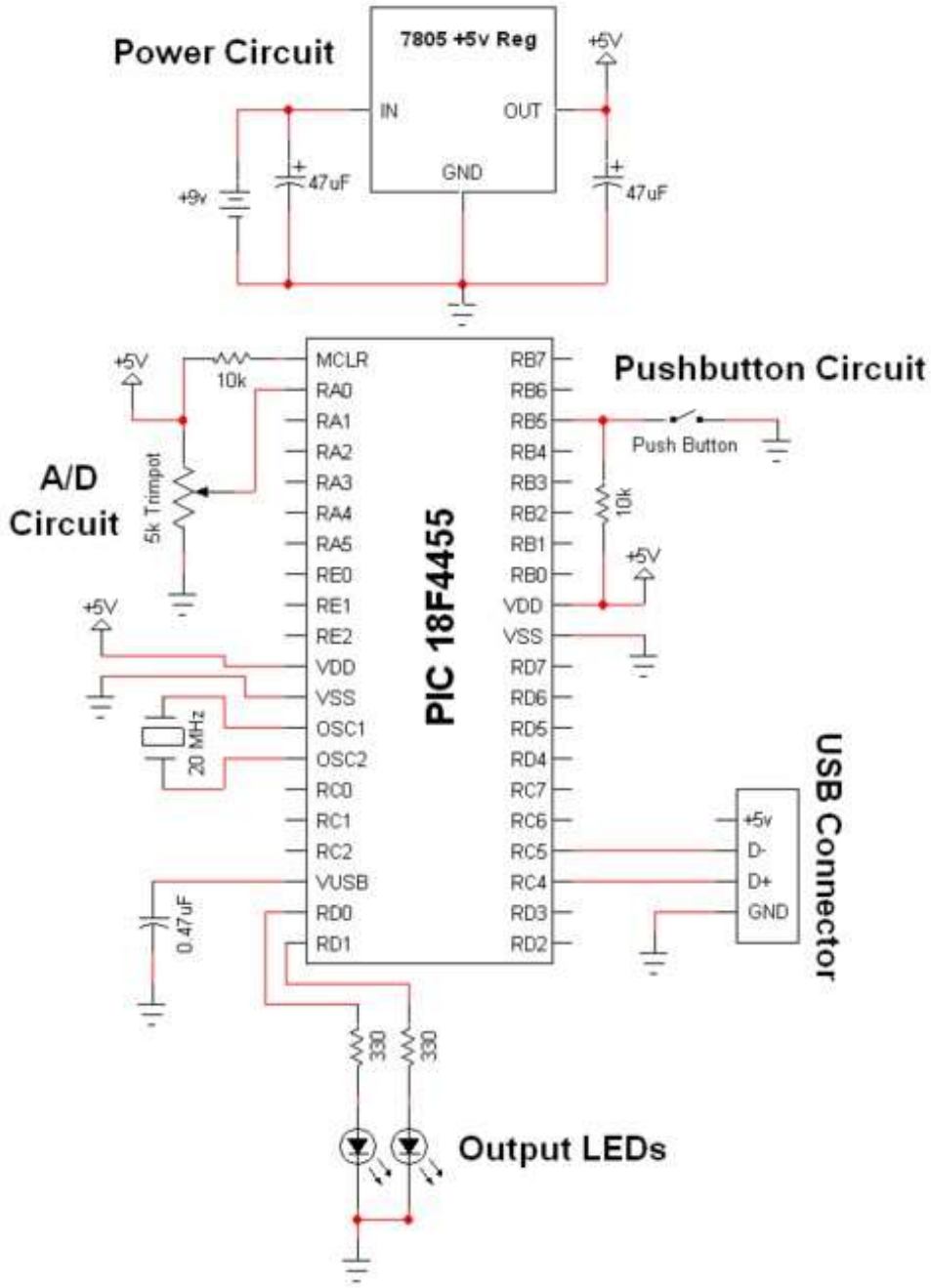
Parts

- PIC 18F4455 Microcontroller
- USB Type A Connector
- USB Cable
- 7805 +5v Regulator
- 2x 330Ω Resistors
- 2x 10kΩ Resistors
- 5kΩ Trimpot
- 2x 47uF Capacitor
- 20 MHz Crystal
- 1x 0.47uF or 0.1uF Capacitor

- Breadboard
- Jumper Wire
- 9v Connector
- Push Button Switch
- 2x LEDs

Schematic Overview

Hardware design for USB is actually quite minimal, which is a big plus for us. However, what you quickly find out with USB is that the easy hardware design means the communication and control software is very complex. The main devices used in the circuit are the PIC18F4455, USB Connector and LM7805.



Schematic Specifics:-

Power Circuit

The +5v output from the power circuit comes from the LM7805 regulator. Notice the 47uF capacitors on the input and output. These are meant to be DC filtering capacitors, which smooth out the constant DC voltage being fed to the microcontroller from the 7805 regulator.

USB Connection and Output LEDs

Make sure you double check your USB pin out. A common mistake when wiring the PIC to the USB connector is getting the D + and D - signals backwards. So if you're sure that the PIC is running your perfect code, but the USB device isn't coming up properly, switch D+ and D-, it might just magically fix your problem! The output LEDs will be simple 'toggle' LEDs. The program running on our laptop will be able to toggle them on and off with the push of a button.

A/D and Push Button Circuits

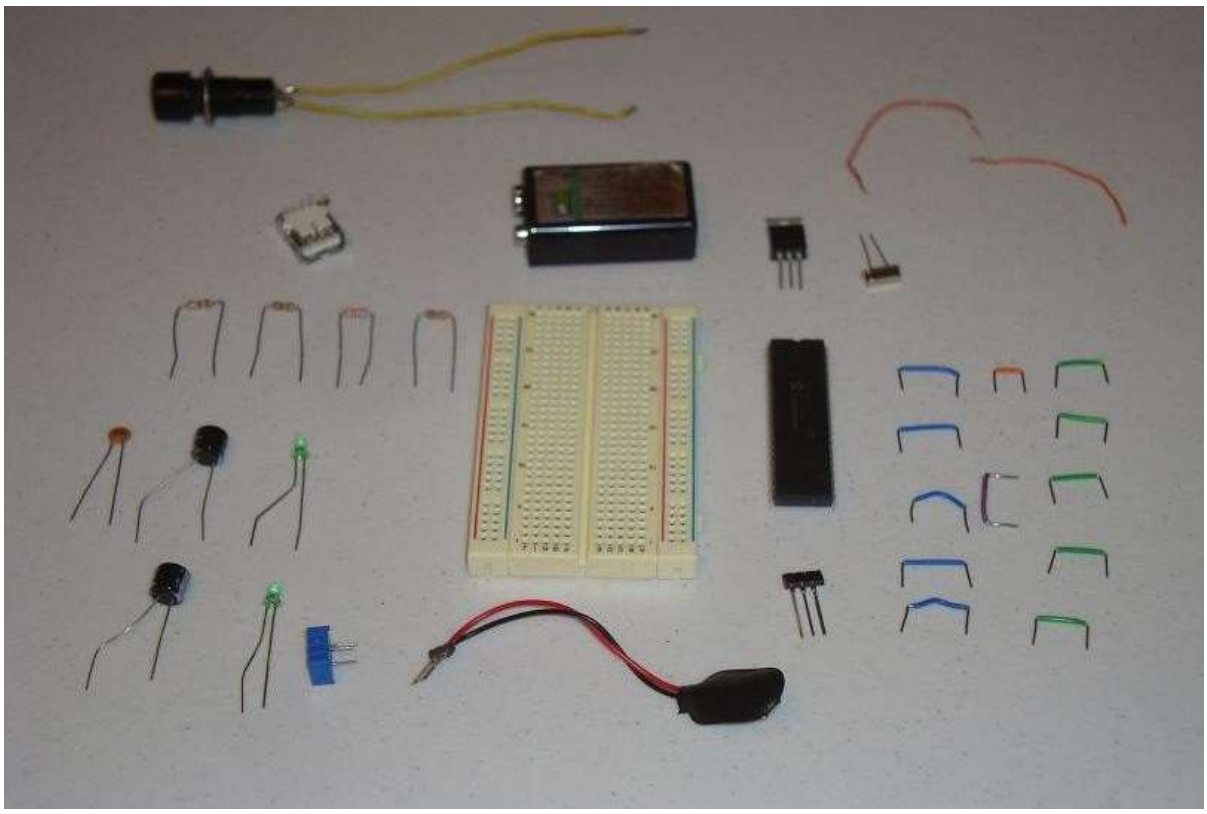
The A/D circuit is a standard 3 pin, Connected to Power, Signal Out and Ground circuit. The signal output goes into RA0 which is the Analog to Digital converter. After the PIC converts this signal it should send the data to the Laptop via USB. The laptop will the visually display the trimpot's value. The push button will do a similar thing, when the button is pushed, the laptop application should update with a notification that it has been pressed. These are simple ideas, but when done over USB they become rather complicated as we'll see in the theory section.

Hardware Design

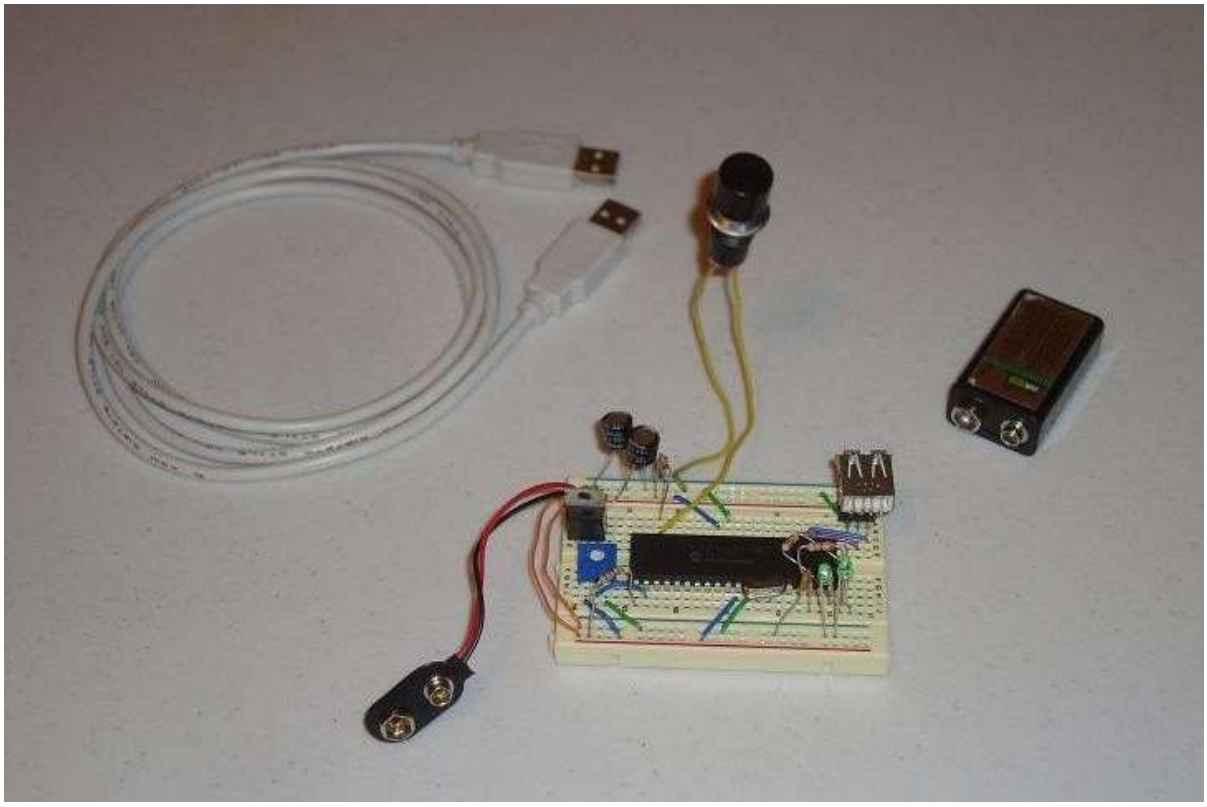
When it comes to USB, the hardware design is as simple as it gets. A few wires and the external input/output parts are all that you need. However, this ease, is made up for by the complexity of the protocol seen in the theory section, and in the software.

Building the Circuit

Here I have all the parts used in this project laid out for you to see. They were also listed in the parts section of this write-up.



