Embedded Systems

UNIT-II (1)

Characteristics of an Embedded System:

ES possess certain specific characteristics and these characteristics are unique to each ES. Some of the important characteristics of an ES are:

1. Application & Domain Specific
2. Reactive ~~and~~ Real time
3. Operates in harsh environment
4. Distributed
5. Small size & weight
6. Power concerns

Application & Domain specific: ES are meant to perform a specific operations only, and they are developed in such a manner to do the intended functions only. They can't be used for any other purpose. We cannot replace the embedded control unit of microwave oven ~~with~~ airconditioner

Reactive and Real time: ES are in constant interaction with the Realworld through sensors and user-defined input devices which are connected to the input port of the system. Any changes happening in the realworld are captured by the sensors or input devices in Real-Time and the control alogrithms running inside the unit reacts in a designed manner to bring the controlled output variables to the desired level.

Embedded systems produce changes in output in response to the changes in the input. Hence they are generally referred as Reactive Systems.

Real time system operation means the timing behaviour of the system should be deterministic; meaning the system should respond to requests or tasks in a known amount of time. ES, such as - systems which are safety critical, like flight control systems, Antilock Brake Systems (ABS) are Real Time systems.

Operates in Harsh Environment:

It is not necessary that all ES should be deployed in controlled environment. The environment in which ES deployed may be a dusty one or a high temperature zone or an area subject to vibrations and shock. Systems placed in such areas should be capable to withstand all these adverse operating conditions. The design should take care of the operating conditions of the area where the system is going to implement.

If the system needs to be deployed in a high temperature zone, then all components used in the system should be of high temperature grade.

Distributed:

ES may be the part of large system. Many no. of such distributed ES form a single large embedded control unit.

Ex: ATM – contains a cardReader embedded unit responsible for reading and validating the user's ATM card, transaction unit for performing transactions, a currency counter for dispatching/vending currency to the authorised person and a printer unit for printing transaction details. We can visualise these as independent ES. But they work together to achieve the common goal.

Small size and weight:

Product look and feel is an important factor in choosing a product. Definitely the product - having - good - looks [size, weight, shape, style, etc] will be one of the deciding factors to choose a product.

Power concerns:

Power management is another important factor that needs to be considered in designing ES. ES should be designed in such a way as to minimize the heat dissipation by the system. The production of high amount of heat demands cooling requirements like cooling fans which in turn occupies additional space and make the system bulky. Also power management is a critical constraints in battery operated application. The more the power consumption the less is the battery life.

Quality Attributes of ES:

These are the non-functional requirements, that need to be documented properly in any system design. If the quality attributes are more concrete and measurable it will give a positive impact on the system development process and the end product. These may be

* Operational Quality Attributes
* Non-Operational Quality Attributes

Operational Quality Attributes:

The operational quality attributes represent the relevant quality attributes related to the ES when it is in the operational mode or 'online' mode. The important quality attributes coming under this category are listed below:

1. Response
2. Throughput
3. Reliability
4. Maintainability
5. Security
6. Safety

Response Time: Response is the measure of the quickness of the system. Most of the ES demands fast response which should be almost real time. The response time is critical in case Hard-Real-Time systems.

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Throughput: This deals with the efficiency of a system. It can be defined as the rate of production or operation of a defined process over a stated period of time. The rates can be expressed in terms of units of productions, batches produced, or any other meaningful measurements. This is generally measured in terms of 'Benchmark'.

Reliability: Reliability is a measure of how much % you can rely upon the proper functioning of the system or what is the % susceptibility of the system to failures.

Mean Time Between Failure (MTBF) & Mean Time To Repair (MTTR) are the terms used in defining system reliability.

MTBF - gives the frequency of failures in hours/ weeks/ months.

MTTR - specifies how long the system is allowed to be out of order following a failure.

Maintainability: This deals with support and maintenance to the end user or client in case of technical issues & product failures or on the basis of a routine system checkup. Reliability & maintainability are two complementary disciplines.

As the reliability of the system increases the chances of failure and non-functioning also reduces, thereby the need for maintainability, is also reduced. Maintainability is closely related to the system availability. Maintainability can be classified into

* Scheduled or periodic Maintenance [Preventive Maintenance]

* Maintenance to unexpected failures [Corrective Maintenance].

Security: Confidentiality, Integrity, and availability are the three major measures of the information security.

