PREPAID POWER CARD FOR EB USING EMBEDDED TECHNOLOGY

PROJECT REPORT P-1140

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DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
KUMARAGURU COLLEGE OF TECHNOLOGY
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CERTIFICATE

This is to certify that the project report entitled

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Is the bonafide work done by

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SYNOPSIS

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"Prepaid power card "aims at modifying the existing energy monitoring and billing mechanism. The core motive is to automate the entire system by supplementing a micro controller to the energy meter there by minimizing the modification required and hence increasing the practical viability of the entire project .The reason behind the work done was to propose a scheme that would appear lucrative to all strata of society.

The currently existing method for monitoring the electricity consumption involves a lengthy process of assigning a person with the duty of noting the consumption reading on the meter and submitting the same to the billing department. The bill is generated accordingly. The consumer goes to the electricity board's office and stands in lengthy queues in order to pay the bill.

The cumbersome process is avoided by using a prepaid card that may be equally beneficial to the Government .The current process has a drawback where in there is a danger of delay in payments. Our system of prepayment would mean elimination of these payment arrears.

This system has provision for a secondary card so as to avoid total power failure when the balance in one of the cards goes to zero. When electric energy purchased by user is used up, and exceeds permitted overdraft amount the meter will cut off power supply automatically until user inserts the prepaid card newly charged. It also has the added advantage of alarming the consumer when the balance reaches a threshold value so that he will have sufficient time for replacement.

A current theft indicator is provided, in which When load exceeds the limit specified by power supplier the meter will give alarm to warn user to reduce load. Meter will release alarm if user reduces the load, else it will cut off power supply. A password protection is provided to avoid any misuse of the card.

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CONTENTS

INTRODUCTION

1. INTRODUCTION

1.1 CURRENT STATUS OF THE PROBLEM TAKEN UP

"Necessity is the mother of invention" goes a famous saying and the necessity to surge ahead in life gave rise to the invention of power. Electricity is a major driving force especially in a country like India because agriculture and power have worked in tandem to help us reach where we are today. Electricity will remain to be of relevance if we are to realize vision 2020.

The existing system for the metering of electricity bills poses certain inconveniences to the end user. In the existing system the electricity board deputes officials to manually note the meter reading. This process not only involves a huge labour force but also the cumbersome process of door-to-door monitoring. In India the payment dues are accepted only on weekdays during working hours .The consumer thus has to take time off his busy schedule and personally make payments at the electricity office.

Wastage of power is that inevitable in large industries. This is because the existing system provides no check on the consumption and therefore there is a tendency to be careless. If there were a system that allotted a fixed ration of power for a period then the workers would be more careful thereby minimizing the electricity loss.

In India a scheme for temporary connection was introduced in the year 1984 under the name of "*Tatkal scheme*". Though this scheme was initially a success it failed to meet its ultimate goal.

Taking into consideration the need to further simplify the existing system, we decided to take up a project that would simplify the entire process of electricity bill payment. Since it is not possible to change the entire system, we adopted a means to alter the existing system with simple modifications. Once implemented this project would save expenses of the EB department, which are otherwise unavoidable.

The field of embedded engineering has made inroads into almost all walks of life. Today we find embedded systems in washing machine, microwave ovens, and other such home appliances. Our project aims at bridging the past and the future .By using micro controllers we aim to change the system that has been in existence for the past 50 years to a completely automated system with minimum human interaction involved.

1.2 RELEVANCE AND IMPORTANCE OF THE PROJECT:

In the previous section we discussed the various problems in the prevailing system. In this section let us see how our project would help tackling each of those problems.

In a completely automated system there is minimal human interaction as a result of which the EB department can cut down on the expenditure incurred in the form of salary. The user can plan his electricity budget before hand.

In big industries wastage of power is inevitable. If we split the distribution of energy department wise and allot a fixed quota to each then the wastage of power would be minimal. This exactly what our project would provide .In the event of a strike or stoppage of work the simple removal of the prepaid card would result in complete power shut down, there by eliminating any possibility of power wastage.

The simplicity of the entire project makes it all the more practically viable because it does not involve any major alteration to the existing system. A single sensor interfaced to the existing meter and a micro controller is enough to automate the entire system.

This project also has the additional facility of warning the user before the card drains out completely. The project also has a LCD display to make it convenient for the user to know his current status. A password protection is provided to avoid any misuse of the card. A load driving circuit has been included in which, When the charge goes down below a certain value, high power consuming and less priority appliances will get tripped off. The buzzer will be activated; this acts as an indication to the user. A theft indicator is included so as to identify any current theft.

We have simulated the entire system with a desktop model using a commercially available meter and the working of the various components involved are discussed in the subsequent chapters.

LITERATURE SURVEY

2. LITERATURE SURVEY

In a recent survey that was conducted by ICAR, 68% of the co-operative societies preferred a change in the existing system of power connection. The major area of complaint was the lack of proximity between the rural user and the EB office. This meant that in order to pay his monthly bills he had to make visits to the far off EB office.

On a trial basis the Japanese government implemented a new scheme in July 1998.Their work involved a case study in a village on the island of Kyoto. Kyoto has a large percentage of agriculturists whose lives greatly benefited from this project. The over whelming response obtained from the natives of Kyoto has prompted the Japanese government to implement the same on a larger scale. The implementation of this project is still in the pipeline because of the fear of piracy of the pre paid cards. Another problem is the reprogramming/replacement of the micro controller involved. The following has been taken care of by sealing the equipment with a hologram which when meddled with will result in prosecution. The menace of piracy has been settled by using the power cable to set up a network with the EB office so as to prove the authenticity of the card. The huge investment involved in creating a wired network has been nullified by using the power cable for data transmission.

The reason to pursue this project was simple. If this project was such a huge success in the small island of Kyoto, there is no reason why it would fail in an agriculture dependent nation like India. The Indian Government would most definitely face the same threats that the Japanese government faced, if implemented. But then again, the same solutions could be adopted.

PROPOSED APPROACH TO THE PROBLEM

3. PROPOSED APPROACH TO THE PROBLEM

The right approach towards a problem is very important. An egregious approach could prove to be drastic and can cause a large number of inconveniences. Taking this into account a large number of approaches were thought of for solving the problem considering factors such as complexity, cost effectiveness and so on.

The present day electricity metering is done manually with the help of energy Meter. Changes in this would cause a large number of overheads. So in our approach we have decided to supplement it with other components. The sensor senses the rotations of the disc in the energy meter and the pulsed output is given to the microcontroller. Every time a pulse is obtained, the microcontroller takes the value stored in the EEPROM that is currently in use and decrements it by one. This denotes the Consumption of a unit (kilowatt) and this system of metering has been done for simulation purposes.

Here we have decided to use 2 cards (EEPROM). The reason being, once the value Of the EEPROM becomes zero, the total power supply will be cut off. This would be very inconvenient and not practical for the user. So here we have given a provision where we make use of 2 EEPROMs. Once the value in one card goes to zero, control is transferred and the value of the second card is verified. If the values in both the cards are zero total Power supply is cut off. As a precaution we have made use of a buzzer, which gets activated once the value in the card goes below a threshold value, to intimate the user that it is a time to replace the card. A password protection for the card has been provided to avoid any misuse of the card.

A load driving circuit has been included for load division purpose. The equipments in the consumer's premises are divided into three groups, such as high power consuming, low priority and very essential equipments. These are connected to three different relays. When the charge value of the card reaches a particular threshold limit these relays will get activated one-by-one and the corresponding equipments will get tripped off in a sequential manner. Every time the buzzer gets activated; this acts as an indication to the user. A current theft indicator is provided, in which When load exceeds the limit specified by power supplier the meter will give alarm to warn user to reduce load. Meter will release alarm if user reduces the load, else it will cut off power supply.

On commercial implementation, a slight modification to the logic would be required; wherein the completion of a rotation causes the increment of a counter, which is checked against another value. For ex: if 200 rotations of the disc indicate the consumption of 1 kilowatt, then each time the disk completes a rotations a counter value is incremented and this value is checked with the value 200.If both these values are equal then one unit is decremented from the EEPROM. This decremented value is now written back onto the EEPROM. The count that is maintained in the EEPROM is explicitly made to zero. This process is repeated till the value in the cards run dry. The balance that is read from the EEPROM is regularly updated on the LCD screen. The display on the LCD tells us about the card Number that is currently in use and the balance on that card in terms of units.