Now, we start assembling the circuit, and connecting it together, we obtain:



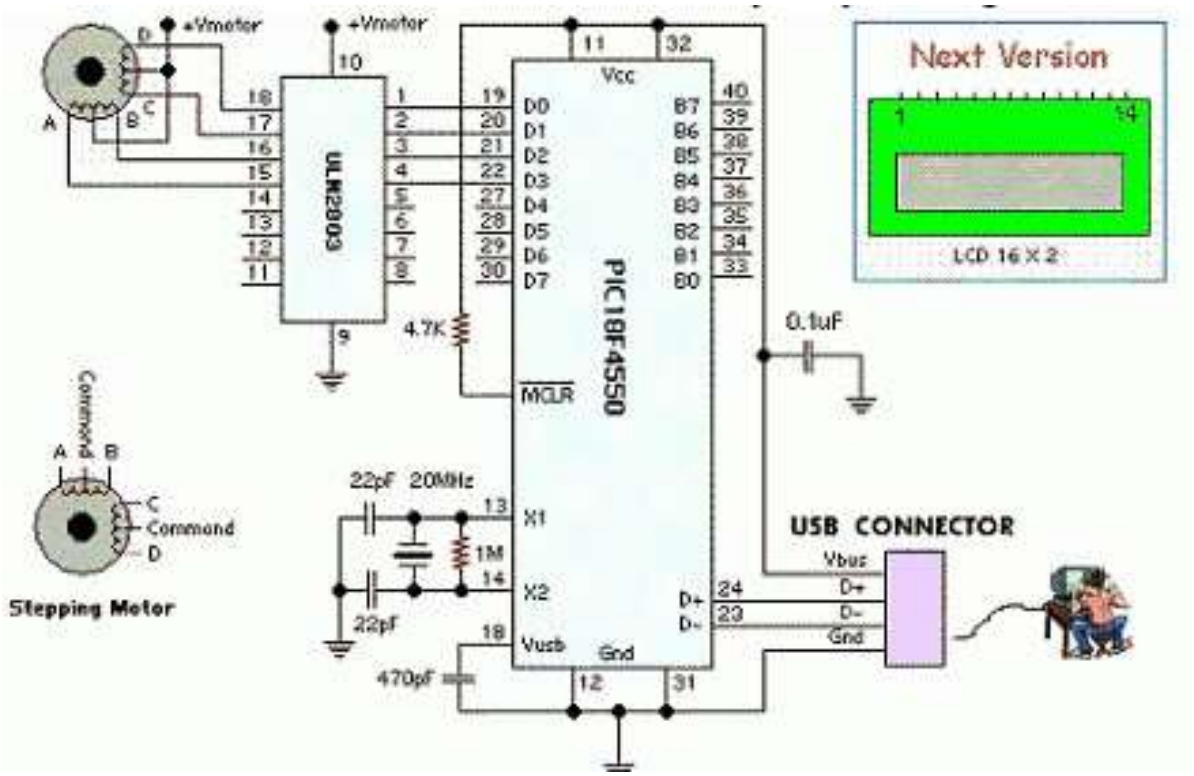
Software

Now since the hardware is ready we have to write the software for the PIC microcontroller. The different compiler vendors provide different ways to setup the PIC.

Control stepper motor via USB:

How to control stepper motor device via USB interface?

Simple solution is to take microcontroller with USB interface built in. PIC15F4550 has full speed USB interface with full speed capability. Microcontroller uses on chip USB driver which is pretty easy to program.



You may want to edit source in order to interface different devices like LCD, relays etc.

PC Interfacing

Fourth Level

Lecture Ten

USB to RS232, USB to Parallel Design

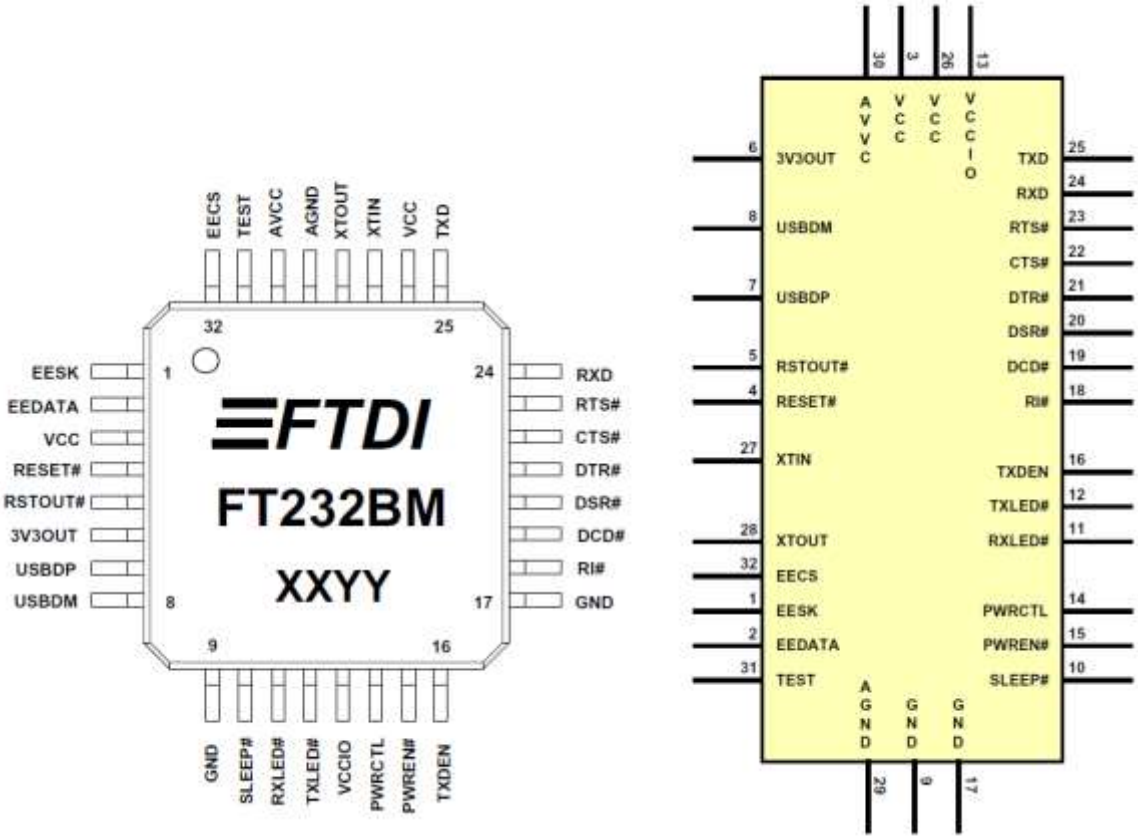
By

Omar Al-farouk Al- dulaimi

USB to RS232 circuit design:

The USB to Serial RS232 adapter is very useful in many situations we need to connect a device with RS232 to a computer without RS232 port. Using FT232BM chip manufactured by Future Technology Devices International FTDI we can make a very simple USB to Serial RS232 adapter using few external components. This USB to RS232 adapter based on the FT232BM driver can support many operating systems (windows, mac, Linux).

What is FT232BM? And what is used for?



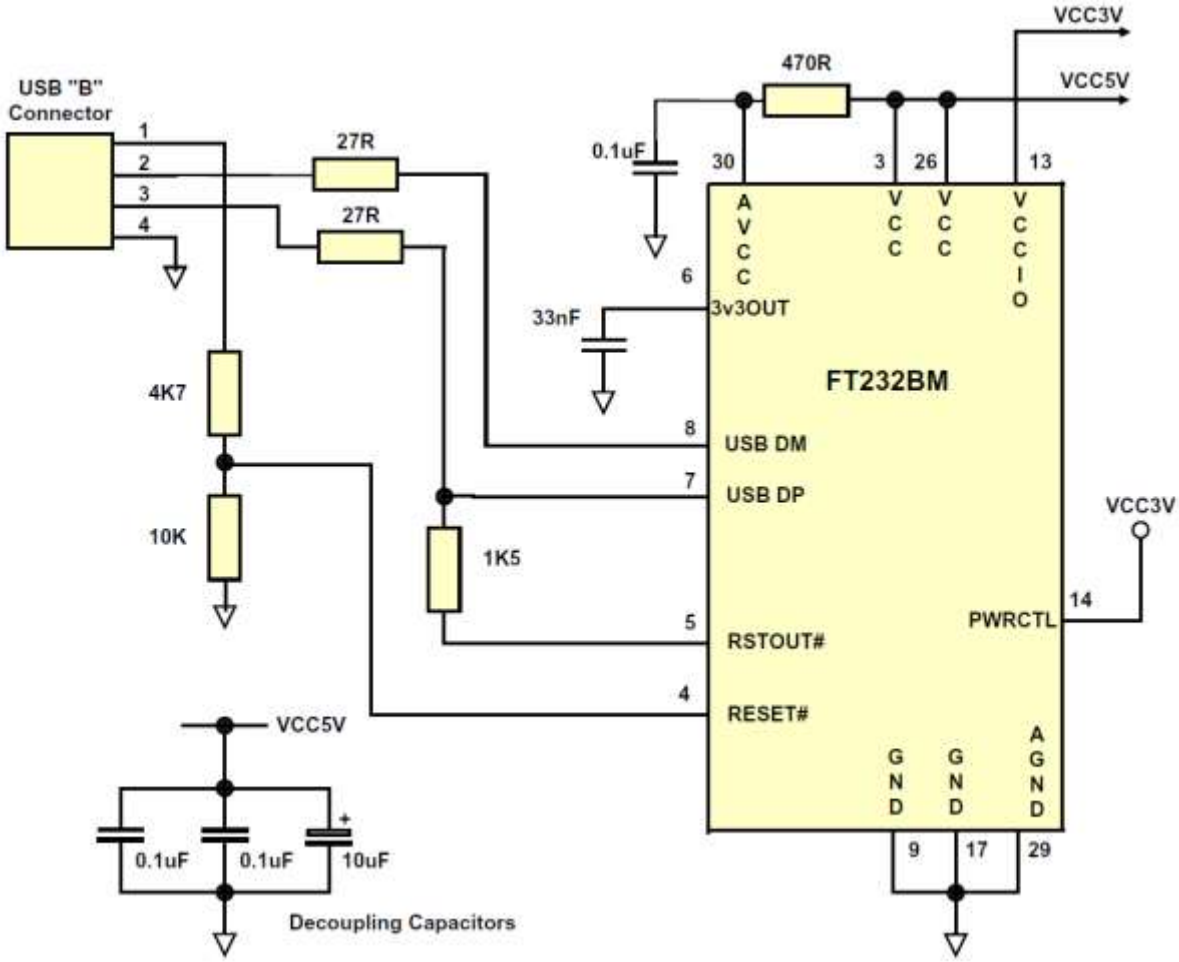
The FT232BM is a USB to serial UART interface with the following advanced features:

- Consist of 32-pin.
- Compatible with USB 1.1 and USB 2.0
- Single chip USB to asynchronous serial data transfer interface.
- Full Handshaking & Modem Interface Signals.
- UART interface support for 7 or 8 data bits.
- Data transfer rates from 300 baud to 3 M baud at TTL levels.
- 384 byte receive buffer and 128 byte transmit buffer.

We will separate the design into two parts: the first part is the connections between USB and FT232BM and the second part is the connections between FT232BM and RS232 through MAX232.

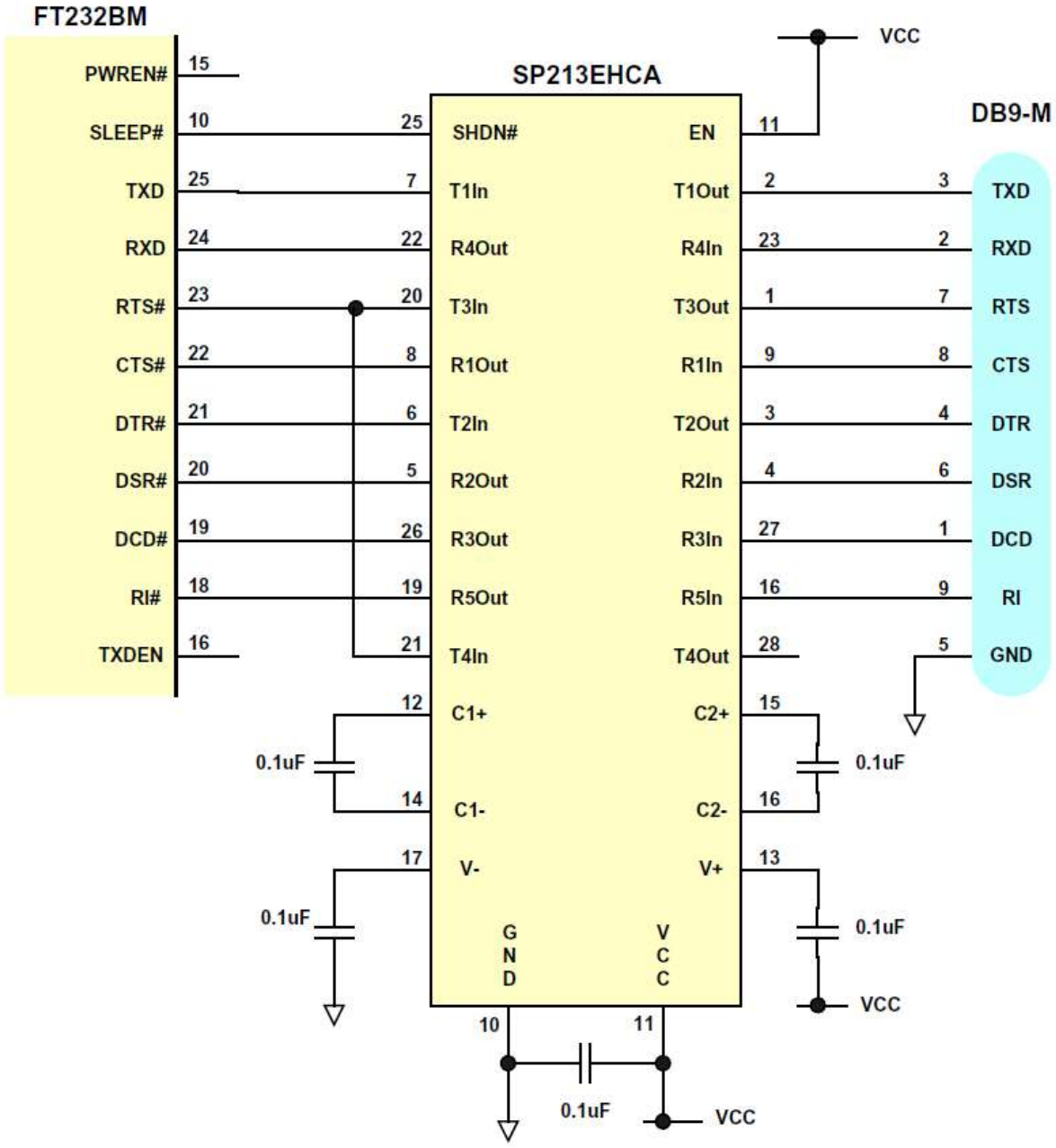
The first part:

The schematic below explain the connections between USB and FT232BM.

