Microprocessors and Microcontrollers
Prof. Santanu Chattopadhyay
Department of E & EC Engineering
Indian Institute of Technology, Kharagpur

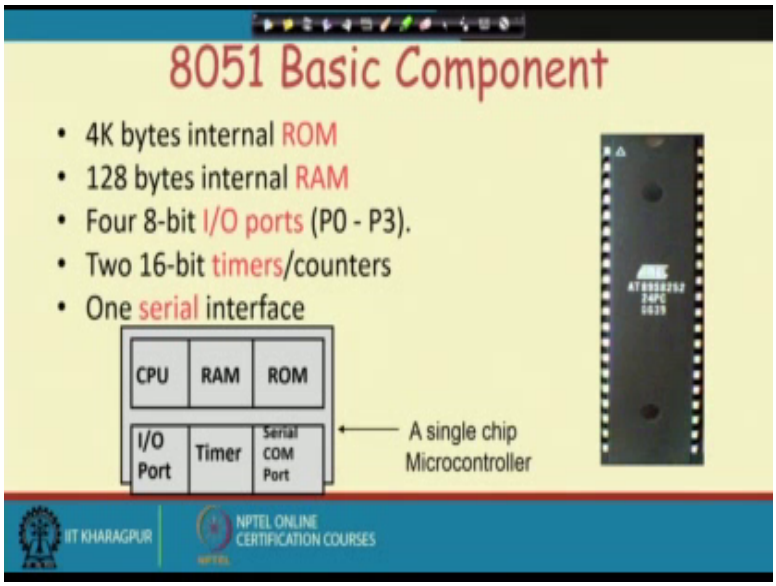
Lecture – 23
8051 Microcontroller

So, next we look into Microcontrollers. So, is MIC after looking into Microprocessors? So, you have seen the microprocessors are basically the CPU. So, microcontrollers are 1 step ahead. So, you can consider it as computers there are several microcontrollers so we will look into some of the standard ones or some of the well-known microcontrollers, but of course, there are so many different microprocessors and microcontrollers are available.

So, it is not possible to cover all of them in any codes, but anyway so hope that if you get exposed to 1 of those microcontrollers then you can extrapolate those ideas to other microcontrollers and get the essential features there.

So, 8051 happens to be 1 of the very prominent microcontrollers that are there in the market and the it is architecture is guided by the design of this processor and along with that we have got essential modules like say RAM ROM and timers and all those additional peripherals. So, we will see them slowly.

(Refer Slide Time: 01:35)



So, the basic components that you have in a microcontroller 8051 microcontroller it has got 4 kilobytes of ROM then 128 bytes of RAM 4 8-bit IO ports 2 16-bit timers or counters and 1 serial interface.

So, this is the chip that we have so there are various manufacturers. So, this is from 1 such manufacturer now microcontrollers. So, they are they can be considered as single chip computer. So, if you remember that in a computer system we need the components like the processor which is the CPU then we need some memory for that and out of that memory some part is the will hold the program. So, that is. So, they are not going to change. So, they can be the wrong part then there will some part where will be storing some data. So, that is the RAM part because that will require read write access and apart from that since the system computer system needs to interact with the outside world. So, there must be some IO ports.

So, for example, in 8 8 5 also we have seen that you can use you can connect some IO devices to the ports to the data bus line and get it as IO port. So, similarly we can have some IO port here and some other important the operable thing component like a serial communication that is also very important because for single bit communication. So, the serial communication is useful and when you are designing a system then many a times what we need to do is the events will or need it needed to be occurred at some particular instants of time.

So, that way we need some very precise timing. So, we can put some delays using instructions and looping like that, but that delay you can understand that you cannot go to a very refined level of granularity, because if you even if you take the smallest say simplest possible instruction like the knop instruction. So, that requires the 1 complete machine cycles. So, 1 machine cycle the fetch cycle that is the 4 t state and 4 t state you. So, you cannot have a delay of 1 t state in that processor. So, that is the problem. So, you need some external timer or counter chip to be connected to the processor. So, if you really want some precise timing.