Confidentiality: Deals with the protection of data and application from unauthorized disclosure.

Integrity: Deals with protection of data and application from unauthorised modification.

Availability: Deals with protection of the data and application from unauthorized users.

Safety: This deals with the possible damage that can happen to the operators, public and the environment due to the breakdown of ES or due to the emission of radioactive or hazardous materials from the Embedded products. The break down of an ES may occur due to h/w failure or firmware failure.

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Non-operational quality attributes:

The quality attributes that needs to be addressed for the product 'not' on the basis of operational aspects are grouped under this category. The important quality attributes listed under this are

1. Testability & Debug-ability
2. Evolvability
3. Portability
4. Time to prototype and market
5. Per unit and total cost.

Testability & Debug-ability: Testability deals with how easily one can test his/her design application and by which means she can test it. In case ES testability is applicable to both the embedded h/w and firmware. Embedded h/w testing ensure that the peripherals and the total hardware functions in the desired manner, whereas firmware testing ensures that the firmware is functioning in the expected way.

Debug-ability is means of debugging the product as such for figuring out the probable sources that create unexpected behaviour in the total system. Debug-ability has two aspects in the ES development context, namely, h/w level debugging and firmware level debugging.

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Evolvability: Evolvability is a term which is closely related to Biology. For embedded product ~~'Evolvability' refers to the~~ ease with which the embedded product can be modified to take the advantage of new firmware or hardware technologies.

Portability: Portability is a measure of 'system independence'. An embedded product is said to be portable if the product is capable of functioning 'as such' in various environment, target processors/ controllers and embedded operating systems. A standard embedded product should always be flexible and portable.

Time - to - prototype and Market: Time-to-market is the time elapsed b/w the conceptualisation of a product and the time at which the product is ready for selling or use. The commercial embedded product market is highly competitive and time to market the product is a critical factor in the success of a commercial embedded product.

Per unit Cost and Revenue: Cost is a factor which is closely monitored by both end user and product manufacturer. Cost is a highly sensitive factor for commercial product.

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Application and Domain - specific - ES

* Washing machine
* Automotive - Embedded Systems.

Factors to be considered in selecting a Controller:

The important factors to be considered in the selection process of microcontroller are listed below

* Features set
* Speed of operation
* Code Memory Space
* Data Memory Space
* Development support
* Availability
* Power consumption
* Cost

Features set: One of the key requirement in selecting the processor is the features set of the processor. Like does the µC supports all the peripherals required by the application, - serial interface, parallel interface etc. Does it satisfy the general I/O port requirements by the application? Does µC supports sufficient no.of timers and counters? Does the µC supports builtin ADC/DAC hardware in case of signal process -ing applications?. Does the µC provides the required performance?

Speed of Operation: Speed of operation or performance of controller is another important design factor. The no. of clocks required per instruction cycle and the maximum operating clock frequency supported by the processor greatly affects the speed of operation of the controller. is usually expressed in terms of million instructions per second (MIPS).

Code memory Space: As the µC supports sufficient space to hold code memory. [ROM]

Data Memory Space: As the µC supports sufficient space for internal data memory. [RAM].

Development Support: Development support is another important factor for consideration. It deals with - does the µC manufacture provide cost-effective development tools? Does the manufacture provide product samples. For prototyping and sample development stuff to alleviate the development pains. Does the controller support third party development tools?

Availability: Availability is another important factor that should be taken into account for the selection process. Since the product is entirely dependent on the controller, the product development time and time to market the product.