A relay circuit has been designed to cut off power supply in the event of the cards running dry. The entire project has been shown on a single board but for Practical purposes the relay circuit will be a part of the electricity post from which energy is distributed to the consumer. This is done to avoid power theft. This project could be propped with a few encryption algorithms and anti-piracy Strategies that have been discussed in the subsequent chapters.

The design has been done bearing two factors in mind

- The cost efficiency and
- Simplicity.

This means that while the project will be cost efficient it will also not involve any major alterations to the existing system thereby increasing the overall viability of the project.

DETAILS OF THE DESIGN

4. DETAILS OF THE DESIGN:

The project was divided into four main modules and each module was integrated finally to get the desired output. Each module was decided based on the research and the study required. The modules were designed such that finally all that was required was a "plug and play" format. At each stage we saw that the tiniest of components were studied and their working completely understood. These modules are discussed in this section and the final integration is also discussed in brief.

4.1 MODULE 1

Identification Of The Components:

The first phase comprised of identifying the various components required for Project. The field of Electronics has a lot of competition and keeping in mind the economic Viability in a country like India, we had to choose the components with utmost care. After a lot of research the following components were chosen.

4.1.1 Microcontroller:

This is the heart of our project. A microcontroller is an Integration of a microprocessor, ROM, and RAM. It also has I/O ports, all in one chip. There were two controllers that we had to choose from. These were products of Atmel and Pic who are renowned the world over for their electronic products. Pic is a RISC processor with 13 I/O pins and is priced higher than Atmel.The Atmel controller, which we have chosen, is a 40-pin CISC processor. It has 32 I/O pins through 4 ports of 8 each. The most important Feature is that in an Atmel microcontroller each port has the bit set-reset facility that enables us to have 32 independent port lines. The Atmel microcontroller has several other features like Power down mode and 3-level memory lock that would be useful in enhancing the security of the final product.

The microcontroller we have used in the main unit is 89C51 by Atmel.The features of the microcontroller are

- 40 pin controller

- 4 I/O ports of 8 pins each
- 4K bytes of flash memory
- 128 byte internal RAM
- Two 16 bit timers
- The clock speed can reach up to 24MHz.

We have also used another Atmel microcontroller 89C2051 in the card-charging unit. The features of this microcontroller is similar to that of AT89C51 except that

- It is a 20 pin IC
- It has 2K Bytes of Reprogrammable Flash Memory
- It has 15 Programmable I/O Lines

4.1.2 SENSOR:

A sensor is a device that understands interruptions and gives an output accordingly. An IR sensor was chosen because of its ability to send pulsed output for every detected rotation. The size of the sensor is small and so interfacing it to the existing meter is trivial. Another consideration was a proximity sensor that requires a flawless surface with absolutely nil wobbling. The IR sensor does not pose these constraints and hence was chosen to fit the purpose.

The construction of the IR sensor is simple. This sensor has two parts, the transmitter and the receiver. The transmitter has two inputs and sends out infrared frequencies, the inputs are the supply voltage VCC (+5V) and the ground GND.The receiver is one that senses these infrared frequencies. It has two pins one is ground GND and the other is the output pin. It has a pulsed output when the receiver detects the IR frequency. It gives a spike of a higher voltage. This is the device that is interfaced with the existing analog meter to detect the number of rotations that it makes. The output of the sensor is given to the microcontroller that keeps track of the number of rotations and decrements the card accordingly.

4.1.3 EEPROM:

EEPROM stands for electrically erasable programmable read only Memory. This is a kind of ROM where we can erase the contents and reprogram. The difference in this and the flash memory of the Microcontroller is that here we can be specific on the bits we erase and with the flash memory we will have to erase the entire ROM and write on to it afresh. The EEPROM chosen provides 32k bytes of memory. This is a serial EEPROM with a common 2-wire bus. There are 2 kinds of EEPROMs that are available in the market. One is the Software programmable EEPROM and the other one is the hardware programmable EEPROM. We have chosen the software programmable EEPROM to economize on the number of port lines required.

In addition we have to take care checking if the EEPROM is a serial or parallel one. We have selected a serial EEPROM by Atmel, the AT24C04.This is the card we Interface with the microcontroller. It has the details of the amount of electricity that can be consumed before cut off. There are two cards of which one acts as the primary and another as a secondary back up. The features of this EEPROM are

- 8 pin IC
- 32K bytes of memory
- 2 wire serial interface
- Write protect pin for hardware data protection.

4.1.4 LCD DISPLAY:

LCD stands for liquid crystal display. This is an output device with a limited viewing angle. The choice of LCD as an output device was because of its cost, ease of use and is better with alphabets when compared with a 7-segment LED display. We have so many kinds of LCDs today and our application requires a LCD with 2 lines and 16 characters per line. This gets data from the microcontroller and displays the same. It has 8 data lines, 3 control lines, a supply voltage VCC (+5V) and a GND.This makes the whole device user friendly by showing the balance left in the card. This also shows the card that is currently being used.

4.1.5 BUZZER:

A buzzer is a device that produces a sound in the audible frequency. This is used to alarm the user about the status of the card. It uses only one of the 32 I/O pins of the microcontroller. It uses simple binary logic wherein logic 1 will make the buzzer ring else it won't. It has two inputs, the supply voltage VCC (+5 V) and the ground GND.A buzzer is activated when there is very little balance left in the card that is currently being used. This acts an indication to the user to replace the card in the other slot with a recharged one. Once this card goes dry the Microcontroller automatically shifts to the other card. Thus the buzzer reminds the user of replacing the card in the secondary slot and ensures that the supply is not cut off. Also, when load exceeds the limit specified by power supplier the buzzer will get activated to warn the user to reduce load.

4.1.6 RELAY:

A relay is like a switch that is in one of the states either on or off. This is used to cut off the power supply when both the cards go dry. This also uses only one of the I/O pins of the microcontroller. The construction of the relay is simple. Once the relay circuit is driven a coil gets charged and so the switch is pulled towards it resulting in an open non-conducting circuit.

It has five pins, one input from the microcontroller, one is the ground GND, one is the supply voltage, and the other two are the outputs. The outputs are the normally closed and normally open states of the relay. When in the normally closed state the relay conducts and the supply is got through this pin. When the relay is in normally open state no supply is possible. A relay circuit provided thus cuts off the power Supply when both the card goes out of balance. Thus this makes sure no power is drawn free of charge.

Once the various components were purchased their data sheets were carefully studied In order to get an in-depth idea of their usage.

4.2 MODULE 2:

Designing and fabrication of the PCB

The design of the PCB involves a lot of sub divisions. First the 230V AC input must be stepped down to a 5V dc supply. A transformer is used for the Voltage step down. This is then passed for an AC to DC conversion. The obtained DC voltage is used for all the components. Various active and passive devices are connected so that a surge or fall in voltage does not affect the performance of the PCB. The microcontroller EEPROMs and LCD are integrated onto the board in such a way that they work in tandem with the active and passive components to achieve their prescribed rating. The entire project was first tried on a breadboard and when it was found to be successful we implemented the same on a printed Circuit board.

4.3 MODULE 3:

Programming the microcontroller:

This phase involved programming the microcontroller. The logic involved is obtaining the value from the EEPROM and performing manipulations based on the number of rotations made by the energy meter. The manipulated reading is then rewritten into the EEPROM .The status of the card has to be continuously shown on the LCD for the convenience of the user. The microcontroller should also drive the buzzer and relay at the appropriate time to serve the purpose of load division and over load protection. The entire programming was simulated in an environment using the software *RIDE* by *Raisonance* shown in fig.*4.1*. Once the program was successfully compiled it was converted into hexadecimal code and then written into the microcontroller using software *EZ UPLOADER V3.1* shown in fig 4.2. A suitable slab for the metering has been implemented. This has been done because it is difficult to implement the existing metering slab followed owing to loads, which are not practically feasible in a simulated environment.