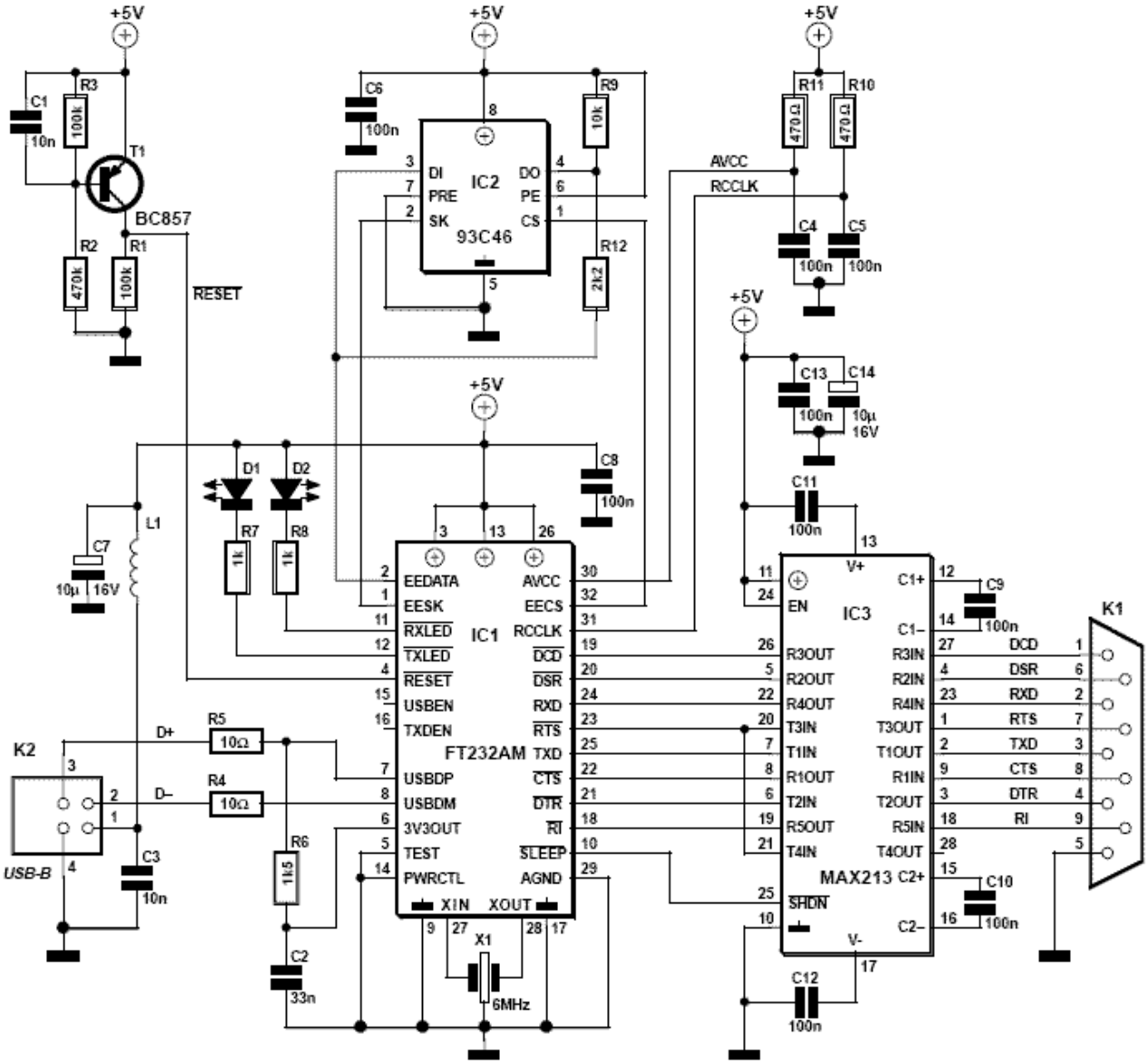


The second part:

The schematic below explain the connections between FT232BM and RS232 through MAX232.



The full design with its connections is present in the next page.



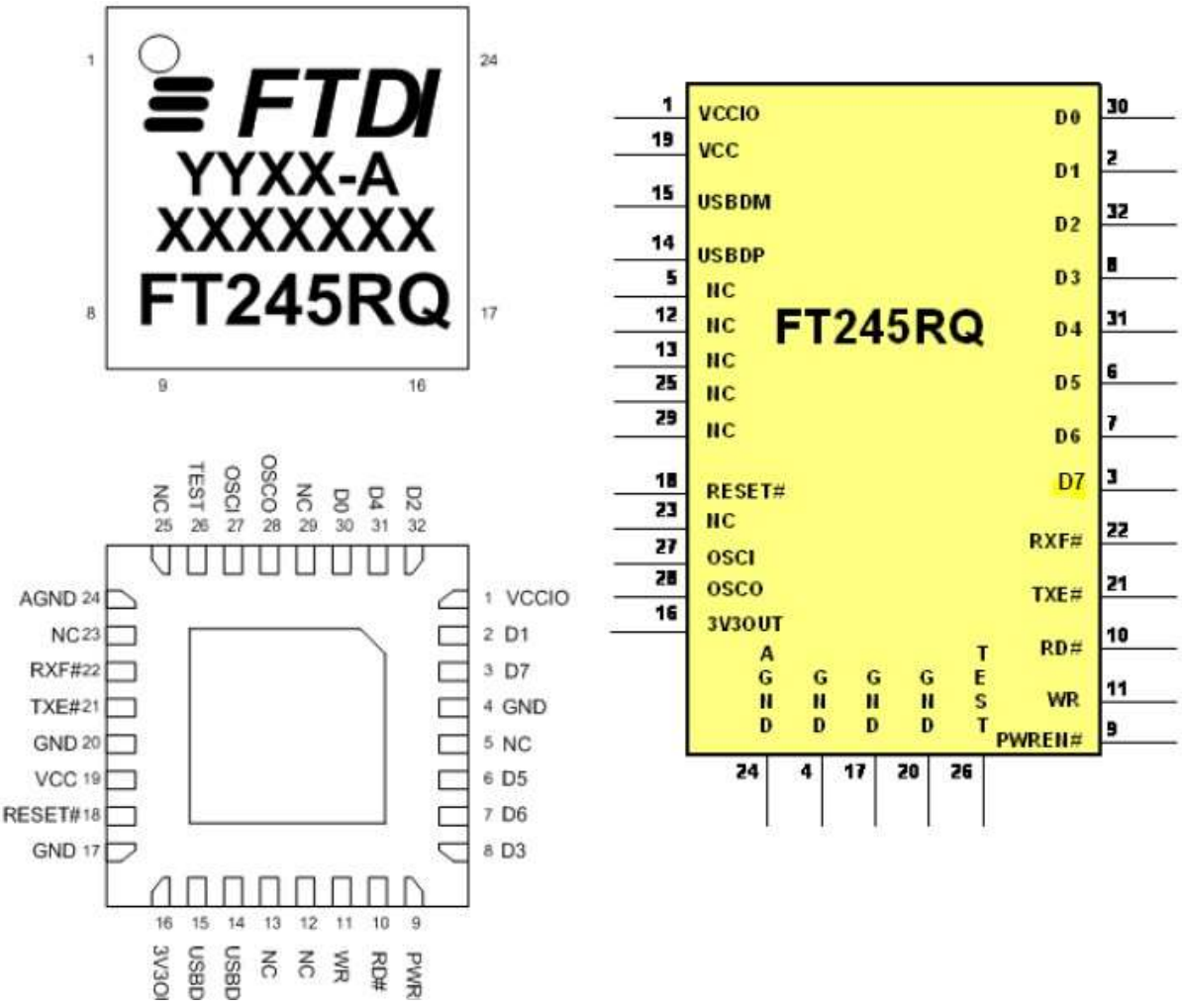
The photo of finished Adapter:

USB to Parallel circuit design:

There are several ways to convert the USB to Parallel:

1. Using FT245RQ:

The USB to Parallel adapter is very useful in many situations we need to connect a device with Parallel to a computer without Parallel port. Using FT245RQ chip manufactured by Future Technology Devices International FTDI we can make a very simple USB to Parallel adapter using few external components. This USB to Parallel adapter based on the FT245RQ driver can support many operating systems (windows, mac, Linux).



The FT245R is a USB to parallel FIFO interface with the following advanced features:

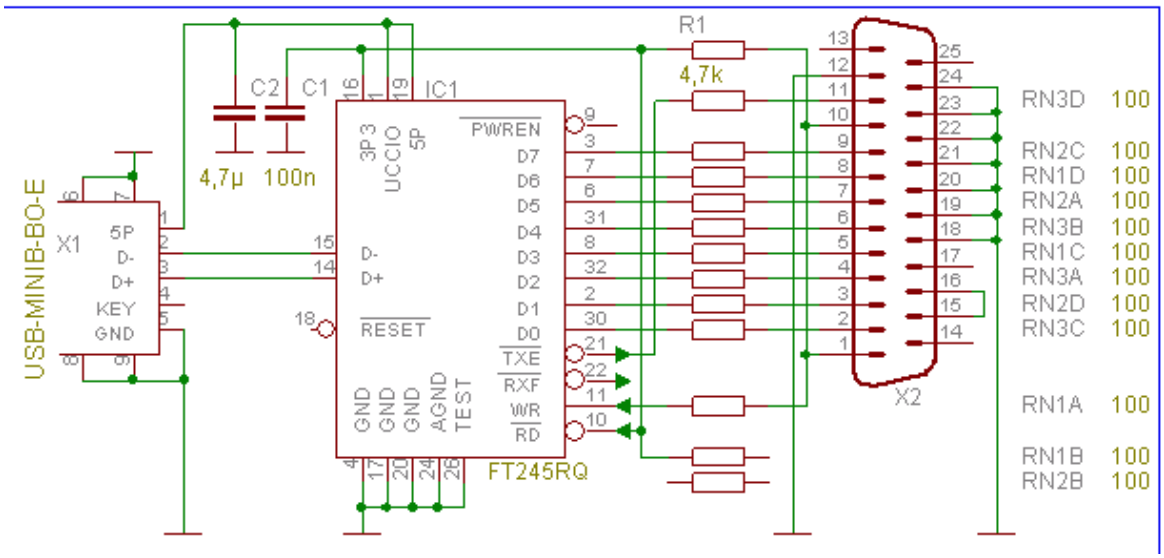
- Consist of 32-pin.
- Compatible with USB 1.1 and USB 2.0
- Single chip USB to parallel FIFO bidirectional data transfer interface.

- USB protocol handled on the chip. No USB specific firmware programming required.
- Data transfer rates up to 1Mbyte / second.

Typical Applications

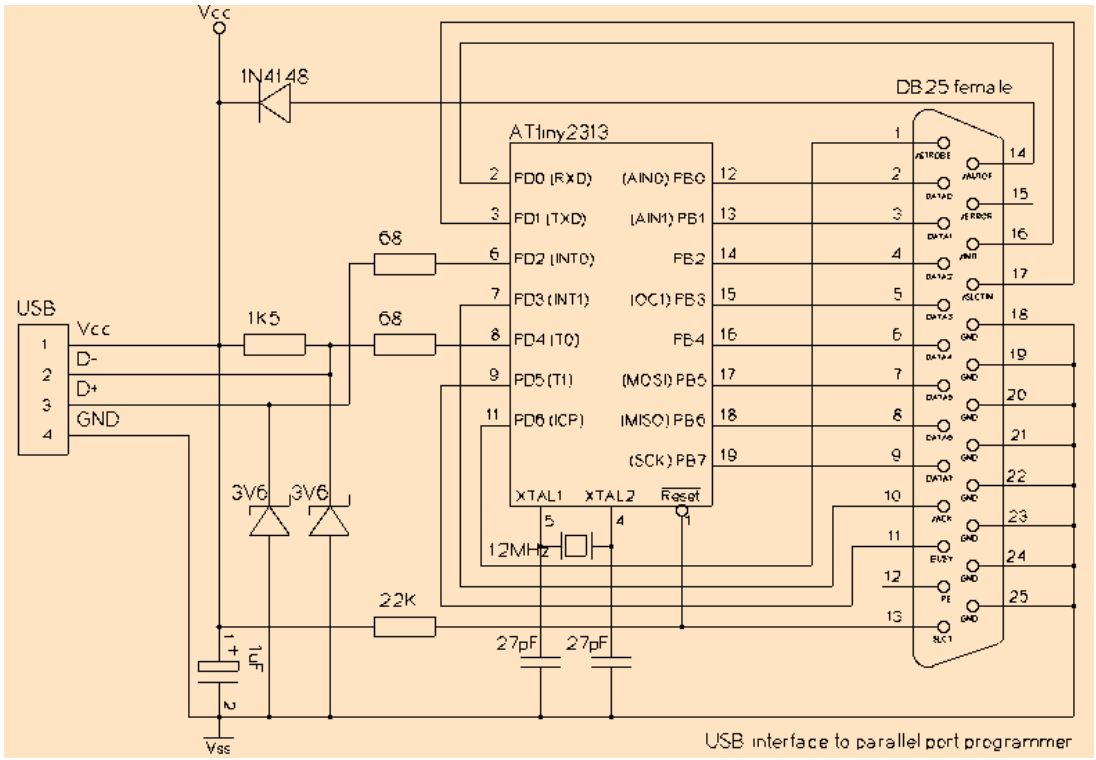
Exactly same as FT232BM.