So, for a system operations so these are the things that we should have, now what is done in 8 0 in the microcontrollers is that the all these components they are put onto a single chip. So, what are the advantage; advantages are like this that first of all the overall system size becomes small. So, instead of having single a separate chips mounted on a

board now in a single chip you have got all these components. So, overall size of the system becomes smaller.

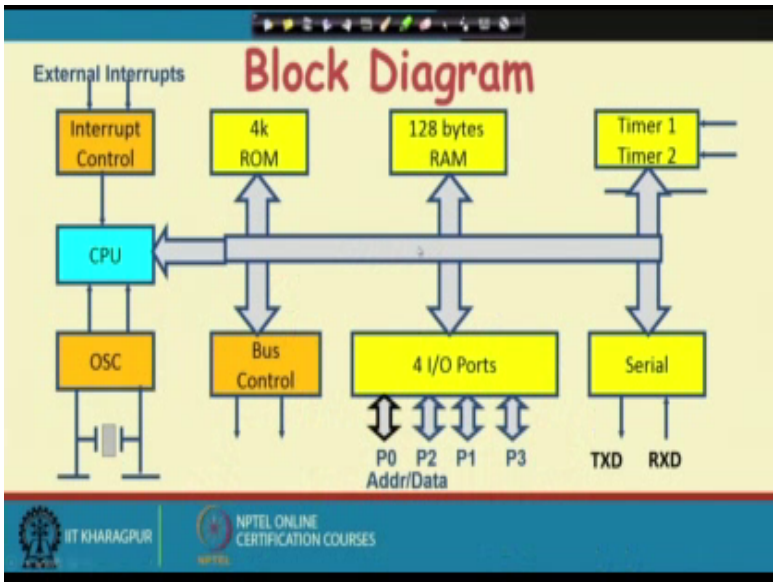
Second important thing is about the speed like when you have got the different components mounted on a printed circuit board. So, between them the connection is the copper line. So, copper line connections since they are external to the chip. So, they will be much slower compared to the on chip that is within the chip if I have connection. So, that compared to that this off chip connections are going to be slower. So, if you are looking for the speed enhancement. So, it is better that all these components we put into the same silicon chip and that is exactly what is happening in microcontroller that all these components they are put onto a single chip.

However so you cannot put the resources to a very large value otherwise the size of the chip will become very hard very large the footprint of the chip will become large. So, 8051 it has got 4 kilobytes of internal ROM. So, you can program this 8051 to load some program onto this ROM. So, that is that that is the internal ROM then the RAM space is really small 128 bytes only and we will see that it is multiplexed in different ways also of course, you can connect external ROM and RAM chips to the microcontroller to extend the total available memory that we will see, but internally it is like that.

So, if your system is very simple it may be that with 4 kilobyte of internal ROM and 128 bytes of RAM. So, we can realize the system for example, if you are implementing a traffic light controller. So, it may be possible that the system is very simple and we can do it with a single 8051 micro controller instead of instead of having separate RAM and ROM chips onto the board 4 8 bit IO ports have been provided. So, that helps that is the large number. So, 8 bit into 4 that is total 3 2 bit IO that processor can support without any additional hardware.

Then 2 16-bit timers counters are there. So, you can so that can do some precise timing calculations. So, you can you can control the timing and you can also count some event that has occurred external. So, how many say if you are measuring if you are counting the items passing on a conveyor belt. So, passing of every component or every item may be sending a pulse to the counter and accordingly the counter will find out we will count the how many such items have passed and serial interface. So, this is useful for doing some serial communication to other devices.

(Refer Slide Time: 07:11)