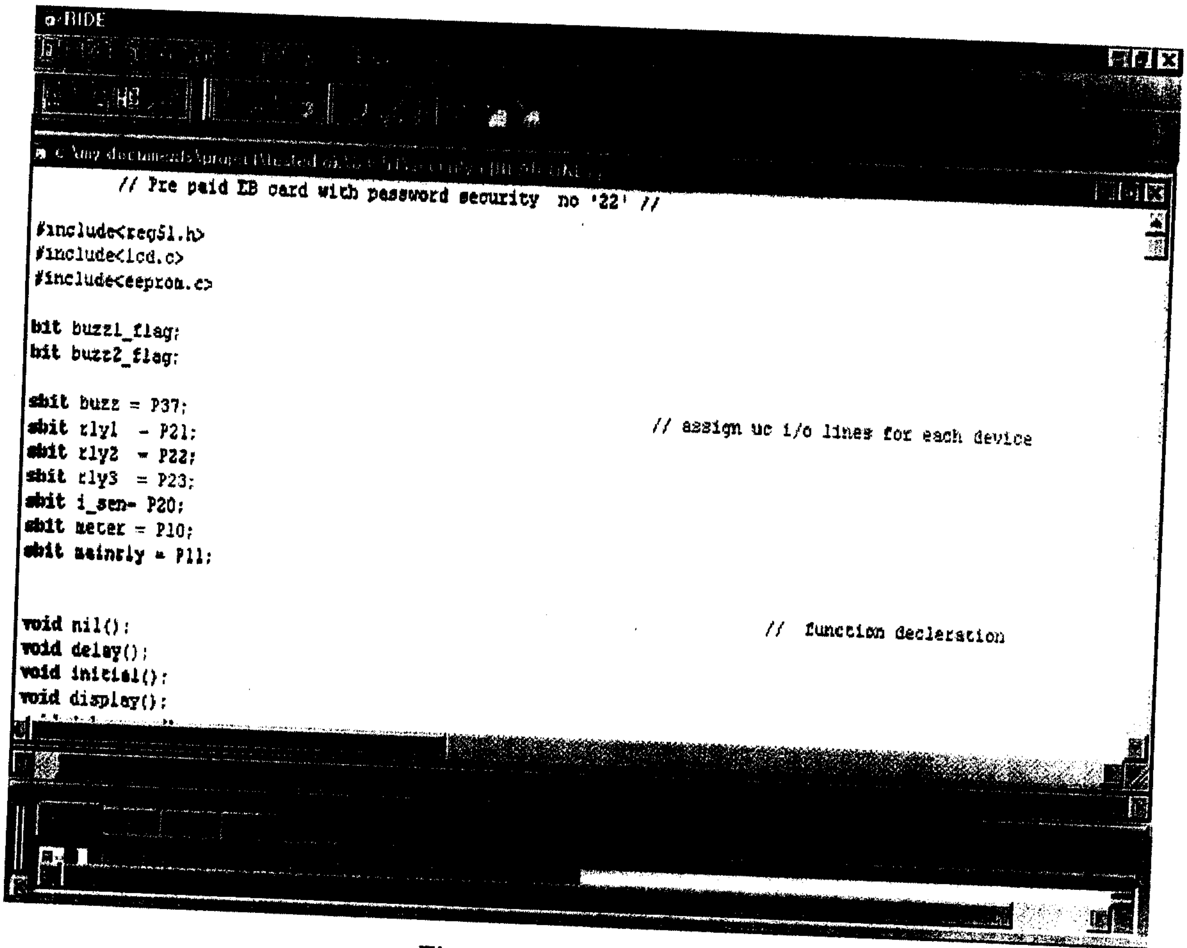


Fig 4.1 Ride software

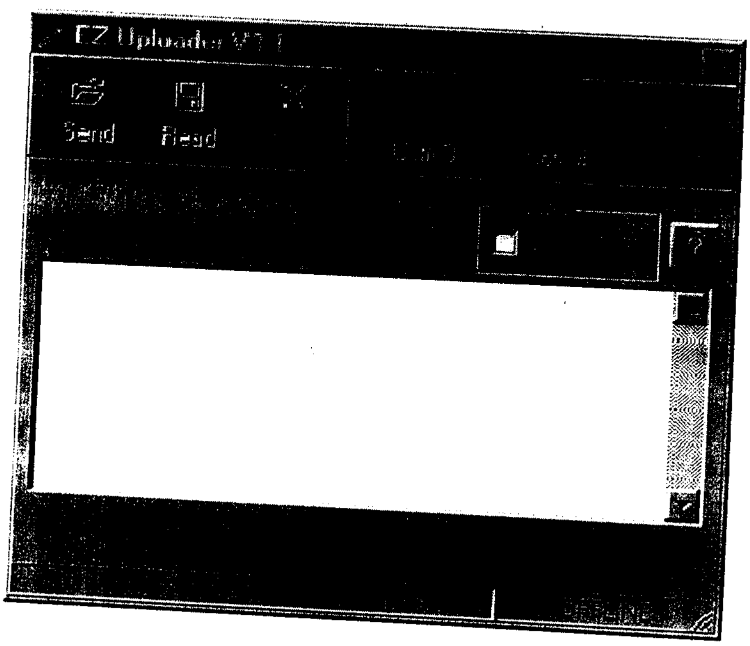


Fig 4.2 EZ Uploader V 1.3

4.4 MODULE 4:

Creating a desktop model

An energy meter that is commercially being used was purchased and a Small hole was drilled on the disk so that the sensor detects the completion of a rotation. The output wire from the sensor is given as input to the microcontroller For the purpose of simulation we connect few loads and demonstrate.

In the current theft indicator, when load exceeds the limit specified by power supplier the meter will give alarm to warn user to reduce load. Meter will release alarm if user reduces the load, else it will cut off power supply. A suitable maximum demand limit has been fixed for simulation purpose.

IMPLEMENTATION DETAILS

MAIN UNIT

5. MAIN UNIT

5.1 BLOCK DIAGRAM

This is the module that is attached to the existing analog meter. The block diagram of the main module is shown in fig 5.1.