As you can see in the schematic below the circuit is very simple and the voltage needed for the circuit is obtained from the USB port.



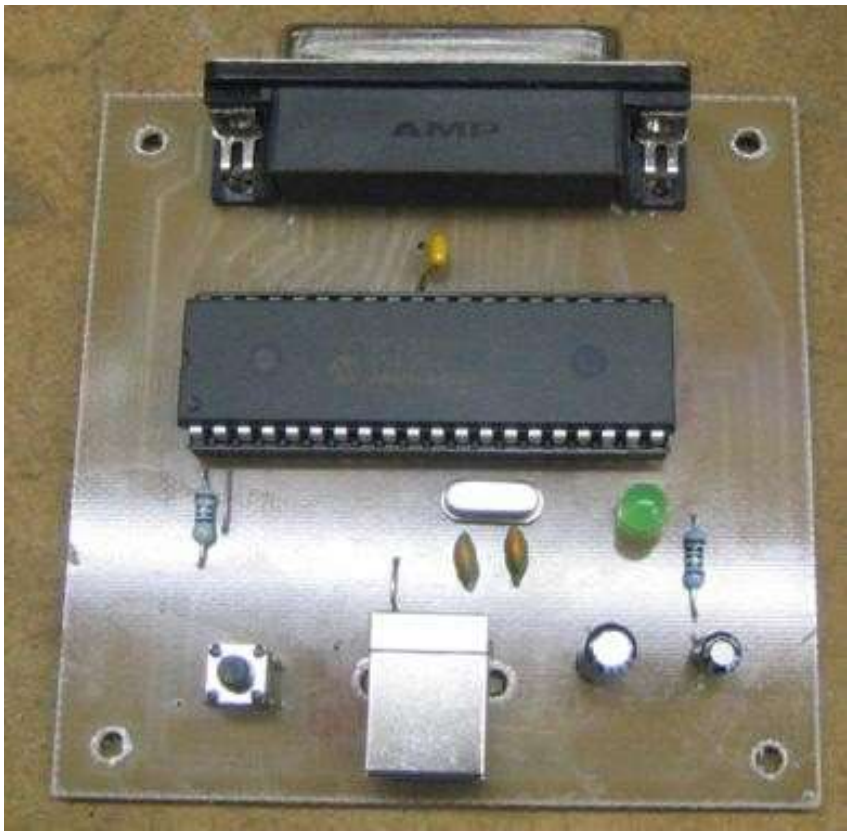
2. Using ATtiny2313:

The ATtiny2313 is a low-power 8-bit microcontroller.



3. Using PIC:

Also we can convert the USB to parallel by using PIC microcontroller.



The most commonly used is the first way because it doesn't need any program to convert the data from USB to Parallel, unlike the second and third way.

The photo of finished Adapter:

PC Interfacing

Fourth Level

Lecture Eleven

Analog to Digital Converters

By

Omar Al-farouk Al- dulaimi

PC Interfacing

Fourth Level

Lecture Eleven

Analog to Digital Converters

By

Omar Al-farouk Al- dulaimi

PC Interfacing

Fourth Level

Lecture Twelve

ADCs Converter with Parallel I/O Interface

By

Omar Al-farouk Al- dulaimi

Analogue-to-digital converters (ADC)

Flash: Highest conversion rate (speed), but low accuracy.

Dual slop: Highest conversion accuracy, but low speed.

Successive approximation: is a good compromise on speed & accuracy**.**

I/O Interface between converters and external circuits can be parallel or serial with control lines required for both.

A/D converters with parallel I/0 interface:-

(a) CA3306 Flash Converter:-

The principle of flash converters is that the input signal is compared with all possible subdivisions of a reference voltage at the same time (see Figure 6.1). The reference voltage (V ref) is divided by a series of resistors. The code generated by the comparators is converted to a binary code by an encode circuit. The number of comparators grows rapidly with the number of bits. An n-bit converter requires 2^n comparators!

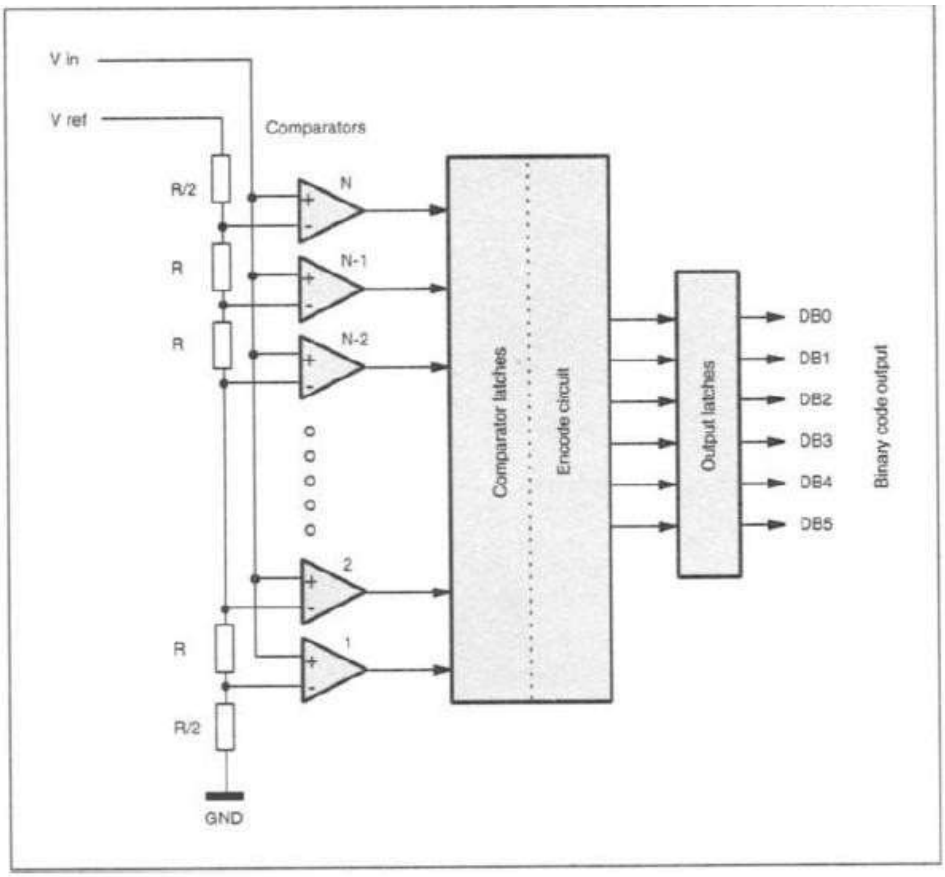


Figure 6.1 Principle of 6-bit flash A/D converters

The CA3306CE has a conversion rate of 15 MHz and 6-bit conversion accuracy. It has 64 comparators and requires a power supply from 3 to 7.5V. The power consumption

is about 50 mW. The pin-out of the chip is given in Figure 6.2. B1 through to B6 output the conversion data. There are two enable pins: CE2 (pin 5) and-CE1 (pin 6). When CE2-1 and -CE1-0, the conversion data appears on B1 to B6 outputs, otherwise the outputs are in the high impedance state. Pin 7 is a Clock input and pin 8 (Phase) controls the sequential operation of A/D conversion. When Phase is high, the rising edge of the clock starts a sampling cycle. When the clock is at the high state, comparators compare the input signal with the reference. At the falling edge of the clock, the converted data from the comparators is latched into the comparator latches. During the low state of the clock, the data propagates through the encode circuit and the encoded data appears at the input of the output latches. At the next rising edge of the clock, the data is latched into the output latches and appears on the pins. At the same time, it initializes a new sampling cycle. V ref- (pin 10) and V ref+ (pin 9) are the voltage reference to the converter.

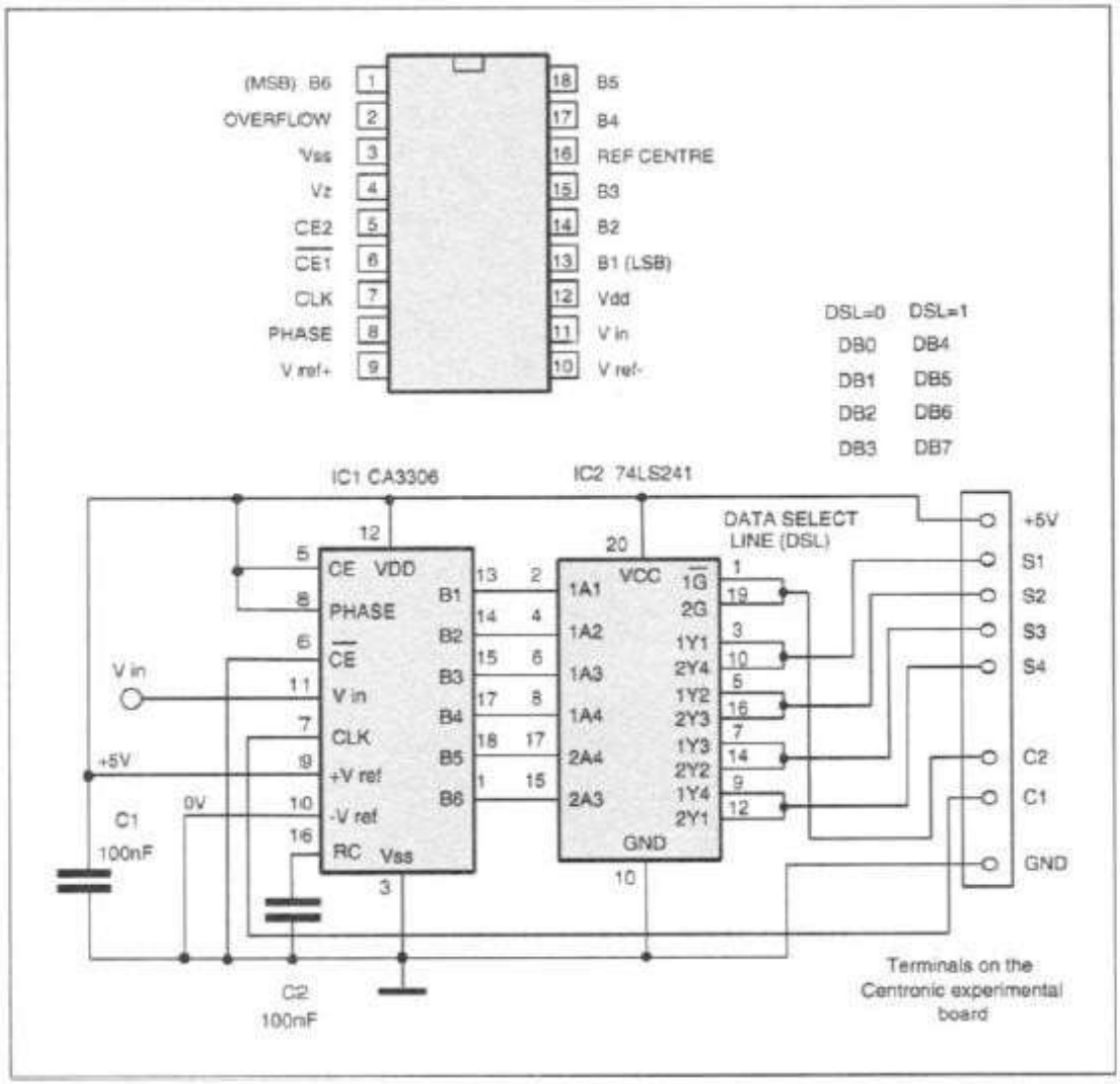


Figure 6.2 Pin-out and experimental circuit of the CA3306

The experimental circuit is given in Figure 6.2. It is connected to the Centronic experimental board. The circuit uses a 74LS241 buffer IC which allows the computer to read the 6-bit conversion data via four input lines. C1 from the Centronic experimental board is connected to the Clock input of the CA3306. To read the previous A/D conversion result and to start a new conversion. The 74LS241 splits the 6-bit data into two parts: the upper two bits and the lower four bits. The two parts are read into the computer in turns using the Data Select Line (DSL).

The data transfer between the CA3306 and the computer is too slow. A solution to this problem is to allow the flash A/D converter to write data temporally into memory buffers. The A/D conversion results can be stored in the buffer at a much higher speed. When the buffer is full, the data are downloaded into the computer.