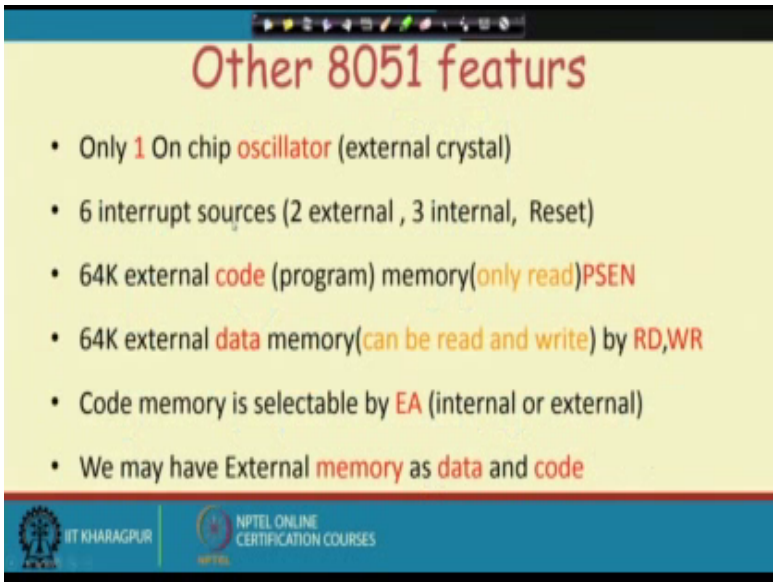


So, if you look into the internal block diagram of 8051. So, as we have said that on a bus. So, these are the components that are hanging. So, you have got 4 kilobytes of ROM 128 bytes of RAM for IO ports 1 serial port there are 2 timers timer 1 and timer 2 and we have got this bus control. So, bus control will be controlling the operation there the processing unit which will be doing the processing.

So, when we are discussing about the microprocessors actually we discussed about this CPU only assuming this that this ROM RAM timers the IO ports and serial communication was also made part of the few, but most of the components are outside, but in case of micro controller all of them are together. So, in the we have got this CPU then the interrupt control and the oscillator that will be generating the clock signal. So, that will be coming from the that will be controlling the CPU.

So, this is the internal block diagram of 8051 other features that we have in 8051 is the only 1 on chip oscillator.

(Refer Slide Time: 08:10)



So, that is external only 1 oscillator is there for the clock generation 6 interrupts sources. So, we have got this external interrupt. So, there are 2 external interrupts and there are 3 internal interrupts in terms of that reset serial input output and the timers.

So, 2 timers 1 serial input output and the reset. So, these are the 6 interrupt sources that we have then we have got 64 kilobyte of external code space. So, that is for the program memory. So, this is. So, internally we have got internally we have got 4 kilobyte. So, you have got 4 kilobyte of ROM. So, if you are connecting external memory. So, you can go up to 64 kilobyte of external space external ROM for the data memory part.

So, it is again another 64 kilobyte of external data memory. So, code memory and data memory if you take it separately. So, it is 64 plus 64 total 128 kilobyte of memory that you can connect to the 8051 system out of that half of it will be programmed memory half of it will be data memory. In many way realizations what we do is that we merge this code and data memory together and we get only 64 kilobyte as the external memory. So, which can be configured both as data memory and program memory so, that may be useful in many applications.

Now, when you are the using this external memory external code memory so, there is a strobe which is known as the program store enable or PSEN. So, this pa PSEN beats. So, that the this particular bit. So, it will be controlling the read operation on the other hand for the data memory axis. So, we have got this read and write. So, in case of normal

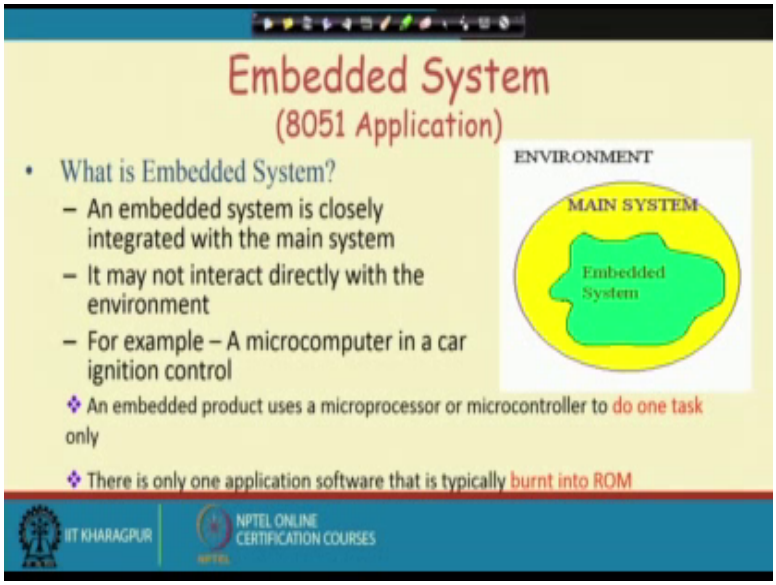
process or 8085 we have seen that whenever we are trying to access outside the memory. So, there were read and control read and writes controls.