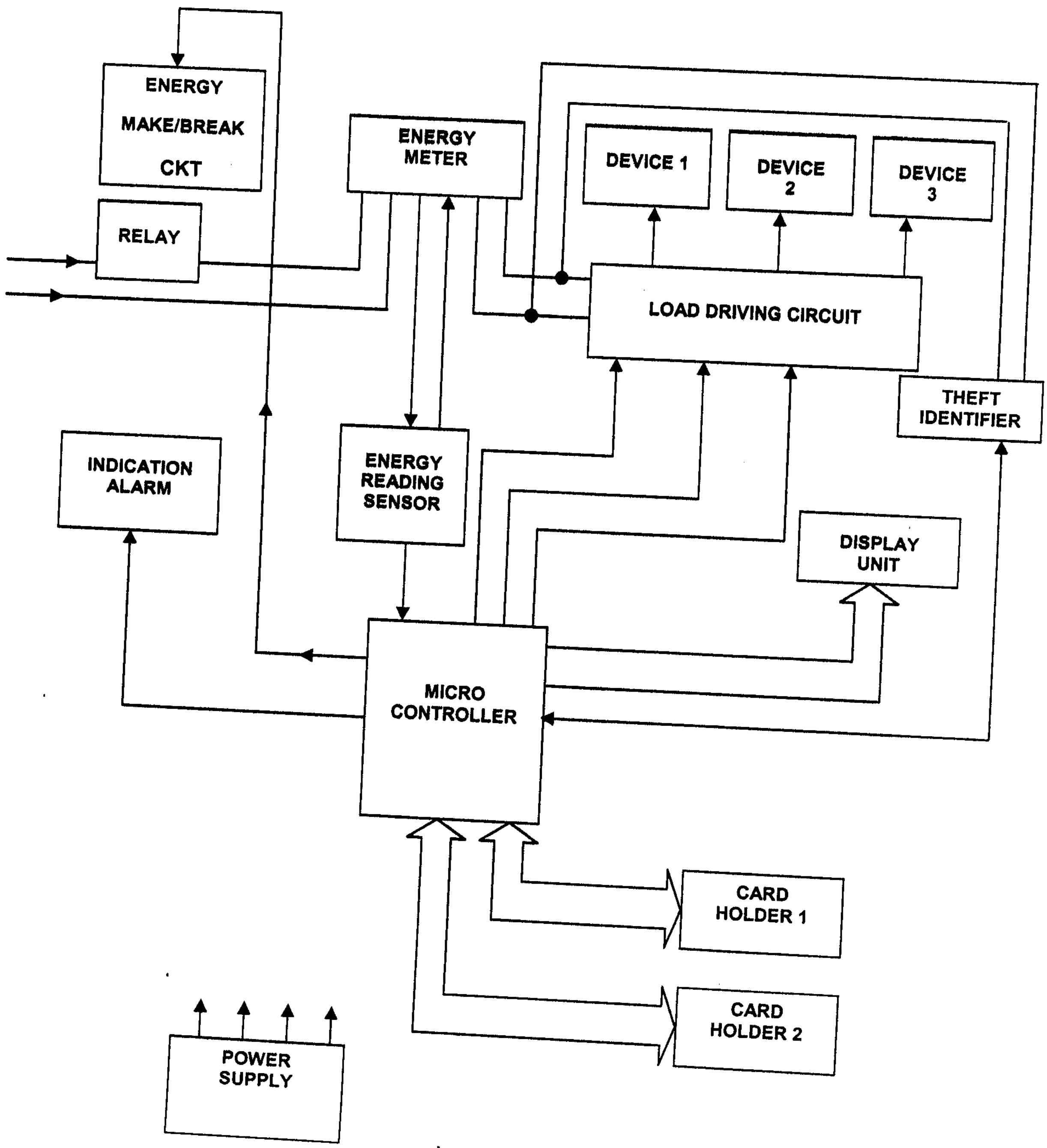


Fig. 5.1 BLOCK DIAGRAM OF MAIN UNIT

Here the IR sensor senses the rotations of the disc in the energy meter and the pulsed output is given to the microcontroller. Every time a pulse is obtained the microcontroller decrements the value stored in the EEPROM by one. We have used two cards in our project; one is the main card and the other acts as the standby card. The buzzer is included to alarm the user about the status of the card at different instances.

LCD is used which shows the balance left out in the card. This also shows the card that has been currently being used. A load driving circuit has been included for load division purpose to avoid abrupt power shutdown when both the cards go dry. A current theft indicator is provided .It causes the total power shutdown during any current theft attempts made by the user.

Relays have been included to cut off the power supply when both the cards go dry. It also gets activated during load division and current theft. For practical purpose it will be the part of the transmission post from which supply lines reaches the consumer's premises. For simulation purpose we have used this relay on the board.

5.2 CIRCUIT DESCRIPTION

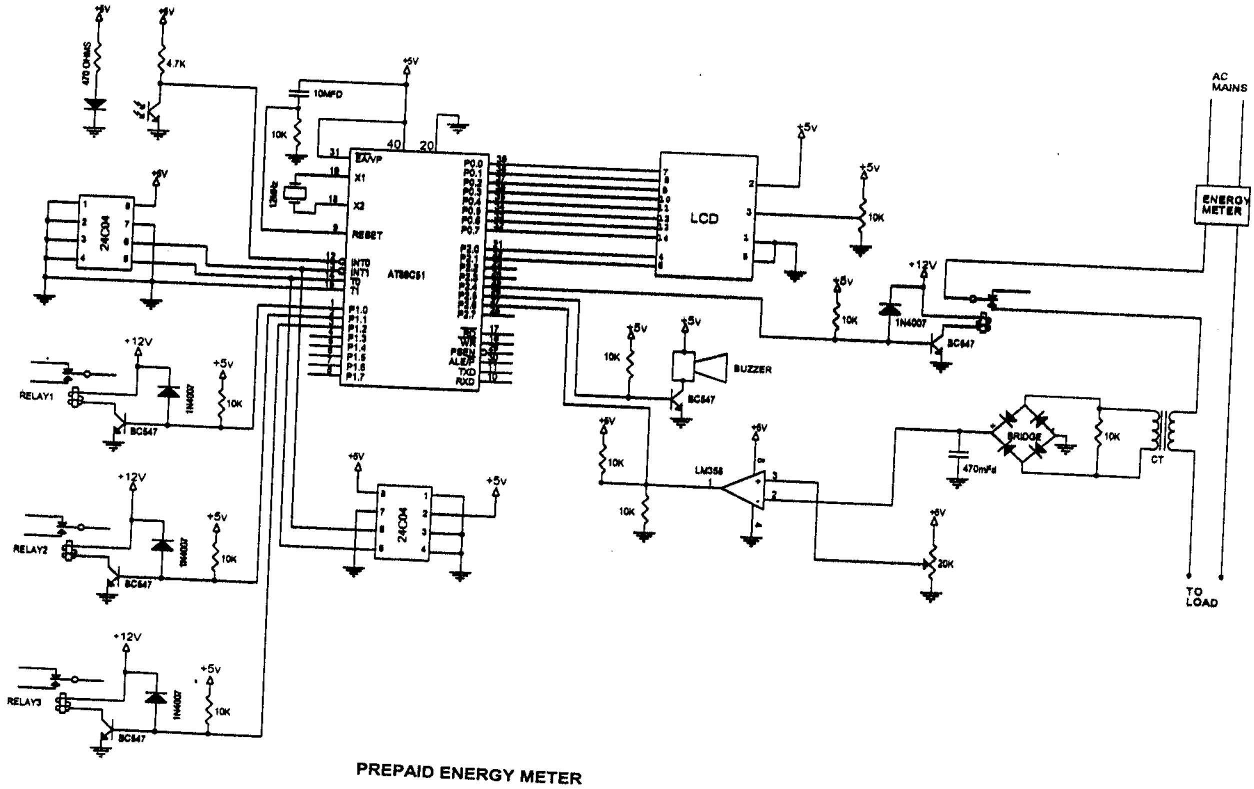


Fig.5.2 CIRCUIT DIAGRAM OF MAIN UNIT

The microcontroller we have used in the main unit is 89C51 by Atmel.It is a low-power, high performance 8- bit microcomputer with the following features,

- 40 pin controller
- 4 I/O ports of 8 pins each
- 4K bytes of flash memory
- 128 byte internal RAM
- Two 16 bit timers
- The clock speed can reach up to 24MHz.

The type of display used here is the LCD with two lines and sixteen characters per line. This gets data from the microcontroller and displays the same. It has 8 data lines, 3 control lines, a supply voltage, VCC (+5V) and a ground pin GND.This indicates the balance left in the card and also indicates the card that is currently accessed.

Basically sensor is a device that understands interruptions and gives an output accordingly. Infra red sensors are used here. This sensor has two parts, the transmitter and the receiver. The transmitter has two inputs and sends out infrared frequencies, the inputs are the supply voltage VCC (+5V) and the ground GND.The receiver is one that senses these infrared frequencies. It has two pins one is ground GND and the other is the output pin. It has a pulsed output when the receiver detects the IR frequency. It gives a spike of a higher voltage. This is the device that is interfaced with the existing analog meter to detect the number of rotations that it makes. The output of the sensor is given to the microcontroller that keeps track of the number of rotations and decrements the card accordingly.

·A buzzer is a device that produces a sound in the audible frequency. This is used to alarm the user about the status of the card. It has two inputs, the supply voltage VCC (+5 V) and the ground GND.

A relay is like a switch that is in one of the states either on or off. It has five pins, one input from the microcontroller, one is the ground GND, one is the supply voltage, and the other two are the outputs. The outputs are the normally closed and normally open states of the relay. When in the normally closed state the relay conducts and the supply is got through this pin. When the relay is in normally open state no supply is possible.

The current transformer, bridge rectifier and the op-amp form the theft identifier circuit. The primary of the current transformer is connected in series with the supply line and it carries the load current that is consumed by the user. This current is induced in the secondary, which gives the output in terms of voltage corresponding to the primary current. The diode bridge rectifier converts the ac voltage to dc voltage and gives it as input to the op-amp. A reference value that is fixed by the power supplier is given in the other input. When the load consumed exceeds the limit the buzzer gets activated and the power gets cutoff.