(b) ZN449 Successive Approximation ADC:

A successive approximation analogue-to-digital converter consists of the following parts: a digital-to-analogue converter, a comparator and a successive-approximation register. Figure 6.3 shows the internal block diagram of a typical 8-bit successive approximation converter. Each bit is brought to logic high successively to test if the output voltage from the D/A converter is higher or lower than the input voltage. If the DAC voltage is higher than the input voltage, the value of the tested bit should return to zero. If the DAC voltage is lower than the input, the value of the tested bit is 1. By testing each bit in such a manner, a value can be established.

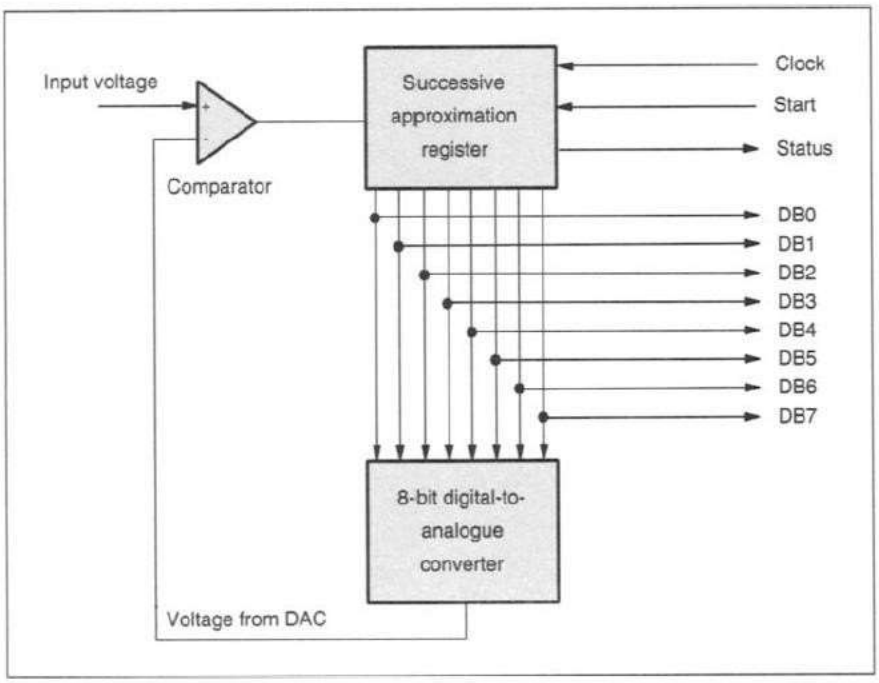


Figure 6.3 Successive approximation ADC

The ZN449 or ZN448 is an 8-bit successive approximation A/D converter. It has a minimum conversion time of 9 µs. An on-board clock generator. The pin-out of the converter is given in Figure 6.4. When the -CONVERT input (pin 4) becomes low, ADC begins an A/D conversion and the -BUSY output (pin 1) becomes low. The -BUSY output will go high at the end of the conversion indicating that the conversion is completed. The -RD input (pin 2) is the data enable line which is taken low to enable the data on the output lines (DB0 to DB7, pins 18 to 11) which otherwise are in the high impedance state.

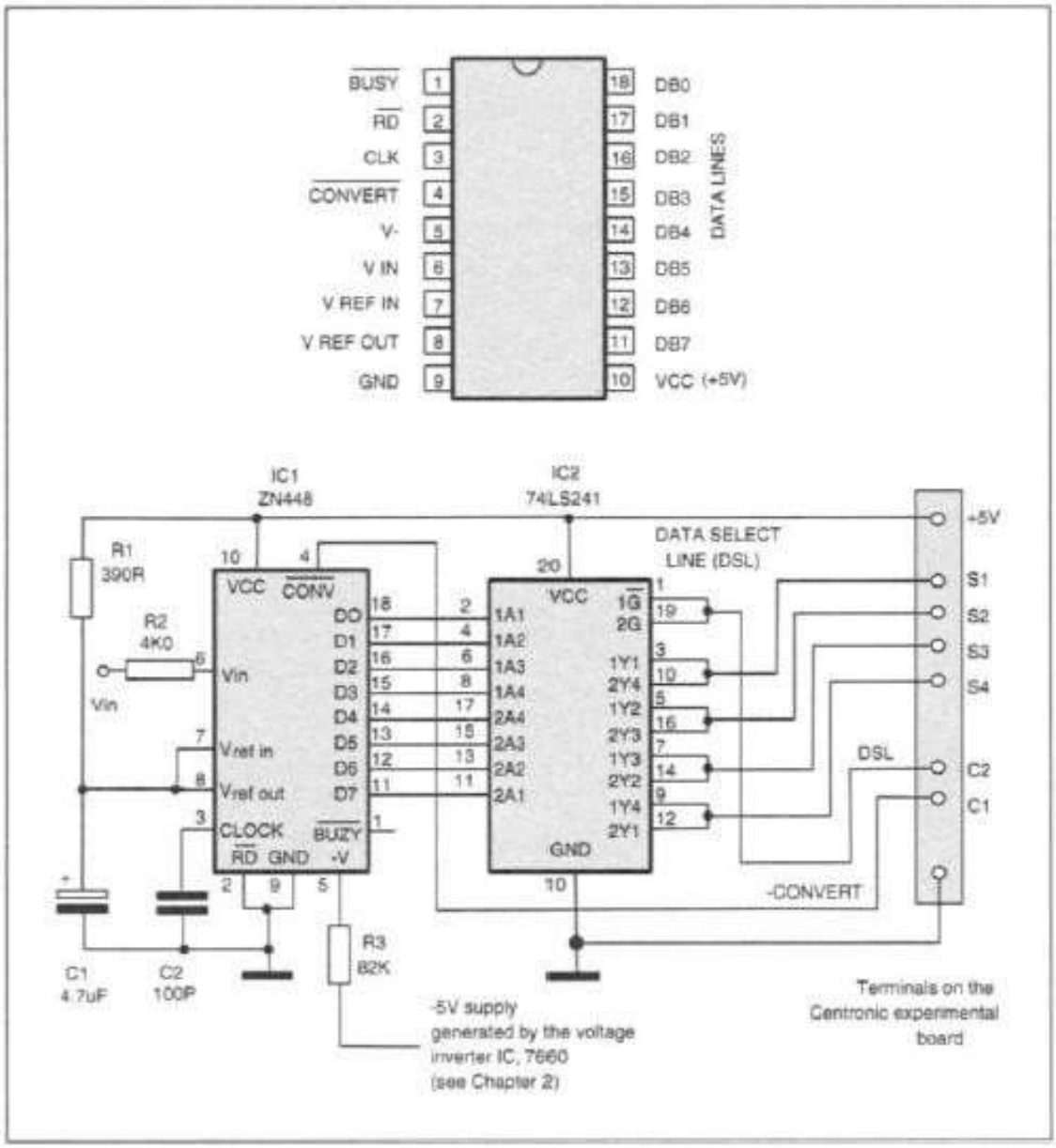


Figure 6.4 Pin-out of the ZN449 and experimental circuit

A clock capacitor (C2) is connected between pin 3 and the ground (pin 9) which enables the onboard clock generator to generate a clock signal. The maximum clock

frequency is obtained with a capacitor value of 100 pF. A negative power supply ranging from-3V to-30V can be supplied to pin 5 (-V) via a resistor. When the negative voltage is -5V, the resistor value is 82 K. Pin 8 is the output of the on-board 2.5V reference Vref out. The input voltage to be measured is fed to Vin (pin 6) via a 4K resistor. A 2.5V input voltage will produce a byte of 255 decimal at the output of the converter. The decimal values for other input voltages are calculated using the following equation:

Decimal value = (Input voltage x 255) / 2.5

The experimental circuit is shown in Figure 6.4. The circuit is connected to the Centronic experimental board. The -CONVERT is connected to C1 terminal; Data Select Line for the 74LS241 is connected to C2 terminal of the experimental board. The data is read into the computer via S1 to S4.

(c) ICL7109 12-bit Integrating A/D Converter (Dual – Slope):-

The working principle of an integrating A/D converter is described in Figure 6.5. The technique involves an integrator and a negative reference voltage. The conversion is in two phases: the signal integration phase and reference de-integration phase. In the first phase, S1 is closed (S2 open) to supply the input voltage to the integrator for a fixed period of time, T_{INT}. After this, the reference de-integration phase starts. S1 is open and S2 is closed. This action supplies the input of the integrator with the negative reference. The capacitor of the integrator starts to discharge at a rate determined by the reference voltage. After a period of T_{DEINT}, the output of the integrator crosses the zero volt level. Knowing the two time periods, the input voltage can be calculated using the following equation:

Input voltage = $(V_{ref} * T_{DEINT}) / T_{INT}$

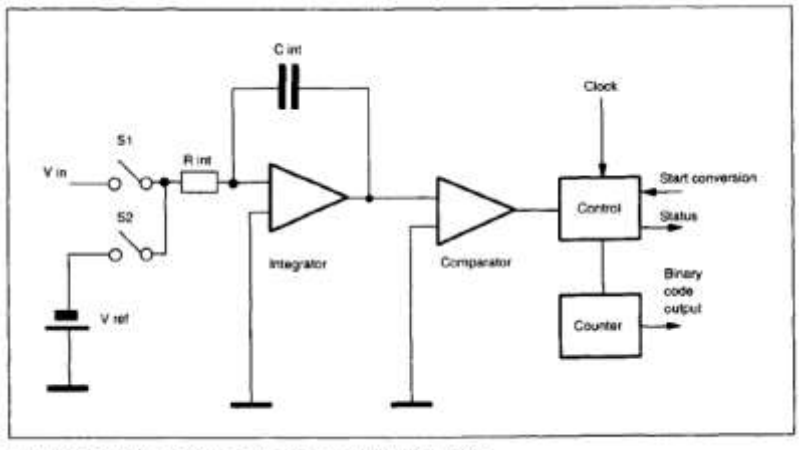


Figure 6.5 Dual-slope integrating A/D converter

An advantage of using a dual-slope converter is that random noise can be averaged to zero during the signal integration phase. It also provides noise rejection automatically. Interference signals with a fixed frequency can be removed by choosing the right integrating period. The integrating converters often have an integration period to reject 50/60Hz mains frequency interferences.

The ICL7109ACPL is a low-power, 12-bit integrating A/D converter. The pin-out is given in Figure 6.6.

The analogue section of the ICL7109 needs four external components. They are the reference capacitor, C_{REF}, the auto-zero capacitor, C_{AZ}, the integrating capacitor C_{INT} and the integrating resistance R_{INT}. The on chip oscillator operates with a 3.5795 MHz TV crystal giving 7.5 conversions per second. The device could work with a conversion rate of 30 samples per second. The IC also provides a reference voltage (pin 29) which is nominally 2.8V.

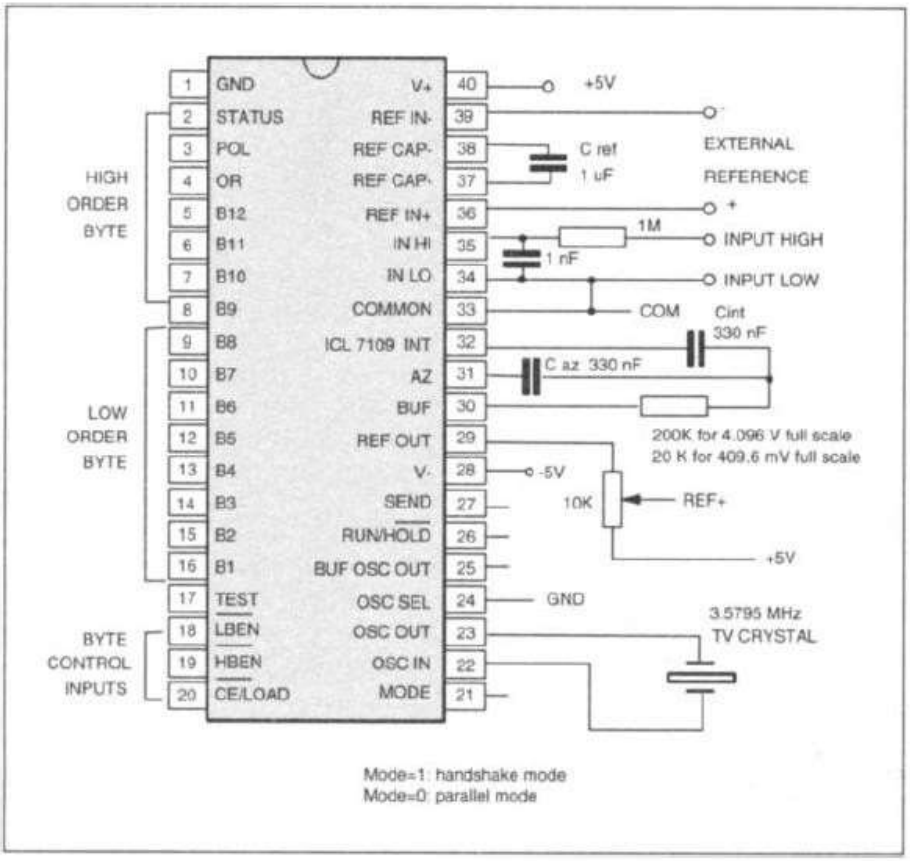


Figure 6.6 Pin-out of the ICL7109 and a typical connection

If RUN/-HOLD (pin 26) high state, the ADC performs conversions continuously. If it is low, the conversion is one shot. The conversion results appear at the 14 tri-state outputs B1 to B12. B1 through B12 give the conversion data.