So, for ROM axis only the read line should be connected to the read of the ROM for the RAM axis the read and write lines have to be connected to the read and write pins of the RAM, but in case of 8051 since program memory and data memory are totally separate. So, the program memory is controlled by this PSEN signal PSEN signal whereas, the data memory is controlled by a read and write signal. So, when the 8051 is accessing is accessing program code. So, it will not activate this read and write signal.

So, we have to be careful in our design because then it will be through the stroke given will be on the this program store enabled line on the other hand when it is doing the read axis or if data axis. So, it will be activating only the read and write lines not the PSEN line. So, you have. So, that way we have to be careful and this code memory is selectable by this e a external axis. So, whether as we said that there is 4 kilobyte of external memory. So, you can ah. So, you can at any point of time you can say whether you want to access external memory or internal memory.

So, that way you can have this a so this external axis there is a pin that you can configure and you can set it to 0 or 1 accordingly you are the instruction will access internal memory or external memory for code axis. And we can as you as I have already said that we may have external memory as both data and code so that is possible.

(Refer Slide Time: 12:06)



So, why this 8051 all on a sudden came so this is this has come because of the new type of systems that we have they are known as embedded systems.

So, an embedded system it is closely integrated with the main system and it so, it may be that in the overall system this embedded system is a part for example, the say the washing machine. So, washing machine has got the interfaces which are to the outside world. So, they we see a set of buttons, but internally there are computations like when the drum is rotated for how many turns it will be rotated what will be the temperature and it will sense the water level and all that.

So, all those are dones by the done by the embedded system or when you are driving a car there are many processors we are which are controlling different operations starting from this steering fuel injection anti brake then then the this braking system this airbags then we have got power windows and all that. So, all of them are processors are there who are doing this computation, but from the users point of view.

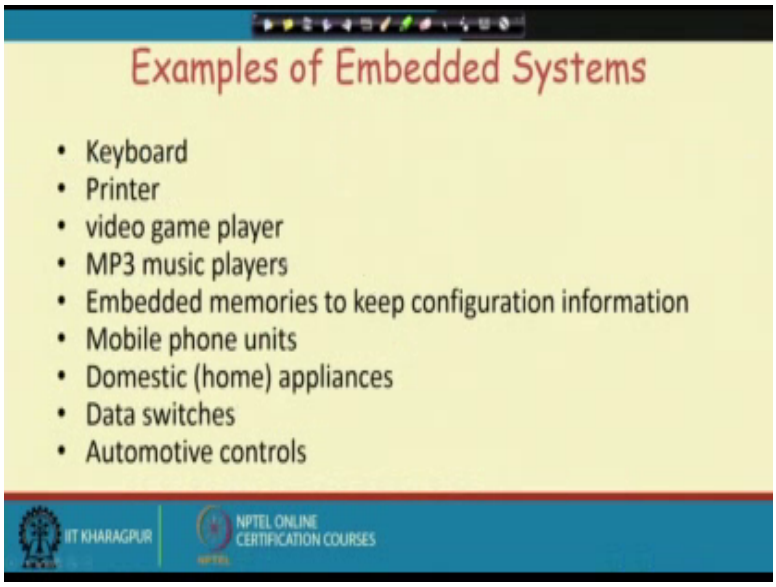
So, we do not see those processors. So, we just see the overall system. So, that these are the examples of embedded system. So, this processors they may not directly interact with the environment they may be interacting with the over the system into which it is put into. So, it is or it is a part of a bigger system. So, it may be interacting with the bigger system.

So, typical example is a car ignition control. So, that is. So, that as I have already said there are many such processors in the in the car in a car that we will be that will help in running and driving the car and it is control. So, an embedded product uses microprocessor or microcontroller to do 1 task on. So, the task is fixed like when you are driving a car. So, the operations that these processors need to do that is fixed. So, the on a car processor I will not try to say run a program which you will find the roots of a quadratic equation. So, we will not do that, but the processor is doing other things like this fuel injection steering control and all that. So, those are being done.