The load driving circuit has been included for load division purpose. The equipments in the consumer's premises are divided into three such as high power consuming, low priority and very essential equipments. These are connected to three different relays. When the charge value of the card reaches a particular threshold limit these relays will get activated one-by-one and the corresponding equipments will get tripped off in a sequential manner.

5.3 ENERGY SENSING MECHANISM

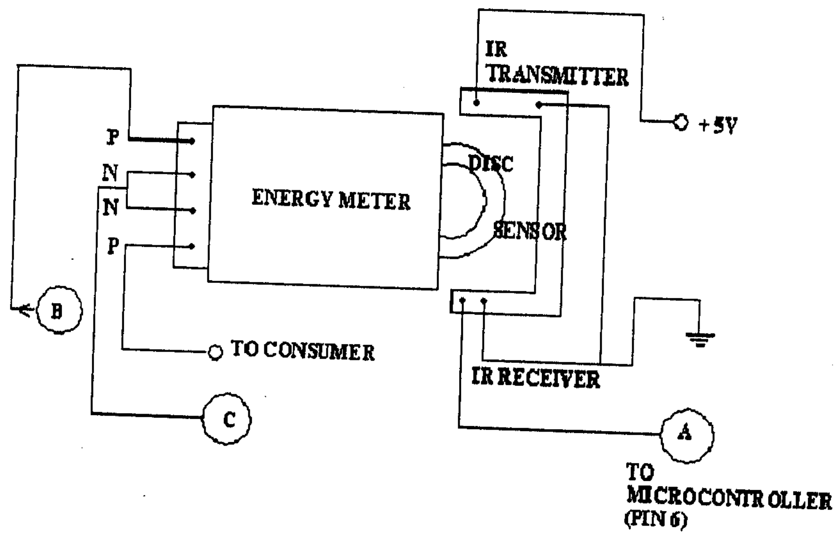


Fig.5.3 ENERGY SENSING MECHANISM

The arrangement of the energy sensing mechanism is shown in fig5.3. The sensor use here is an Infrared sensor that has two parts namely a transmitter and a receiver. The transmitter is a LED with two inputs VCC and GND.It sends out infrared frequencies. The receiver is a phototransistor with 2 pins a GND and an output. It gives pulsed output i.e. the pin is always in one state. When the receiver detects the infrared frequency it gives a spike of higher voltage.

A hole is made on the disc of the energy meter and it is placed between the transmitter and receiver of the sensor. This sensor senses the rotation of the disc and gives the signal to the microcontroller which decrements the card accordingly.

CARD CHARGING UNIT

6. CARD CHARGING UNIT

6.1 BLOCK DIAGRAM

The block diagram of the Card charging unit is shown in fig.6.1 and its circuit is shown in fig 6.2.

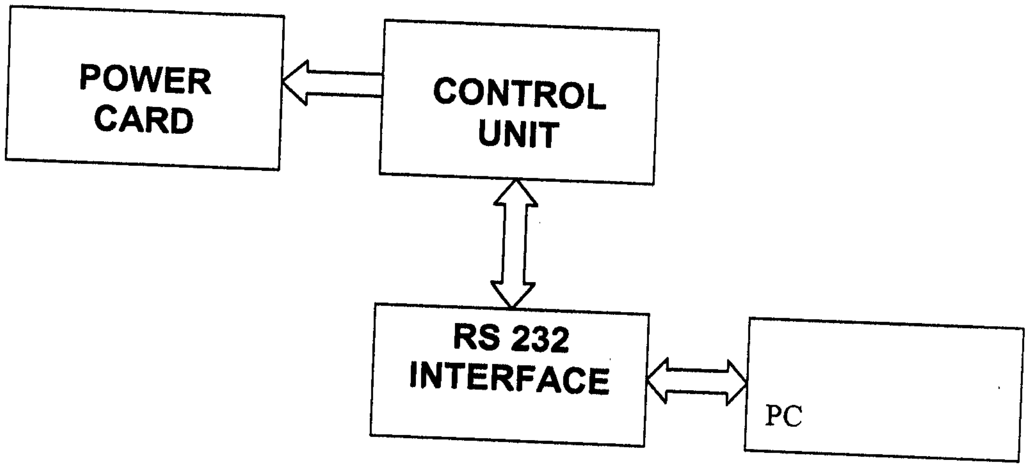


FIG 6.1 BLOCK DIAGRAM OF CARD CHARGING UNIT

The card used is an EEPROM i.e. IC24C04. We have used two cards in our project. The card is charged using the card-charging unit. Here we have interfaced a pc with micro controller to store the charge value in the card. The charge value to be entered in the card is given in the PC, which transfers the value to the EEPROM using RS-232 logic. The interfacing with the PC is done through RS232 cable.

6.2 CIRCUIT DESCRIPTION

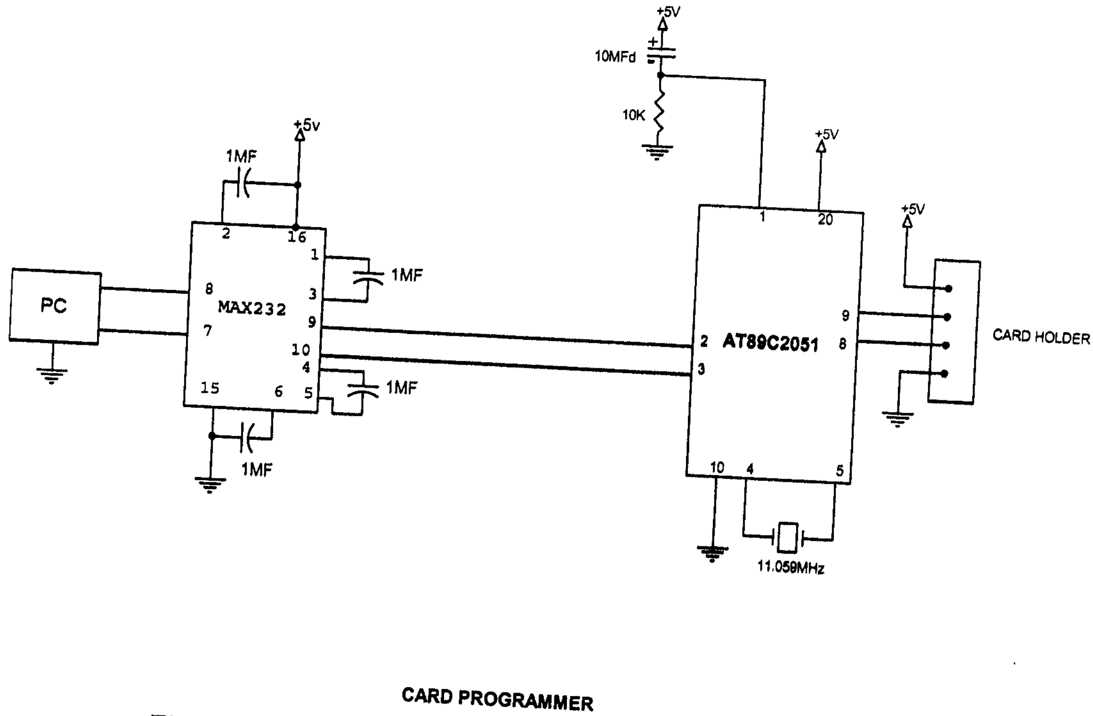


FIG 6.2 CIRCUIT DIAGRAM OF CARD CHARGING UNIT

Here the PC is interfaced with micro controller through MAX232 IC. The output of the PC is +12V to -12V DC. But the micro controller needs 0 to +5V DC. This conversion from +12V to -12V to 0 to +5V is done by MAX232 IC. The MAX232 IC acts as a voltage controller as well as a voltage doubler. It interfaces RS232 logic and TTLogic.TTL stands for Transistor Transistor Logic.