Data can be read from in one of the two modes: the direct mode and the handshake mode. Data transfer mode is configured using the Mode (pin 21) input, MODE-0 to select the direct mode and MODE-1 to select the handshake mode. In the direct mode, the 12-bit conversion data is accessible from the output pins under the control of-CE/LOAD, and -LBEN. All the pins are active low. The chip enable -CE/LOAD is low to enable the IC. When -LBEN is low, B1 to B8 output the data. When -LBEN is high, B1 to B8 are in the high impedance state. During a conversion, the STATUS goes high. It goes low after the converted data is latched into the output latches.

ICL7109 can be connected to a 6402 UART in the handshake mode. When the ICL7109 operates in the direct mode, it can be connected to a computer via an 8255 PPI or a 16-to-1 data selector circuit. An experimental circuit diagram using two 4051 analogue switches is shown in Figure 6.7. The circuit is connected to the Centronic experimental board.

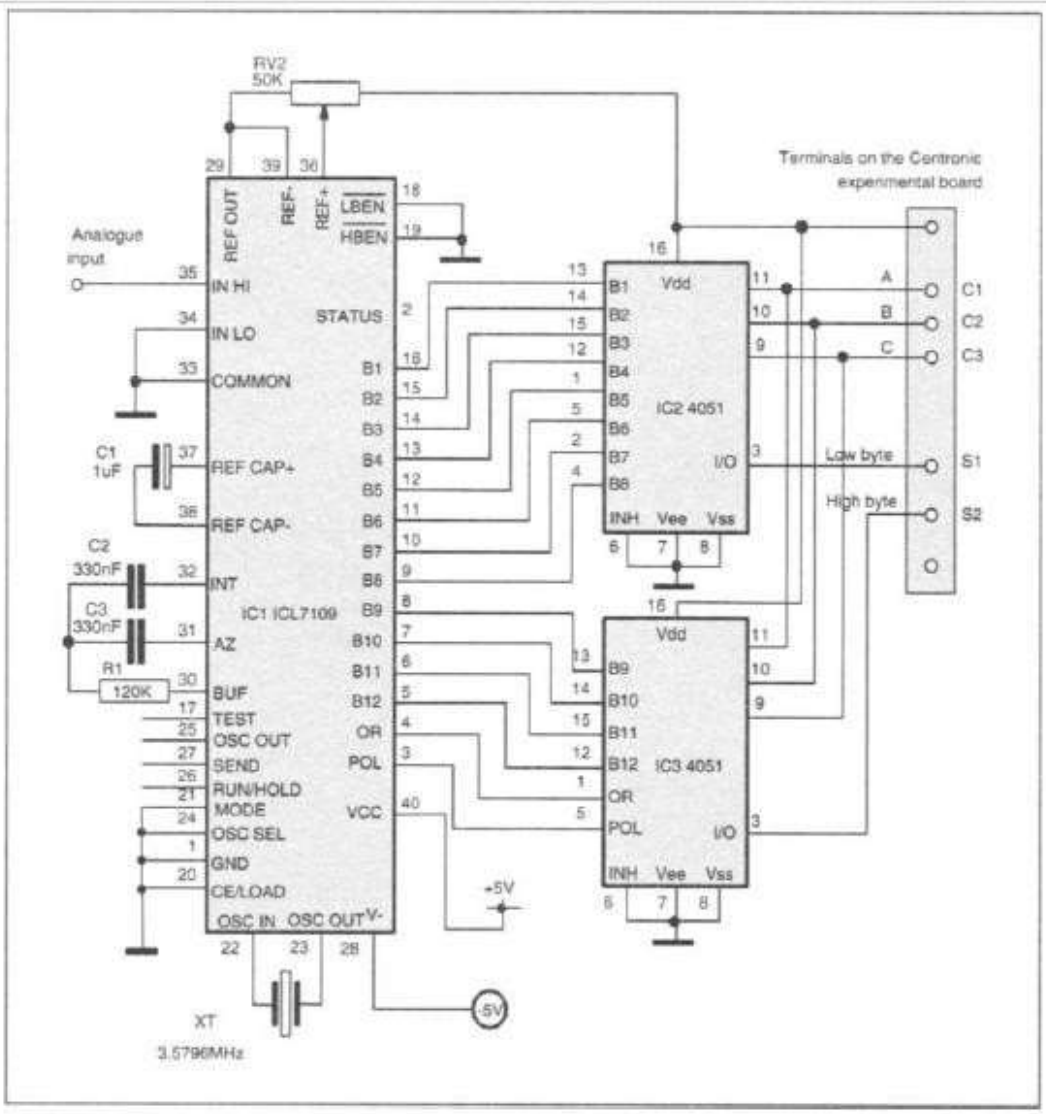


Figure 6.7 Experimental circuit of the ICL7109

PC Interfacing

Fourth Level

Lecture Twelve

ADCs Converter with Parallel I/O Interface

By

Omar Al-farouk Al- dulaimi

Analog to Digital Converters:-

Analog to Digital Converters (ADC) are an electronic integrated circuit (IC) which transforms a signal from analog (continuous) to digital (discrete) form. Analog signals are directly measurable quantities. Digital signals only have two states. For digital computer, we refer to binary states, 0 and 1.

Why ADC is needed:-

ADC is needed for many reasons but the most important are: Microprocessors can only perform complex processing on digitized signals. When signals are in digital form they are less susceptible to the deleterious effects of additive noise. Also ADC Provides a link between the analog world of transducers and the digital world of signal processing and data handling.

Application of ADC:-

ADCs are used virtually everywhere where an analog signal has to be processed, stored, or transported in digital form. Some examples of ADC usage are digital volt meters, cell phone, thermocouples, and digital oscilloscope. Microcontrollers commonly used 8, 10, 12, or 16 bit ADCs.

Classification of ADC according to accuracy and speed:-

ADC can be classified into two general groups based on the accuracy and speed:-

flash-type and counter, successive-approximation,includes**groupfirstThe** converters.

The second group includes integrator converters and voltage to frequency converters.

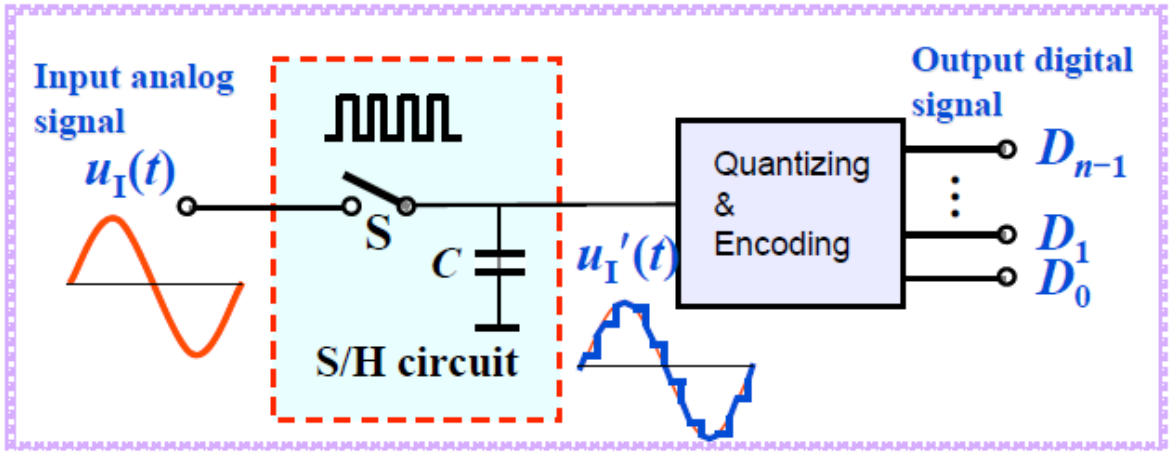
The tradeoff between two groups is based on accuracy VS speed. The successive-approximation and flash-type converters are faster but generally less accurate than the integrator and voltage to frequency type converters. Furthermore, the flash-type is expensive and difficult to design for high accuracy.

The most commonly used ADC: The successive-approximation and the integrator. The successive-approximation is used in applications such as data loggers, and instrumentation, where conversion speed is important. The integrator types are used in applications such as digital meter, and monitoring system where the conversion accuracy is critical.

ADC process:-

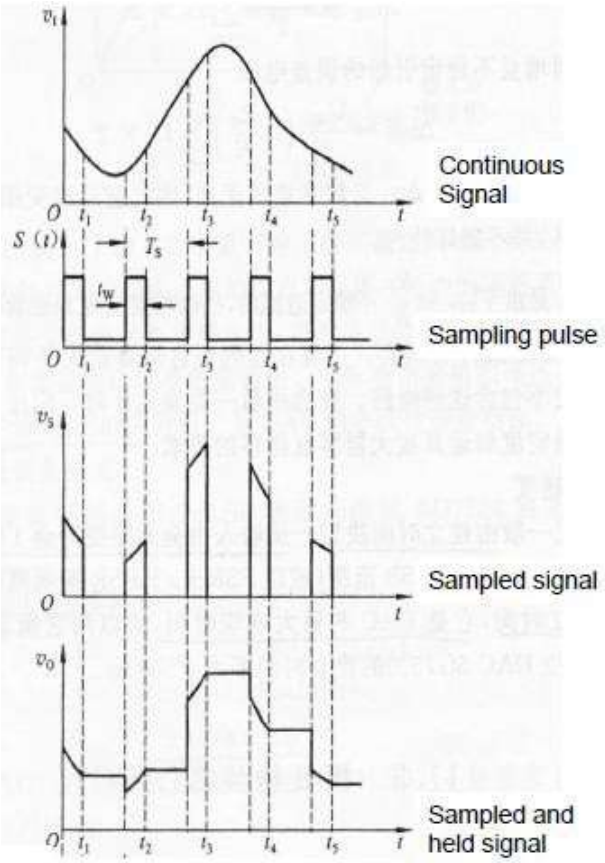
There are two steps process as shown in figure below:-

Sampling and Holding (S/H). .1
Quantizing and Encoding (Q/E). .2



Sampling and Holding:-

It is a process of taking a sufficient number of discrete values at point on a waveform that will define the shape of waveform. The more samples you take, the more accurately you will define the waveform. It converts analog signal into series of impulses, each representing amplitude of the signal at given point as shown in figure below.



Quantizing and Encoding:-

Quantizing - is the process of converting the sampled continuous signals into discrete-valued data (set of finite states).

Encoding - assigning a digital word or number to each state and matching it to the input signal.

The number of possible states that the converter can output is:

$$N=2^n$$

Where n is the number of bits in the ADC.

Example: if you have 0-10V signals. What is the Discrete Voltage Ranges and Output Binary Equivalent by using 3 bit A/D converter?

Solution:-

$N=2^n$

For a 3 bit A/D converter, $N=2^3=8$.

Analog quantization size:

$Q = (Vmax – Vmin) / N = (10V – 0V) / 8 = 1.25V$

Step 1: Quantizing:

Output States	**Discrete Voltage Ranges (V)**
0	**0.00-1.25**
1	**1.25-2.50**
2	**2.50-3.75**
3	**3.75-5.00**
4	**5.00-6.25**
5	**6.25-7.50**
6	**7.50-8.75**
7	**8.75-10.0**

Step 2: Encoding:

Here we assign the digital value (binary number) to each state for the computer to read.

Output States	Output Binary Equivalent
0	000
1	001
2	010
3	011
4	100
5	101
6	110
7	111

Resolution:-

Resolution is the number of bits used for conversion (8 bits, 12 bits, …)

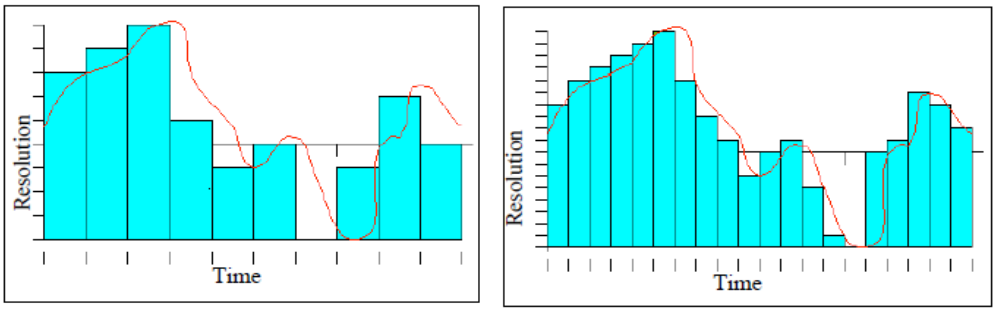
- Resolution (number of discrete values the converter can produce) = Analog Quantization size (Q)
- (Q) = Vrange / 2^n, where Vrange is the range of analog voltages which can be represented
- In our previous example: Q = 1.25V, this is a high resolution. A lower resolution would be if we used a 2-bit converter, then the resolution would be 10/2^2 = 2.50V.