So, they are doing only 1 task at a time. So, if you are using microprocessor as I have said that the size of the system may become large. So, as a result we are doing some we are putting a microcontrollers and since we are doing only a single application or a only a small set of applications on a on a microcontroller based system or an embedded system. So, we know the programs that we need to execute.

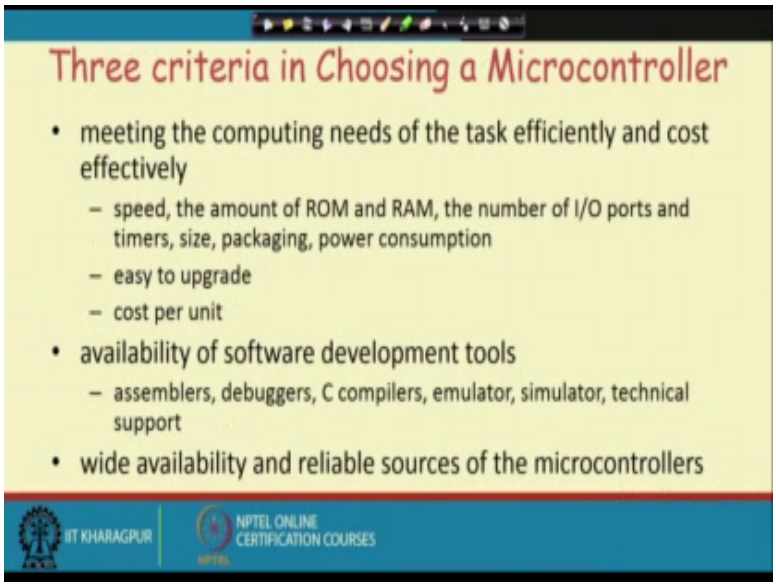
So, we can burn those programs to the ROM directly. So, unlike our general system where different users may come up with different programs so we need to load that programs on to RAM and from there we need to execute, but for an embedded application the programs are fixed. So, that. So, we can just lower we can burn those programs on to the ROM so that, this programs can though only those programs will be executed by the processor.

(Refer Slide Time: 15:18)



So, that is the point where this 8051 may be useful typical examples of embedded system like keyboard printer video game player MP 3 music players. So, embedded monitors, mobile phones, cameras so automotive control. So, all these are a different examples of embedded systems. So, they have got these processors built into it.

(Refer Slide Time: 15:38)



Now, how do you choose a micro controller as I have said that there are several micro controllers available in the market? In fact, 8 0 5 1 also there are variants. So, we have got 8 0 3 1 we have got 8 0 5 2 like that and their capacities are varying like 8 0 3 1 will not have any internal ROM 8 0 5 2 will have 1 more timer in it. So, that way the features will vary so which 1 to take.

So, for the criteria for choosing a micro controller is first of all the meeting the computing needs of the task efficiently and cost effectively. So, speed should match the amount of RAM the speed of the processor should match my requirement they because most of the time these embedded applications that we have. So, they are real time in nature. So, that the task has to be completed within some fixed amount of time. So, if the processor is slow so, will not be able to complete the task within the reasonable amount of time. So, the speed of the processor is 1 parameter then the amount of ROM and RAM that we have in the system if the ROM is small and my application have program size is large then I need to connect external memory to the chip that way the footprint will go up ok.

So, we can have if we take if we go for a higher family of microcontroller then possibly my program will fit into the ROM that is available there and will be able to compare hold that task within the microcontroller itself, and the RAM also like how much of data that

we need to store the basically the temporary data that we have so how much of those temporary data that we need to store.

For example, 8 0 5 1 it has got only 128 bytes of RAM internal RAM. So, if you need more RAM space then you have to connect external RAM chip. So, how is it? So, are you going to do that? So, if we find that going to the next higher family. So, I can manage the RAM space the variables then possibly that is fine.