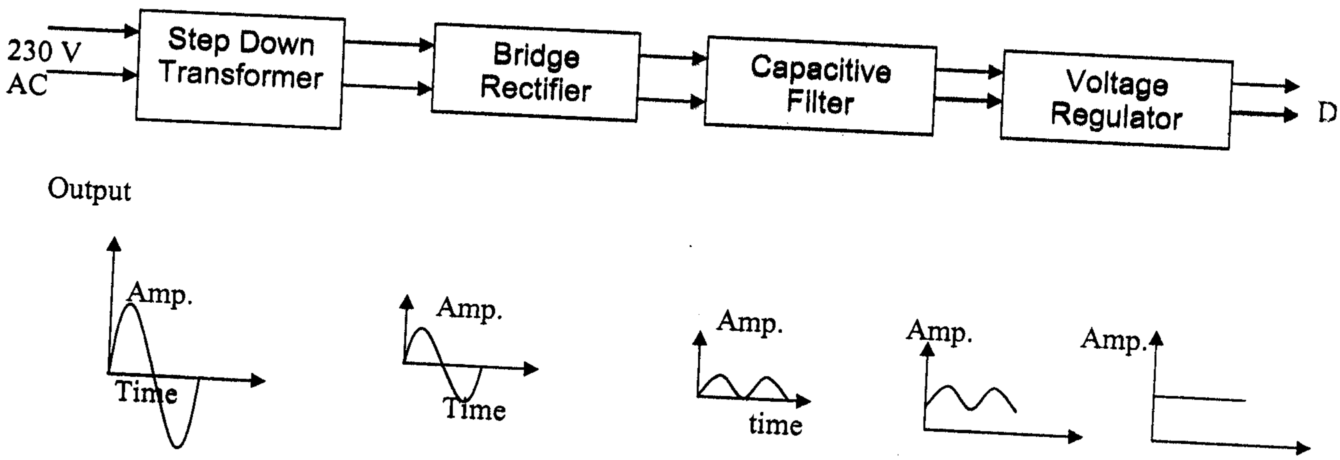
In RS232 logic, logic 0=+12V, and logic 1=-12V. The communication between PC and MAX232 IC is through RS232 logic.

In TTL logic, logic 0=0V, logic 1=+5V.The communication between MAX232 IC and micro controller is through TTL logic. The charge value is sent from the PC to the micro controller through MAX232 IC. From the micro controller the value is stored onto the card in the card holder using IIC logic (Intel Integrated Circuit). While reading the charge value from the EEPROM and writing the same into the pc the MAX232 acts as voltage doubler and converts 0V to +5V in to +12V to -12V. So that a permanent record of the charge value could be created in the PC.

POWER SUPPLY UNIT

7. POWER SUPPLY UNIT

The block diagram of the power supply unit is shown in fig 7.1 and its Circuit is shown in fig 7.2



Figs 7.1 BLOCK DIAGRAM OF POWER SUPPLY UNIT

The operation of the main unit needs only 12 V.To get the required voltage, 230/12 V step down transformer is used. The 12V is given to the bridge rectifier circuit to obtain 12 V DC.To obtain a pure DC voltage, various sections such as filtration, regulation are provided.

For rectification process the double bridge rectifier is used. the purpose of double rectifier is to give voltage for both +12 V and –12 V.

The rectification process contains more ripple content. To reduce this content, filtration is required. The filtration process is carried out by the combination of capacitors and resistors.

In this stage, two regulators namely positive regulator (7812) and Negative regulator (7805) are used. The 7812 provides + 5V and 7805 provides –5V at its output if the input voltage is in the range of 5V to 30 V.

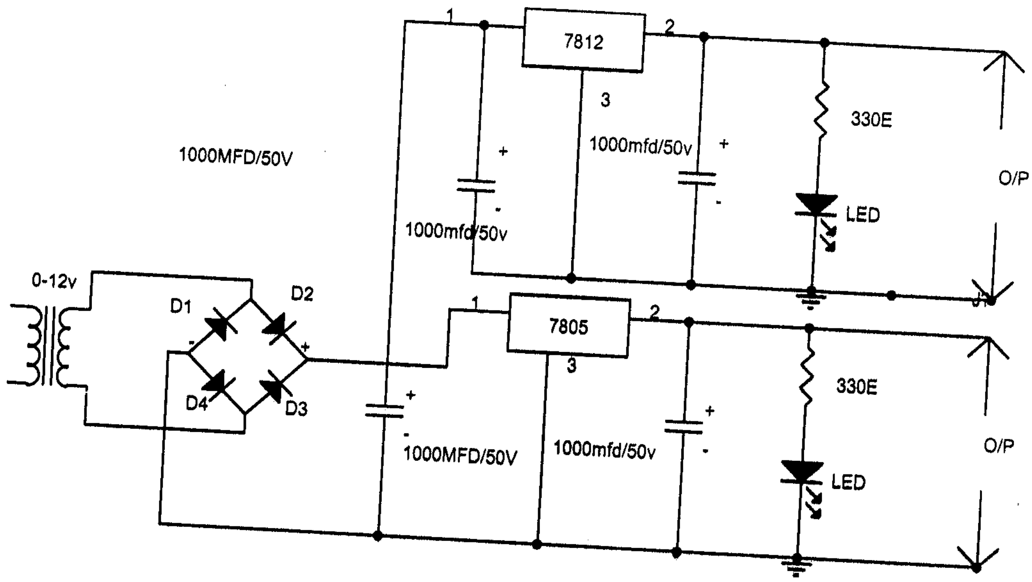


Fig 7.2 CIRCUIT DIAGRAM OF POWER SUPPLY UNIT

Finally the output of 12 V DC is obtained. This is given for the operation of the main unit and the charging unit.

TESTING

8. TESTING

In a domestic environment, there are several appliances running at the same time. These may vary from electric geysers to simple electric bulbs and according to the load that is applied the consumption increases and thereby the speed of rotation of the disc is also increased. In a simulated environment it is not possible to connect many loads for the purpose of demonstration. Instead we fix our own parameters similar to the original parameters and demonstrate the same. In our project we have made use of three electric bulbs of 200 watts each that will be used as the load.

In a commercially available energy meter 200 rotations of the disc will signify the consumption of one kilowatt-hour. That means, if a load of 1 kilowatt runs for one hour then the meter will rotate 200 times in that hour. Since it is difficult to connect a 1 KW load for demonstration purposes and because it is time consuming we use a similar rule. With 3 x 200w bulbs, the consumption will be 600 watts, which is 0.6KW. Hence we will get only 60% of the rotations made by the disc if 1KW was connected.60% of 200 is 120 rotations per hour and on further simplification we get 2 rotations per minute. Hence for the purpose of demonstration we have kept 2 rotations a minute to signify the consumption of 1 unit. This has been done only for our convenience and is no benchmark to go by.

The entire system was tested under various conditions of load and it was found to function normally under all the loads. The results were highly satisfying and it presented a completely automated system with cost efficiency as well. This was the core aim of the project and it has been successfully adhered to. Once it has been completely tested along with encryption algorithms and other small modifications (if required by the market), this project can be made into a commercial product and can be implemented for the benefit of the people.

CONCLUSION AND FUTURE OUTLOOK

9. CONCLUSION AND FUTURE OUTLOOK

The main aim of our project was to ease the existing complexity in the metering and billing process of electricity. It is quite impossible to bring a complete change to the existing system and so the best alternative is adopted which suits all strata of the society.

The field of embedded engineering has made rapid strides and is today an integral part of the smallest home appliance. Though this field has been around for well over a decade, it is only now that it has sprung into significance. The microcontroller that we have used (manufactured by the company ATMEL) is used to make simple modifications to the existing system.

The experiment of using prepaid cards has been extremely successful with cellular phone subscribers. Today people prefer smart cards for everything including buying fuel, which is why we have petro cards today. The success of smart cards could spread to the consumption of electricity as well because such cards are a major relief to those with little requirement and to those who need temporary connection.

The system that we have designed has been done with the intention to make the end-user feel minimum strain. In the event of a complete drainage of one card, the microcontroller automatically shifts to another card that is kept as standby. This is done to give the user enough time to replace his card without interrupting power supply. It is only if card 2 drains out completely, the relay circuit in the device cut off supply from the mains.

A few enhancements that could be done in future according to the then prevailing market are

- A display of the balance in terms of currency in addition to the balance shown in terms of units will give the user a better idea of usage.
- By incorporating an additional timer and by providing scrolling keys the user could view his usage over periods of time. He could view his usage per day, per week or per month.
- A complicated encryption algorithm that would use the power line to establish contact with the EB to verify the authenticity of the card could be done.