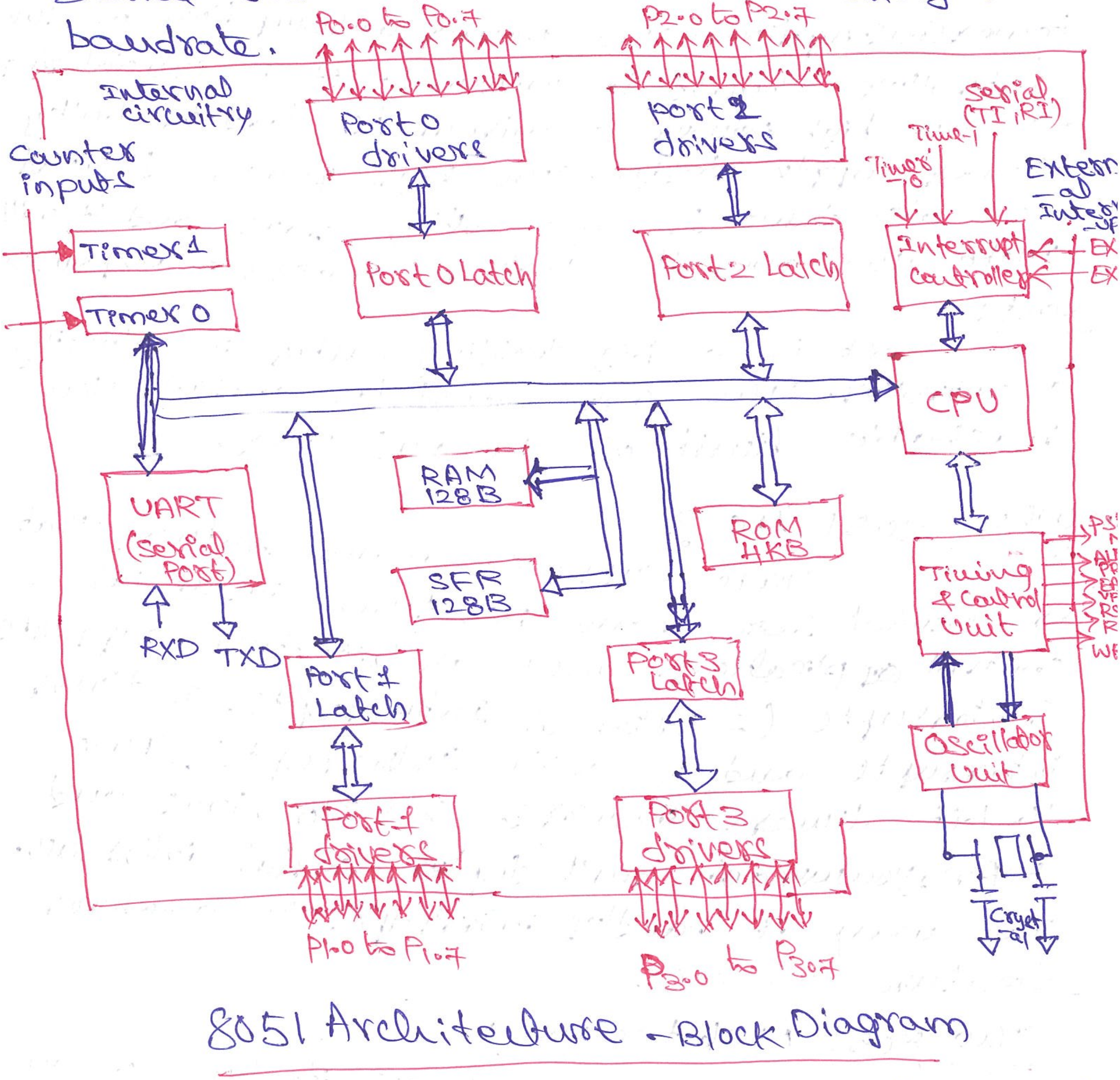
Power Consumption: The power consumption of the controller should be minimal. It is crucial fact-r since high power requirements lead to bulky power supply design. The high power dissipati-on also demands for cooling fans and it will make the overall system messy & expensive.

Cost:
Cost is a big deciding factor in selecting a controller. The cost should be within the reachable limit of the end users.

✓ **Why 8051 μC?**
This supports many features that are useful for many real time industrial control applications. 8051 architecture supports 6 interrupts (2 External Interrupts, 2 timer interrupts and 2 serial Interrupts). Two 16-bit timers/counters, 32 I/O lines and a programmable full duplex serial interface. The way it handles interrupts is another feature of 8051.

The 8051 Architecture:
The basic 8051 architecture of an 8 bit CPU with Boolean processing capability, Oscillator driver unit, 4K bytes of on-chip program memory, 128 bytes of internal data memory, 128 bytes of special function memory, 128 bytes of special function register memory area, 32-general purpose I/O lines organised into four 8 bit bidirecti-onal ports, two 16 bit timer units and

a full duplex programmable UART for serial data transmission with configurable baudrate.