Number of IO ports like we can have 8 0 5 1 it has got 3 2 IO bits 4 IO ports and. So, if that is sufficient then it is if it is not we have to go for the higher 1 the timers number of timers that we have. So, each timer may be dedicated for controlling 1 operation. So, if you need precise timing for say more than 2 operations then possibly and they are parallel parallely. So, then possibly we cannot go for 8 0 5 1 in size of the system it is packaging it is power consumption. So, they all will contribute to the choice of the microcontroller.

Second important thing is the up gradation. So, today we are using some microcontroller. So, tomorrow we can we can we go to the next higher microcontroller in my system as a result the system performance will be enhanced and, but at the same time I do not want to change the hardware that we have too much. So, the pin configuration and this thing the software compatibility so, they should be there. So, they it should be easy to upgrade and the cost per unit. So, when you are when you are built a system based on a microcontroller then every unit that you sell the microcontroller price will come into picture.

So, if the cost per unit is not low then the cost of the system who may get dominated by the cost of the microcontroller. So, that way we have to be careful. Second important thing that we have is the availability of software development tools now as some time back I have said that that so many microprocessors and microcontrollers that you possibly cannot learn about the assembly language programming of all those all those processors.

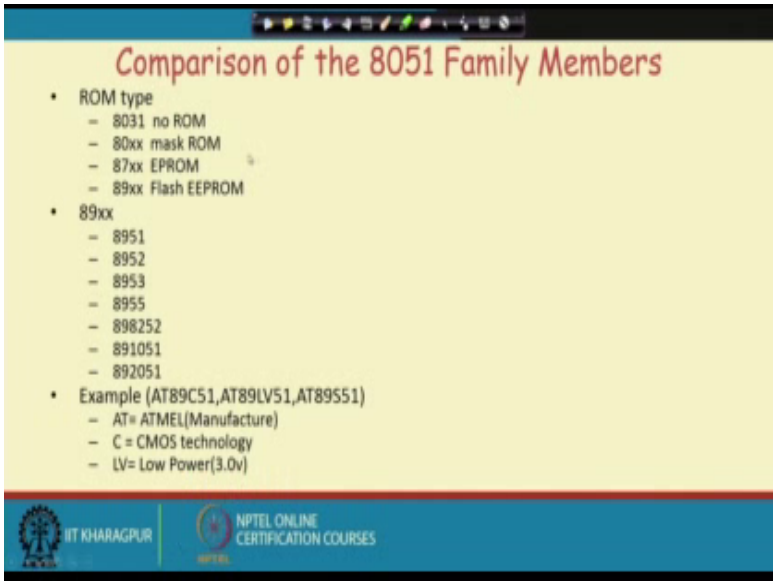
So, it is desirable that we can write our program our control program in some high level language like say C and then the compiler should be there which will translate this C code into the machine code of the processor.

So, these assemblers debuggers compilers emulators simulator technical supports all these should be available for the microcontroller that we take wide availability it should be widely available and this reliable sources for the microcontroller. So, you should have the these easily easy availability you can say and it is available in large amounts. So, these are the criteria that will guide us to choose the microcontroller. So, as you can see that some of these decisions are based on the electronics that we have like this speed amount of ROM RAM etcetera, but many of them are economic also like say availability of availability and you have reliable resource sources and all that.

So, they are not there and similarly that development platform. So, they do not that is not again the part of the basic hardware. So, they are the additional things that are done by the vendor to promote the product so that the developers can use those platforms to develop product on or develop applications on that product.

So, that way you see that many decisions are not done it is only based on the quality of the processor, but the quality of other things as well.

(Refer Slide Time: 20:59)