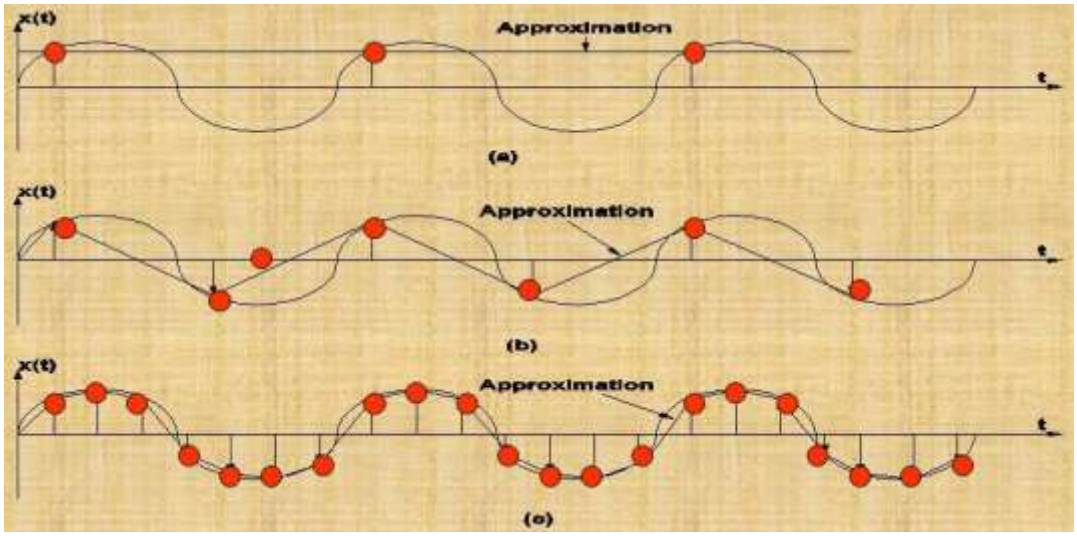
Accuracy of A/D Conversion:-

There are two ways to best improve accuracy of A/D conversion:

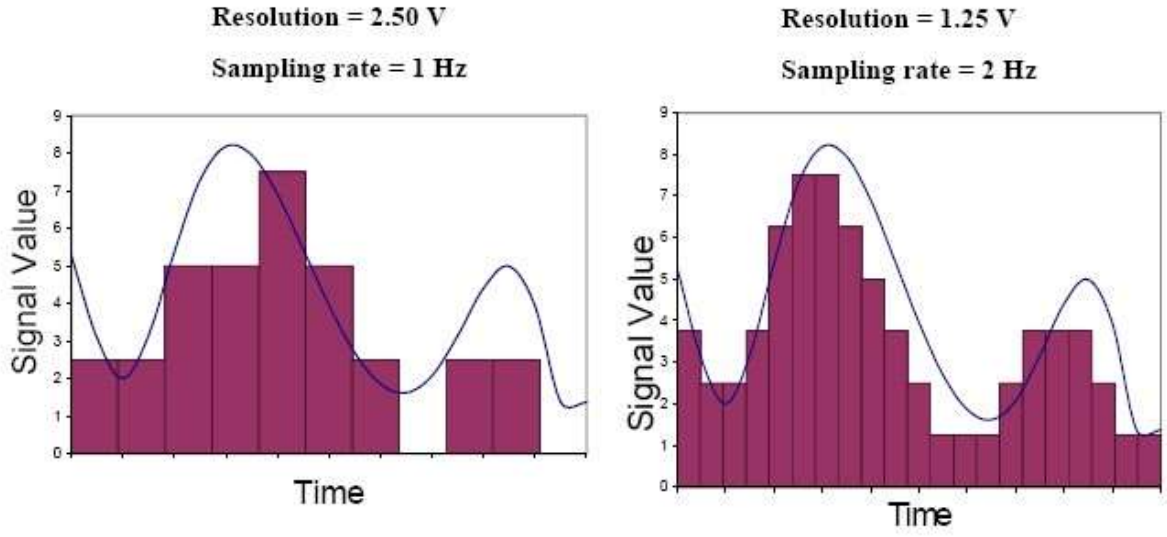
- Increasing the resolution which improves the accuracy in measuring the amplitude of the analog signal.
- Increasing the sampling rate which increases the maximum frequency that can be measured.

■ Low Accuracy ■ Improved





Overall Better Accuracy: Increasing both the sampling rate and the resolution you can obtain better accuracy in your AD signals.



Types of A/D Converters

- Flash ADC
- Delta-Sigma ADC
- Dual Slope (integrating) ADC
- Successive Approximation ADC

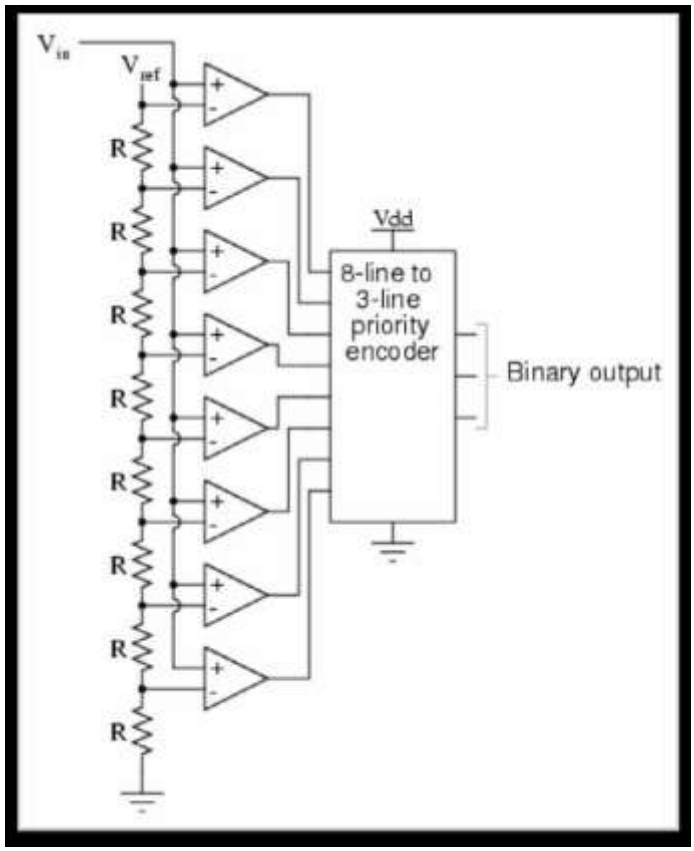
1. Flash A/D Converter

Fundamental Components

Resistors use the resistors to form a ladder voltage divider, which divides the reference voltage into equal intervals.

Comparators Consists of a series of comparators, which comparing the input signal to a unique reference voltage.

Priority encoder the comparator outputs connect to the inputs of a priority encoder circuit, which produces a binary output.

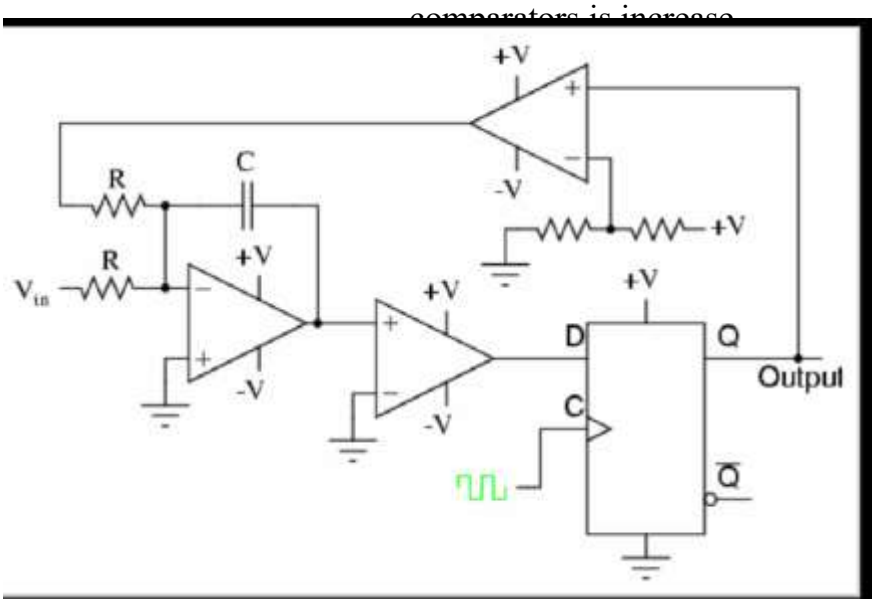


How does it work?

- Uses the comparators to determine in which the input voltage V_{in} is exceed or not the V_{ref}.
- When the analog input voltage exceeds the reference voltage at each comparator, the comparator outputs will sequentially saturate to a high state.
- The priority encoder generates a binary number based on the highest-order active input, ignoring all other active inputs.

Advantages and Disadvantages

- Simplest in terms of operational theory, most efficient in terms of speed, very fast
- Lower resolution, Expensive, for each additional output bit, the number of comparators is increase



How does it work?

- Input is over sampled, and goes to integrator.
- The integration is then compared to ground.
- Iterates and produces a serial bit stream
- Output is a serial bit stream with # of 1's proportional to V_{in}

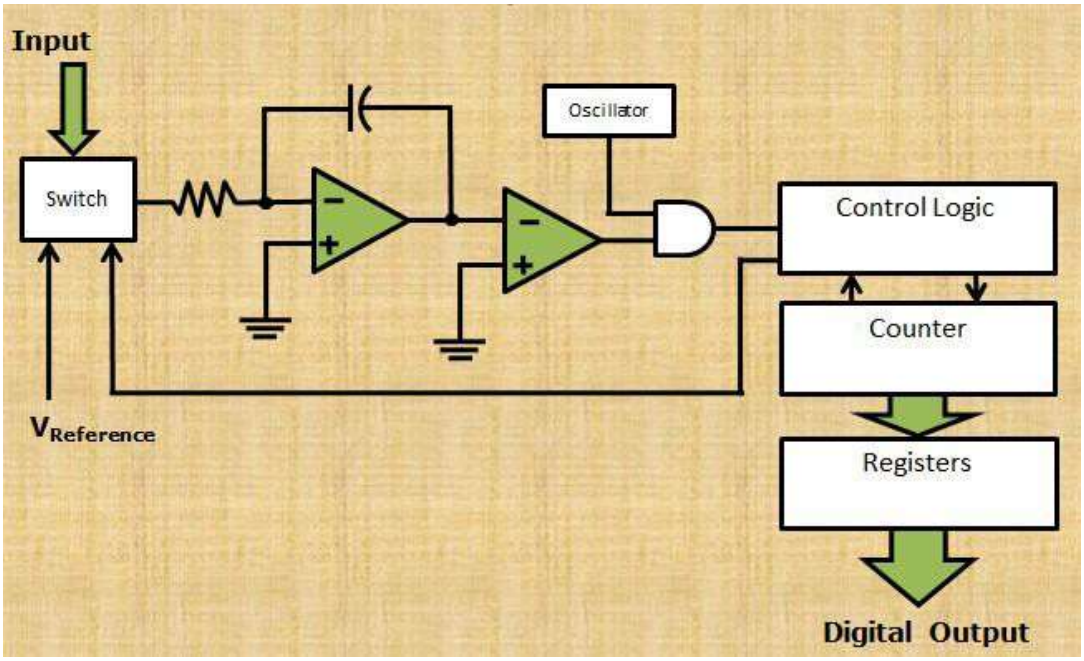
Advantages and Disadvantages

- High resolution, No need for precision components external.
- Slow due to oversampling.

3. Dual Slope Converter

Fundamental components

- Integrator
- Electronically Controlled Switches
- Counter
- Clock
- Control Logic
- Comparator



The Dual Slope ADC functions in this manner:

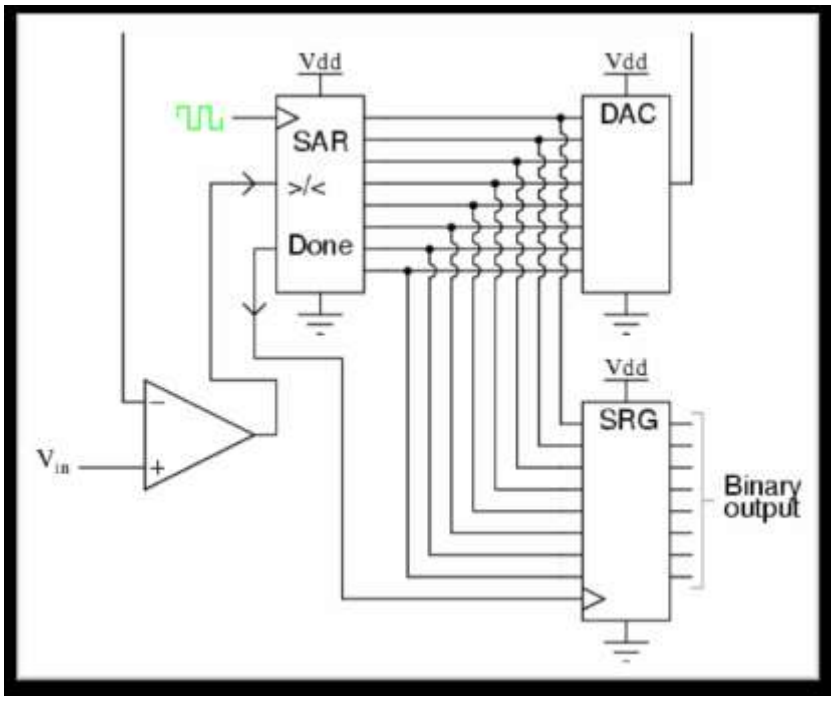
- When an analog value is applied, the capacitor begins to charge in a linear manner and the oscillator passes to the counter.
- The counter continues to count until it reaches a predetermined value. Once this value is reached the count stops and the counter is reset. The control logic switches the input to the first comparator to a reference voltage, providing a discharge path for the capacitor.
- As the capacitor discharges the counter counts.
- When the capacitor voltage reaches the reference voltage the count stops and the value is stored in the register.