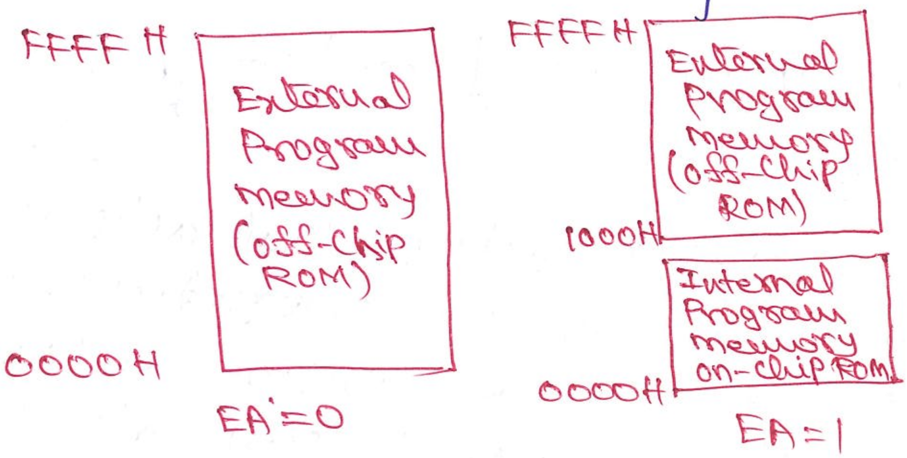


8051 Architecture - Block Diagram

The Memory Organization: 8051 is built around Harvard processor architecture. The program & data memory of 8051 is logically separated and they physically reside separately. Separate address spaces are assigned to both. The address bus is 16-bit wide and it can address up to 64KB (2^{16}) memory.

The program Memory: The basic 8051 architecture provi-des lowest 4K bytes of on chip memory. There could be external program memory which is accomplished by changing the logic level of the pin External Access (EA). When EA = 0 external program memory access and EA = 1 Internal program memory access. The control signal for external program memory execution is PSEN (Program Strobe Enable).

If the program memory is external, 16 I/O lines are used for accessing the external memory. Port 0 and Port 2 are used for exter-nal memory accessing.



Data Memory: The basic 8051 architecture supports 128 bytes of internal data memory and 128 bytes of special Function Register memory. SFR memory is not available for the user for general data memory applications. The address range for inter-nal user data memory is 00H to 7FH. The SFR are residing at memory area 80H to FFH. 8051 Supports interface for 64K bytes of external data memory. The control signals used for external data memory access are RD and WR and 16-bit register holding the address of external data memory address to be accessed is Data Pointer (DPTR).

Registers:

Registers of 8051 can be broadly classified into CPU Registers and Scratchpad Registe-rs.

CPU Registers: Accumulator, B register, Program Coun-ter (PC), Program Status Word (PSW), Stack Pointer (SP), Data Pointer (DPTR — DPL and DPH) consti-tute the CPU registers.

Accumulator: It is the most important CPU register which acts as the heart of all CPU related arithmetic operations. AC is an implicit operand in most of the arithmetic operations. This is bit addressable register.

ACC7	ACC6	ACC5	ACC4	ACC3	ACC2	ACC1	ACC0

← 8 - bits →

B Register: It is a CPU register that acts as an operand in multiply and division operations. It also stores the remainder in division and MSB in multiplication instructions. B can also be used as a general purpose register for programming. [SFR - F0H]

Program Status Word: PSW [SFR - D0H]

It is an 8-bit, bit addressable SFR signalling the status of accumulator related operations and register bank selector for scratch pad registers R_0 to R_7. The bit details of PSW register is

PSW.7	PSW.6	PSW.5	PSW.4	PSW.3	PSW.2	PSW.1	PSW.0
CY	AC	F0	RS1	RS0	OV	General Flag	P
carry	Auxiliary Carry	Flag	Register bank		overflow		Parity

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Data Pointer (DPTR) [DPL: SFR-82H, DPH: SFR-83H]
It is a combination of two 8-bit registers DPL & DPH. DPTR holds 16-bit address of the external memory to be read or written in the external data memory operations. These even act of general purpose registers for application programming.

Program Counter: It is a 16-bit register holding the address of the code memory to be fetched. It is an internal part of the CPU and it is hidden from the programmer.