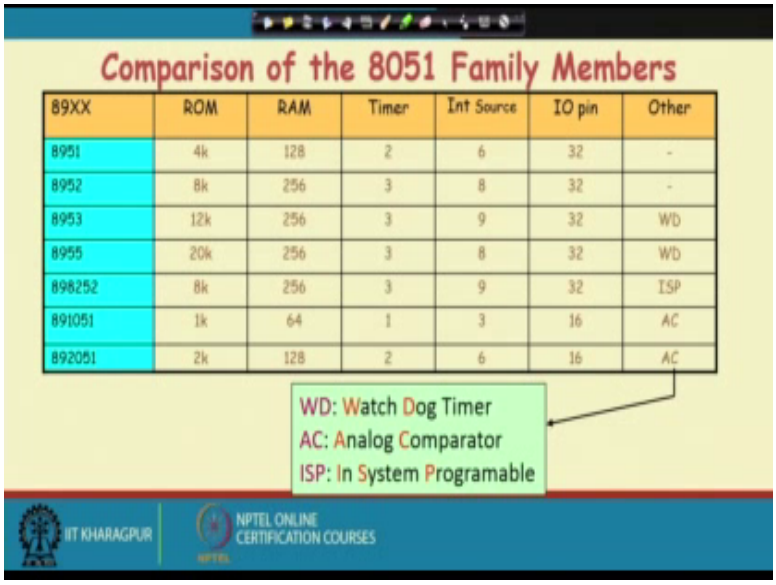


If you look into this 8 0 5 1 family then this this ROM type so 8 0 3 1 it does not have any ROM 8 0 5 1 8 0 5 2 then 8 7 5 1 8 7 5 2 it is a 8 8 0 5 1 they have got mask ROM 8 0 8 7 5 1 they have got EPROM. So, they are electrically programmable ROM and. So, and then we have got flash EEPROM in 8 9 series. So, 8 9 series has got. So, many

processors and they had got they have got e EEPROM electrically erasable programmable read only memory.

So, you have. So, these are some of the examples that you see. So, these first 2 words this. So, they will tell the manufacturer the A T stands for ATMEL C is stands for the technologies the CMOS technology and LV is the low power version. So, the supply voltage is low 0.3 0 volt whereas, the normal processor the supply voltage will be 5 volt. So, this way there are many vendors of this 8 0 5 1 series of processors and accordingly you can find out the you can you can see the series number there.

(Refer Slide Time: 22:08)



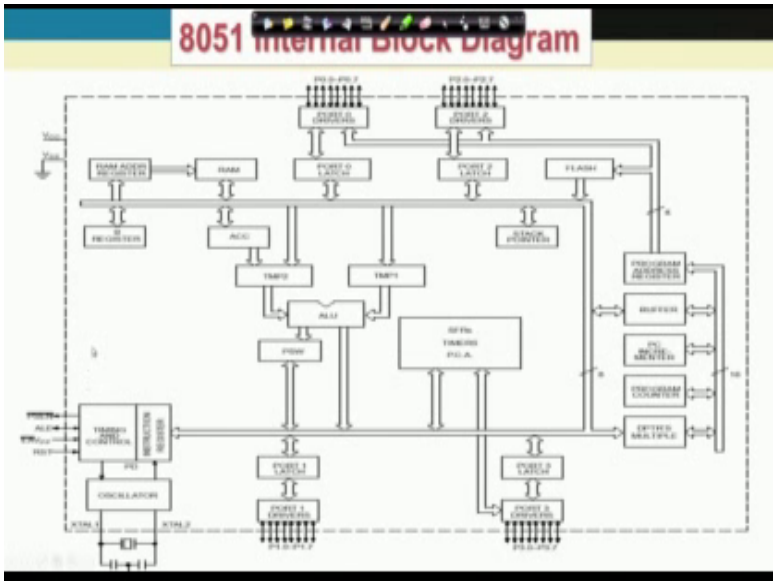
So, if you try to compare across these family members. So, this we are just comparing the 8 9 series. So, 8951 which is basically the 8051 only so it is 4 kilobyte of RAM ROM 128 bytes of RAM 2 timers 6 interrupt sources and 3 2 IO pins. 8952 or 8052 it has got 8 kilobytes of ROM 256 bytes of RAM. So, you see the ROM and RAM have been doubled then timer is also 1 more interrupts sources are also 2 more IO pin remains same.

8953 so they are the ROM size is increasing further. So, you see that we have got many choices. So, we have got many choices. So, based on the application that we have we can have we can go for additional the higher family of processor and this 1 this a 8 9 1 0 5 1 and 8 9 2 0 5 1. So, they have got some additional things like watchdog timer. So, they

are useful when you have when you have got some deadlines for tasks and you want to detect whether the task has missed it is deadline or not.