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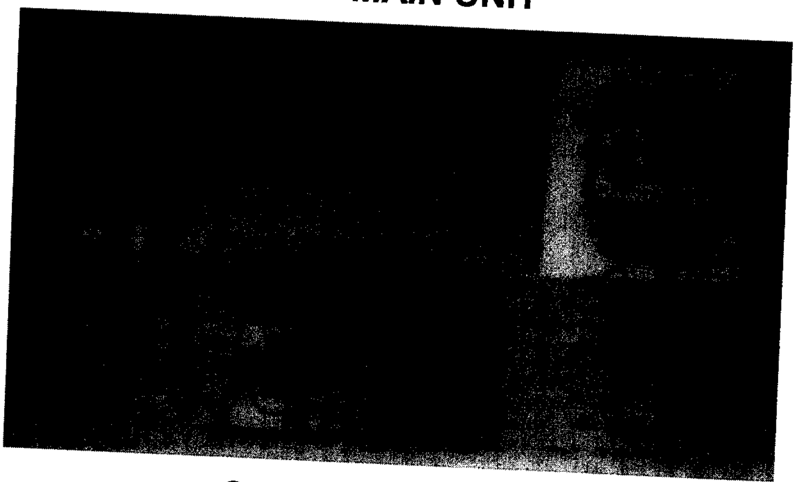
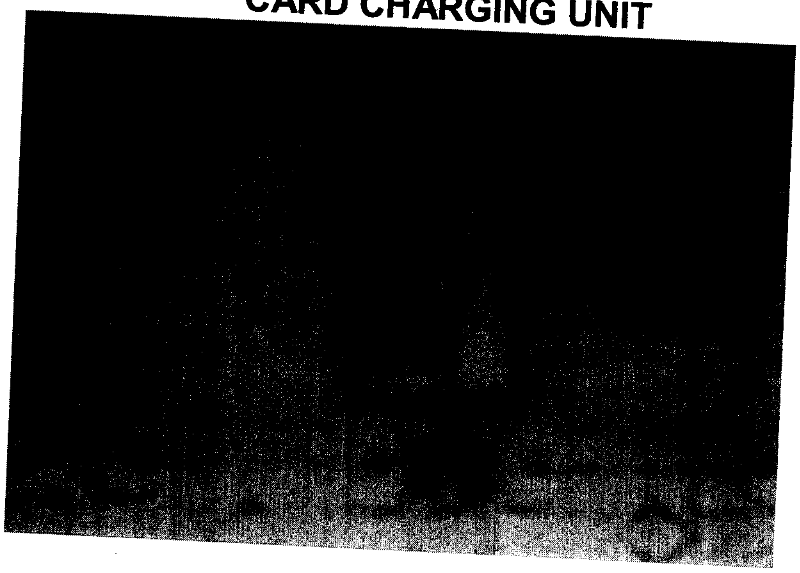
APPENDIX-I