Advantages and Disadvantages

- Conversion result is insensitive to errors in the component values, High Accuracy.
- Slow, Accuracy is dependent on the use of precision external components, Cost.

4. Successive Approximation ADC

- Much faster than the Dual Slope.
- A comparator and a DAC are used in the process.
- A Successive Approximation Register (SAR) is added to the circuit
- Instead of counting up in binary sequence, this register counts by trying all values of bits starting with the MSB and finishing at the LSB.
- The register monitors the comparators output to see if the binary count is greater or less than the analog signal input and adjusts the bits accordingly.



Advantages and Disadvantages

- Capable of high speed and reliable, medium accuracy compared to other ADC types, Good tradeoff between speed and cost.
- Higher resolution successive approximation ADC's will be slower.

ADC Specifications:

- Conversion time
- Resolution
- Accuracy
- Linearity
- Missing code

PC Interfacing

Fourth Level

Lecture

Thirteen

ADCs Converter with Serial I/O Interface

By

Omar Al-farouk Al- dulaimi

ADC converters with Serial I/O interface

(a) 8 bits Successive Approximation ADC (TLC548):

The TLC548CP/TLC549CP is an 8-bit successive-approximation converter. It has an on-board sample-and-hold circuit, a 4 MHz system clock generator and a serial I/O interface. The TLC548 is able to sample 45,500 times per second and the TLC549 samples 40,000 times per second.

The pin-out of the converter is shown in Figure 6.11. Pin 8 (VCC) and pin 4 (GND) are connected to the positive and negative rails of the power supply. The range of the power supply voltage is between 3 and 6V with a typical current assumption of 1.9 mA. Pin 1 (REF+) and pin 3 (REF-), REF- and GND are normally wired together. Pin 7 the I/O Clock Input (I/O CK) and Chip Select Input (-CS, pin 5) and one Data Output line (DATA OUT, pin 6).

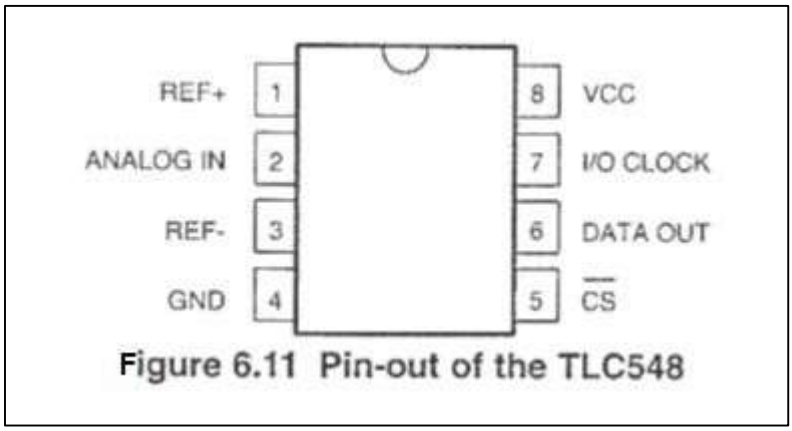


Figure 6.11 Pin-out of the TLC548

The operational sequence is explained below and is shown in Figure 6.12.

1. When -CS is high, the data output line is at high-impedance state. It also disables the clock input, I/O CLK. -CS goes low to start a read cycle. To reduce errors, the internal circuitry waits for two rising edges and then a falling edge of the internal system clock after a high-to-low transition is detected on the -CS pin. Then it is accepted. The MSB of the previous conversion result (DB7) automatically appears on the DATA OUT pin.
2. The falling edges of the first four I/O CLKs shift out DB6, DB5, DB4 and DB3 of the previous conversion result on the DATA OUT pin. The on-chip sample-and-hold begins sampling an analogue input after the fourth falling edge of the I/O CLK.
3. Three more clock cycles are applied to the I/O CLK, DB2, DB1 and DB0 of the previous conversion result are shifted out on each falling edge of the I/O CLK.

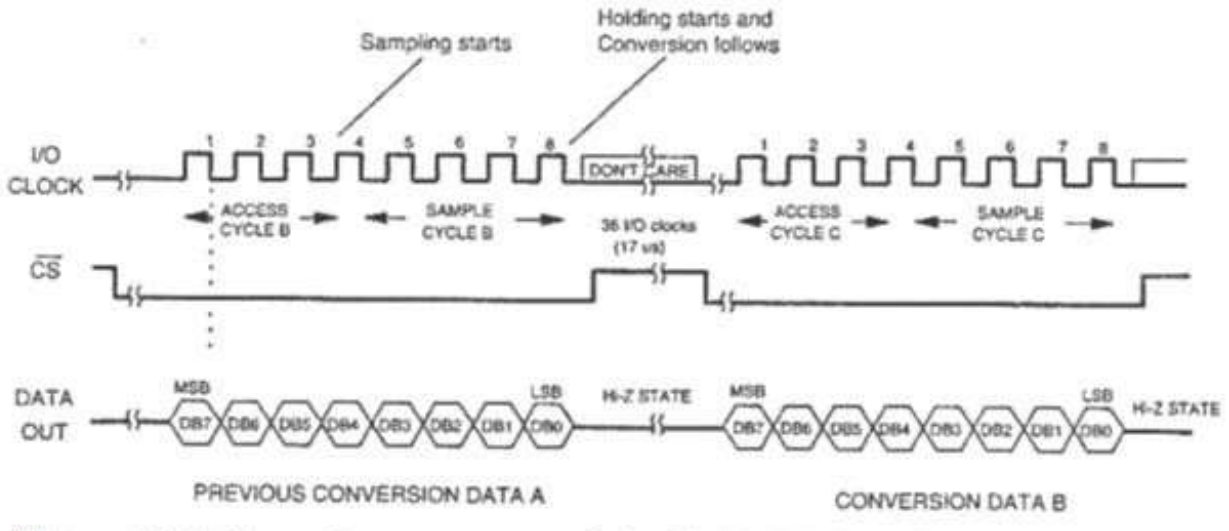


Figure 6.12 Operation sequence of the TLC548/549 serial A/D converter

4. The final (eighth) clock cycle is applied to the I/O CLK. The falling edge of this clock terminates the sample process and initiates the hold function. The hold function continues for the next four internal system clock cycles. After that the hold function terminates and A/D conversion is carried out during the next 32 system clock cycles. A complete conversion takes 36 internal system clock cycles. During the conversion, -CS must go high or the I/O CLK remains low for at least 36 system clock cycles. If-CS is taken high; it must remain high until the end of the conversion.

(b) TLC541 12-Channel Successive Approximation Converter:-

The TLC541IN/TLC540IN is a successive-approximation A/D converter. It has an on-board sample-and-hold circuit, a 12-channel analogue multiplexer and a serial I/O interface which enables it to perform simultaneous read and write operations. The TLC540 is able to sample 75,180 times per second and the TLC541 40,000 times per second.

The pin-out of the IC is shown Figure 6.14. Pin 20 (VCC) and pin 10 (GND) are connected to the positive and negative rails of the power supply. The range of the power supply voltage is between 4.75 to 6.5V with a typical power dissipation of 6 mW. Pin 14(REF+) and pin 13 (REF-), REF- and Ground (pin 10) are normally wired together.

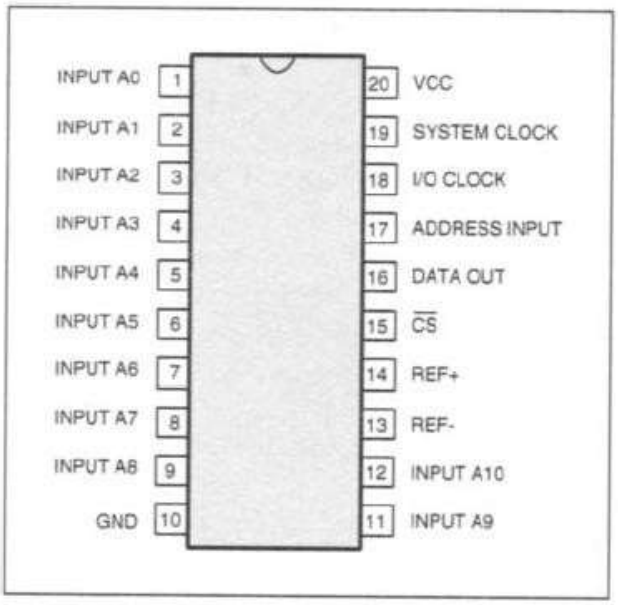


Figure 6.14 Pin-out of the TLC541

Amongst the 12 analogue multiplexers, the first 11 inputs could be accessed at pins 1 to 9, 11 and 12, corresponding to analogue inputs from 0 to 11. The twelfth input is connected internally to a voltage reference. To select an analogue I/p channel, a 4 bits address should be written serially. The serial interface consists of five I/O lines: the System Clock input (SYS CK, pin 19), the I/O Clock input (I/O CK, pin 18), Chip Select input (-CS, pin 15), Address Input (ADD IN, pin 17) and Data Output (DATA OUT, pin 16). The SYS CK is the clock for A/D conversion operation. A maximum 4 MHz system clock can be applied for the TLC540 and 2.1 MHz for the TLC541, giving 75,180 and 40,000 samples per second respectively. For TLC1540/TLC1541 converters the maximum system clock is 2.1 MHz, giving 32,258 samples per second. The I/O CLK is used for synchronizing I/O operations. ADD IN is the serial address input for selecting the analogue multiplexers. DATA OUT is the serial data output. -CS is the chip enable. It must be at logic low to enable the IC.

The writing and reading sequences of the IC are explained as follows (see Figure 6.15).

1. -CS goes low to start read/write cycle. To minimize errors, the internal circuitry waits for two rising edges and then a falling edge of the SYS CLK after the high-to-low transition is detected on the CS pin. Then it is accepted. The MSB of the previous conversion result (DB7) automatically appears on the DATA OUT pin.
2. A new multiplexer address (AD0, AD1, AD2 and AD3) are appears on the ADD IN. The falling edges of the first four I/O CLKs shift out DB6, DB5, DB4 and DB3

of the previous conversion result on the DATA OUT pin. The on-chip sample-and-hold begins sampling the newly addressed analogue input after the fourth falling edge of the I/O CLK.

3. Three clock cycles are further applied to the I/O CLK, DB2, DB1 and DB0 of the previous conversion result are shifted out on each negative edge of the I/O CLK.

4. The final (eighth) clock cycle is applied to the I/O CLK. The falling edge of the clock completes the sample process and initiates the hold function. Data conversion is then carried out during the next 36 SYS CLK cycles. After this I/O CLK, either -CS must go high or the I/O CLK remains low for at least 36 SYS CLK cycles to allow for the data conversion. If -CS is taken high; it must remain high until the end of the conversion.

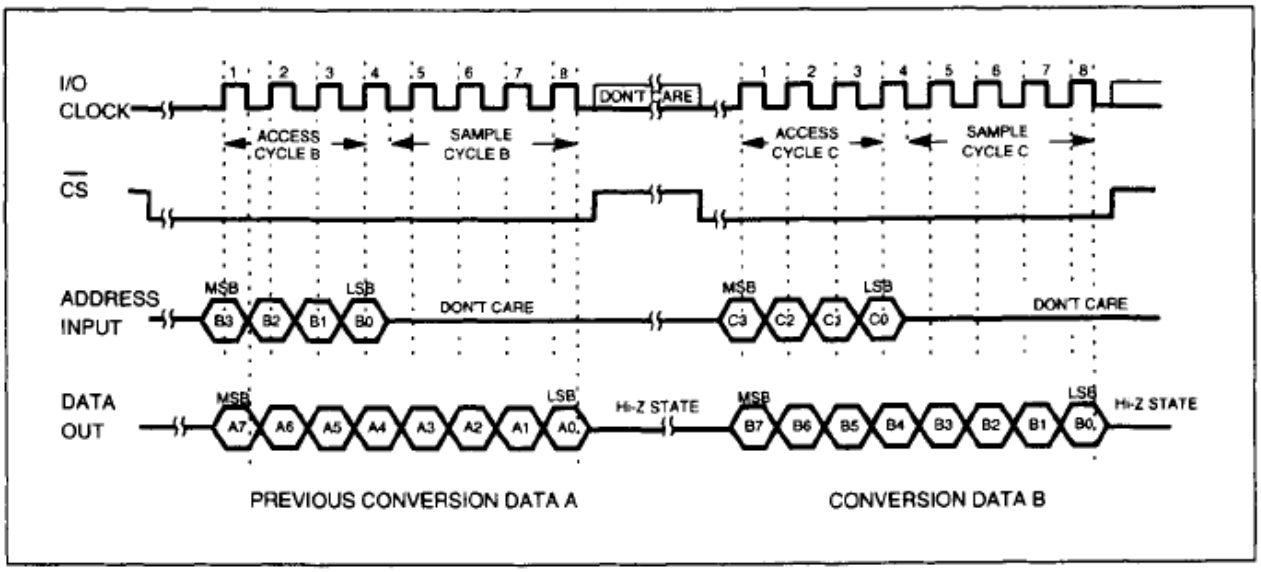


Figure 6.15 Operation sequences of the TLC541 serial A/D converter