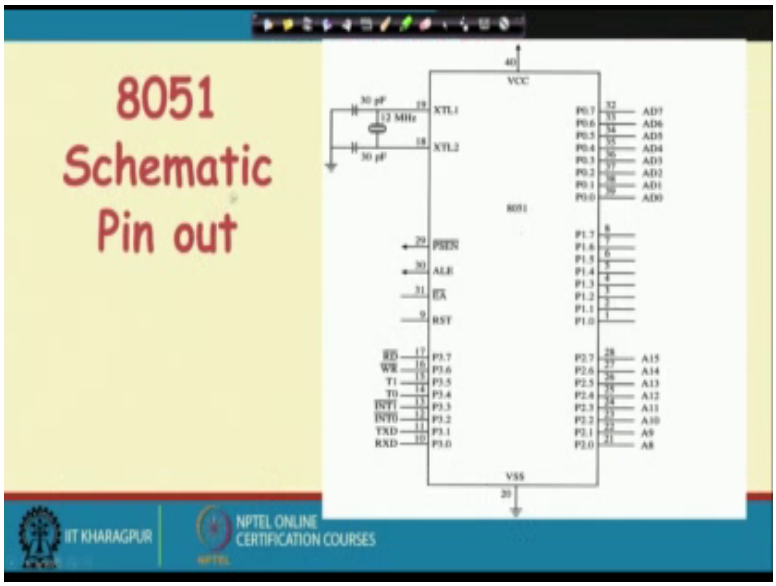
So, for those type of applications. So, we need these watchdog timers. So, then the analog comparator so analog voltage comparator then the in system programmable that is when the system is operating so can you change the program. So, those series so the ACS have marked as ACS. So, they have got these features. So, naturally the beta processors we have got better flexibly facilities, but the cost of the system will also go up.

(Refer Slide Time: 23:45)



So, this is the overall diagram that we have. So, we will explain it by parts.

(Refer Slide Time: 23:53)



So, in the schematic; so this is a better view of the processor. So, you can see that we have I said that there are 4 ports. So, this is P 0 pone P 2 and P 3. So, these are the 4 ports that we have and they are all 8 bit ports then we have got this RST which is the reset then there is e a bar external axis. So, they are actually this RST and E A bar. So, they are coming to the chip. So, their input to the chip it is not shown here explicitly

So, this E A bar. So, if this line is made 0; that means, the system designer wants that the 8 0 5 should use the code space from the external memory it should take the code from the external memory external ROM and for normal operation we should said this said this E A bar P into 1. So, if this pin is made high then the 8 0 5 1 when it is accessing code it will be using the internal RAM internal ROM and we have got this. So, many of these pins so they are multiplexed like you see that this P 0 the port 0 the these pins at pin number 3 2 to 3 9. So, they act as the port pin as well as the multiplexed address data bus 80 through 87.

So, here also like 8 0 8 5 the bus is multiplexed. So, you have got this lower order address bus and data bus multiplexed 80 to 8 7. Then if you look into port 2 here also you see that the it is the pins they are multifunctional pin and if they can they will act as IO pin as well as the higher order address bus. So, if you are connecting some external memory then this 8. So, these all these pins 21 to 28 and 20 20 32 to 39, they will be used by the external data bus external address and data bus.

So, you cannot use those ports for IO device after IO operation. Similarly if you look into this port 3 you will find that these pins are also multiplexed that is pin number 3 the pin number 17 it is it acts as the bit 7 of port P 3 as well as the read bar signal. So, when if you are connecting external memory then this read bar write bar lines are required and then you cannot use this port 3 as the port for accessing as port bits ok.

So, all these are there similarly this 3.0 is used for receive data and 3.1 is used for transmit data. So, these are for serial communication like we have got S id and S OD in case of 885. So, here we have got T X D and R X D then these are the 2 interrupts that we have from outside int 0 and int 1, then this T 0 and T 1. So, they are for the counter operation of the timers and then this ale is same as that we have in 8085 and PSEN bar. So, this is for the external memory access the you can give the you can you can connect to the read bar pin of the ROM then we have got the crystals.