Stack Pointer: [SFR-81H] It is an 8-bit register holding the current address of stack memory. Stack memory stores the program counter address, other memory and register values during a subroutine/function call. It is the responsibility of the programmer to assign sufficient stack memory by entering the starting address of stack into SP.

✓ **Scratchpad Registers (R0 to R7):** These are located in the lower 32-bytes of internal RAM. It can be on one of the four banks, which is selected by the register selector bits RS0 and RS1 of the PSW register. By default RS0 and RS1 are 0 and the default bank selected is bank 0. The register names and their memory address corresponding to bank 0 are given as

R7	R6	R5	R4	R3	R2	R1	R0
07H	06H	05H	04H	03H	02H	01H	00H

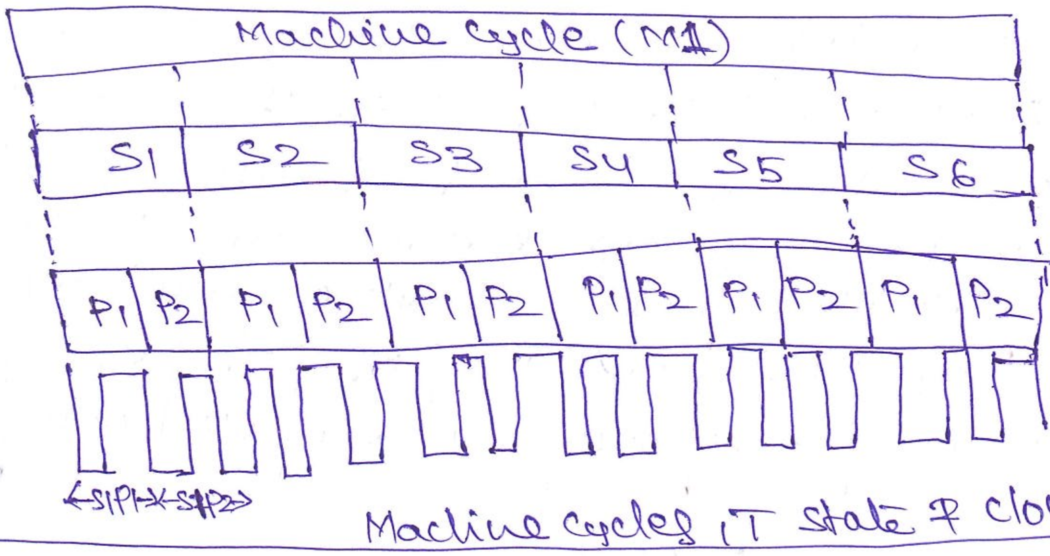
Registers R0 and R1 are used as general purpose working registers. R0 and R1 also handle the role of index addressing or indirect addressing register. These can also be used for external memory access in place of DPTR.

Oscillator Unit: The program execution is dependent on the clock and the oscillator unit is responsible for generating the clock signals. All 8051 family μC contain an on-chip oscillator. This contains all necessary oscillator driving circuits. The 8051 on chip oscillator circuit provides external interface option through two pins of μC, namely XTAL1 and XTAL2.

The execution speed of the processor is directly proportional to the oscillator clock frequency.

Each machine cycle is made up of a sequence of states called T states. The original 8051 μp machine cycle consists of 6T states and is named S1, S2, S3 ... S6. Each T states in turn consist of two oscillator periods (clock cycles) and so one machine cycle contains 12 clock cycles.

If the system clock frequency is 12MHz, it takes 1 μs time to execute one machine cycle.



Machine cycles, T state & clock periods

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Port: Port is a group of Input/Output (I/O) lines. Each port has its own port control unit, port driver and buffers. The original version of 8051 supports 32 I/O lines grouped into 4 I/O ports consisting of 8 I/O lines per port. The ports are named as port 0, port 1, port 2 and port 3. One o/p driver and one input buffer is associated with each I/O line. All ~~fours~~ ports are bi-directional and an 8 bit latch is associated with each port.

Port 0: It is a bi-directional port, which is used as multiplexed address/data bus in external data memory/program operations. Port 0 SFR(P0) (SFR-80H). which is used as a general purpose I/O port.

Port 1: SFR(P1) [SFR-90H] It is also a bit addressable Special Function Register that acts as the bit latch for ~~the~~ each pin of Port 1.

BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
P1.7	P1.6	P1.5	P1.4	P1.3	P1.2	P1.1	P1.0

Port 2: It is designed to operate in two different modes. It acts as a general purpose I/O port in normal operational mode and acts as higher order address bus in external data memory/Program memory operations. It is a bit addressable Special Function Register that acts as the bit latch ~~for~~ for each pin of Port-2

BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0
P2.7	P2.6	P2.5	P2.4	P2.3	P2.2	P2.1	P2.0

Port 3: It is a general purpose I/O port which is also configurable for implementing alternative functions. This is also bit addressable special function Register that acts as the bit latch for each pin of port 3. SFR P3 [SFR-B0H]

BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0
P3.7	P3.6	P3.5	P3.4	P3.3	P3.2	P3.1	P3.0

✓ Source current & Sink current for 8051 Ports

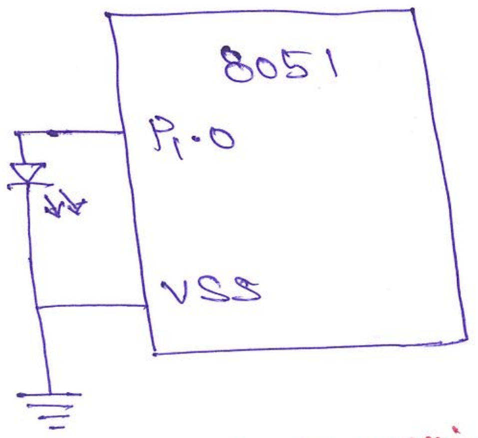
Source current: The term source current refers to how much current the 8051 port pin can supply to drive an externally connected device. The device can be an LED, a buzzer or a TTL logic device. For TTL family of 8051 devices the source current is defined in terms of TTL logic. TTL logic has two logic levels namely logic 1 (High) and logic 0 (Low). The voltage levels are

Logic Level	Input signal level		o/p signal level		Vcc
	min	max	min	max	
Low	0V	0.8V	0V	0.5V	5V
High	2V	5V	2.7V	5V	5V

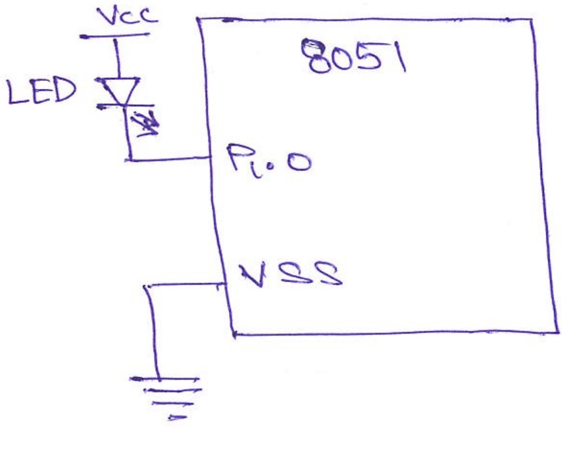
The maximum current that a port pin can source is 60 μA.

Sink current: It refers to the maximum current that the 8051 port pin can absorb through a device which is connected to an external supply. The device can be an LED, a buzzer or a TTL logic device. Pins of ports P_1, P_2, and P_3 can sink a maximum current of 1.6 mA. Port 0 pins can sink currents upto 3.2 mA.

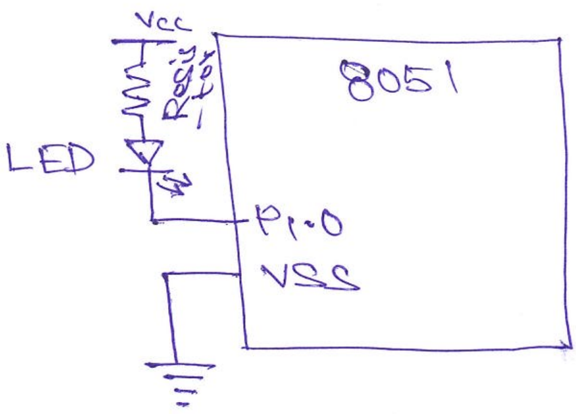
Max sink current per port pin = 10 mA, Max sink current per 8-bit port for port0 = 26 mA, max sink current per 8-bit port for port 1, 2, & 3 = 15 mA, Max total sink current for source all output pin = 71 mA.



Current sourcing



Current sinking



Ideal pin Interface for 8051