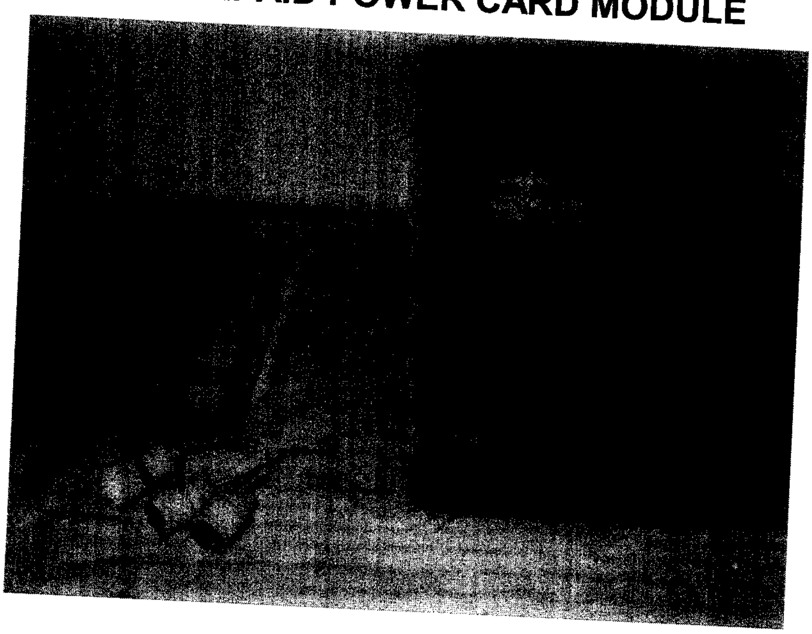
MAIN UNIT



CARD CHARGING UNIT



PREPAID POWER CARD MODULE



APPENDIX-II

PROGRAM CODE FOR 89C51

// Pre paid EB card with password security no: '22' //

```
#include<reg51.h>
#include<lcd.c>
#include<eeprom.c>
bit buzz1_flag;
bit buzz2_flag;
sbit buzz = P37;                    // assign mc i/o lines for each device
sbit rly1  = P21;
sbit rly2  = P22;
sbit rly3  = P23;
sbit i_sen= P20;
sbit meter = P10;
sbit mainrly = P11;

                                    // function decleration
void nil();
void delay();
void initial();
void display();
void delay_sec();
void read_data();
void hex_bcd();
void load_data();
void dis_update();

unsigned char digit1,digit2,digit3,digit4,digit5;
unsigned int count,temp,card1,card2;
// unsigned long int  sec ;

void main()
  {
  initial();

                                    // intialize uc i/o's and variables
```

```
while(1)
{
do{
if(card1 >=10000 && card2 >= 10000)
nil();
if(card1 >=10000 || card2 >= 10000)
dis_update();
if((card1<=10 && card2>=10000)  || card2 <=10 )
{
if(i_sen == 0)                          //  indication only total     unit < 10
buzz = 1;
else
buzz=0;
}
}
while(meter ==1);
delay();
do{
read_data();
if(card1 >=10000 && card2 >= 10000)
nil();
if(card1 >=10000 || card2 >= 10000)
dis_update();
if((card1<=10 && card2>=10000)  || card2 <=10 )
{
if(i_sen == 0)
buzz = 1;
else
buzz=0;
}
}
while(meter==0);
delay();
read_data();
```

```
if(card1 >=1 && card1 <=9999 )
{
card1--;
if(card1>=100)
{
ep[0] =card1/100;
ep[1] =card1%100;
}
else if(card1 <=99 && card1 >=01)
{
ep[0] =0;
ep[1] =card1;
}
else if(card1 ==0)
{
ep[0]=0xff;
ep[1]=0xff;
card1 = 0xffff;
}

word_add=0x11;
nof_data=2;
dev_add=0xa0;
eep_write();
dis_update();
if( card1 <=20 && card2 >=10000)
{
rly3 = 0;
if(buzz1_flag ==0)
{
buzz = 1;
delay_sec();
buzz =0;
buzz1_flag =1;
```

```
}
if(card1 <= 10 && card2 >=10000)
{
rly2 = 0;
if(buzz2_flag ==0)
{
buzz = 1;
delay_sec();
buzz =0;
buzz2_flag =1;
}
if(card1 <=0 && card2 >=10000)
rly1 = 0;
}
}
if(card1 <=0 && card2 >=10000)
nil();
}
else if(card2 >=1 && card2 <=9999)
{
card2--;
dis_update();
if(card2>=100)
{
ep[0] =card2/100;
ep[1] =card2%100;
}
else if(card2 <=99 && card2 >=01)
{
ep[0] =0;
ep[1] =card2;
}
else if(card2 ==0)
{
```

```
ep[0]=0xff;
ep[1]=0xff;
}
word_add=0x11;
nof_data=2;
dev_add=0xac;
eep_write();

if(card2 <=20)
{
rly3 = 0;
if(buzz1_flag ==0)
{
buzz = 1;
delay_sec();
buzz =0;
buzz1_flag =1;
}

if(card2 <= 10)
{
rly2 = 0;
if(buzz2_flag ==0)
{
buzz = 1;
delay_sec();
buzz =0;
buzz2_flag =1;
}
if(card2 <=0)
rly1 = 0;
}
}
if (card2 <= 0)
```

```
nil();
}
}
}

void initial()
{
    buzz =0;
    count =0;
    lcd_pulse();
    init_lcd();
    clr_display();
    buzz1_flag =0;
    buzz2_flag =0;
//  load_data();
//  delay();
    read_data();
    if(card1 >=10000 && card2 >=10000)
    nil();
    dis_update();
}

void read_data()
  {
    word_add=0x11;
    dev_add=0xac;
    nof_data=3;
    eep_read();
    if(ep[2] == 22)
    {
   card2 = ep[0] *100;
   card2 += ep[1];
   }
   else
```

```
        card2 = 12000;
        delay();
        delay();
        word_add=0x11;
        dev_add=0xa0;;
        nof_data=3;
        eep_read();
        if(ep[2] == 22)
        {
        card1 = ep[0] *100;
        card1 += ep[1];
        }
        else
        card1 =120000 ;
    }

    void hex_bcd( )
     {
       digit1 =  count/10000;
       temp  =  count%10000;
       digit2  = temp/1000;
       temp   = temp%1000;
       digit3  = temp/100;
       temp   = temp%100;
       digit4  = temp/10;
       digit5  = temp%10;

      digit1 += 0x30;
      digit2 += 0x30;
      digit3 += 0x30;
      digit4 += 0x30;
      digit5 += 0x30;

    if(count >=1000)
```

```
        {
          digit1 = digit2;
          digit2 = digit3;
          digit3 = digit4;
          digit4 = digit5 ;
          digit5 = 0x20;
        }
       else if(count<=999 && count >=100)
        {
          digit1 = digit3;
          digit2 = digit4;
          digit3 = digit5;
          digit4 = 0x20 ;
          digit5 = 0x20;
        }

       else if(count<=99 && count >=10)
        {
          digit1 = digit4;
          digit2 = digit5;
          digit3 = 0x20  ;
          digit4 = 0x20  ;
          digit5 = 0x20;
        }

       else if(count<=9 && count >=1)
        {
          digit1 = digit5;
          digit2 = 0x20 ;
          digit3 = 0x20 ;
          digit4 = 0x20 ;
          digit5 = 0x20;
        }
}
```

```
void display()
  {
      disp[3]   = 'C';
      disp[4]   = 'A';
      disp[5]   = 'R' ;
      disp[6]   = 'D';
      disp[8]   = ' ' ;
      disp[9]   = '=';
      disp[10] = ' ' ;
      disp[11] = digit1;
      disp[12] = digit2;
      disp[13] = digit3;
      disp[14] = digit4;
      disp[15] = digit5;
}


void nil()
 {
     buzz = 0;
     rly1 = 0;
     rly2 = 0;
     rly3 = 0;
     mainrly = 0;

    display();
    disp[7]  = '1' ;
    disp[11] = 'N';
    disp[12] = 'i' ;
    disp[13] = 'l' ;
    disp[14] = ' ' ;
    disp[15] = ' ' ;
    dis_line_one();
```

```
        display();
        disp[7]  = '2' ;
        disp[11] = 'N';
        disp[12] = 'i' ;
        disp[13] = 'l' ;
        disp[14] = ' ' ;
        disp[15] = ' ' ;
        dis_line_two();

        while(1)
        {
           buzz = 1;
           delay_sec();
           buzz =0;
           delay_sec();
        }
    }

  void dis_update()
  {
   if(card1 >9999)
    {
    display();
    disp[7]  = '1' ;
    disp[11] = 'N';
    disp[12] = 'i' ;
    disp[13] = 'l' ;
    disp[14] = ' ' ;
    disp[15] = ' ' ;
    dis_line_one();
  }
  else
  {
```

```
count = card1;
hex_bcd();
display();
disp[7] = '1';
dis_line_one();
}
if(card2 >9999)
{
display();
disp[7]  = '2' ;
disp[11] = 'N';
disp[12] = 'i' ;
disp[13] = 'l' ;
disp[14] = ' ' ;
disp[15] = ' ' ;
dis_line_two();
}
else
{
count = card2;
hex_bcd();
display();
disp[7] = '2';
dis_line_two();
}
}
void load_data()
{
ep[0]=00;
ep[1]=25;
word_add=0x11;
nof_data=2;
dev_add=0xa0;
eep_write();
```

```
        delay();
        delay();

        ep[0]=00;
        ep[1]=25;
        word_add=0x11;
        nof_data=2;
        dev_add=0xac;
        eep_write();

        ep[0]=00;
        ep[1]=50;
        word_add=0x22;
        nof_data=2;
        dev_add=0xa0;
        eep_write();
        delay();
        delay();

        ep[0]=00;
        ep[1]=00;
        word_add=0x22;
        nof_data=2;
        dev_add=0xac;
        eep_write();

}


void delay()
 {
 unsigned int delay;
 for(delay= 0; delay<=4000; delay++)
 {}
```

```
   }

void delay_sec()
 {
   unsigned int loop, inner;
   for(inner = 0;inner<=40;inner++)
33   {
   for(loop=0;loop<=20000;loop++)
   {}
   }
}
```

```
// #include<reg51.h>
// EEPROM COMMUNICATION PROGRAMME with 89c51 security '22'//

unsigned char eep_data,epdata,word_add,nof_data;
unsigned char ep[15],temp2,ab,bc,eep,dev_add;
void eep_read();
void eep_write();
void eep_send();
void eep_recev();
void eep_start();
void eep_stop();
void eep_clock();
void eep_dly();
void recev_ack();

sbit sda = P13;  //5
sbit scl = P12;   //6

void eep_start()
{
    sda=1;
    scl=1;
    eep_dly();
    sda=0;
    eep_dly();
    scl=0;
}

void eep_stop()
{
  sda=0;
  eep_dly();
  scl=1;
  eep_dly();
```

```
        sda=1;
        eep_dly();
        scl=0;
     }

     void eep_dly()
     {
       // int a;
       for(ab=0;ab<=25;ab++)
       {;}
     }

     void eep_clock()
     {
       scl=1;
       eep_dly();
       scl=0;
     }

    void eep_ack()
    {
      //int b=0;
      for(bc=0;bc<=200;bc++)
      {
      while(sda==1)
      {
     goto jmp;
      }
      }
     jmp:
    eep_clock();
}

void recev_ack()
```

```
{
    sda=0;
    eep_clock();
    sda=1;
}

void eep_send()
{
    unsigned char m,n;
    for(n=0;n<=7;n++)
    {
    m=eep_data;
    m=m&0x80;
    if(m==0x80)
    {
    sda=1;
    }
    else
    {
    sda=0;
    }
    eep_clock();
    eep_data=eep_data<<1;
    }
}

void eep_recev()
{
    unsigned char m,n;
    m=0;
    for(n=0;n<=7;n++)
    {
    m=m<<1;
    if(sda==1)
```

```
{
m=m|0x01;
}
else
{
m=m&0xfe;
}
eep_clock();
}
eep_data=m;
}

void eep_write()
{
eep_start();
eep_data=dev_add;  //0xa0;  // device add
eep_send();
eep_ack();
temp2=word_add&0x0f;
if(temp2==0)
word_add=word_add+1;
eep_data=word_add;
eep_send();
eep_ack();
for(eep=0;eep<=nof_data;eep++)
{
eep_data=ep[eep];
eep_send();
eep_ack();
}
eep_stop();
}

void eep_read()
```

```
{
eep_start();
eep_data=dev_add;  //0xa0;  //device add
eep_send();
eep_ack();
temp2=word_add&0x0f;
if(temp2==0)
word_add=word_add+1;
eep_data=word_add;
eep_send();
eep_ack();
eep_start();
eep_data=dev_add+1; //0xa1 ; device add +1
eep_send();
eep_ack();
for(eep=0;eep<=nof_data;eep++)
{
eep_recev();
ep[eep]=eep_data;
if(eep!=nof_data)
{
recev_ack();
}
}
eep_stop();
}
```

```
// LCD  INTERFACE
// 0x0c for cursor blinkling
// 0x0d for  cursor remove
// 4 = 1 data
//     = 0 command / address
// 5 = r/w
// 6 = enable , low  to high pulse

//  #include<reg51.h>
#define lcdport  P0
#define functionset  56
#define fcurserdisplayshift  16
#define fentrymode   6
#define cleardisplay   1
#define displayon  12
#define cursoron   13

sbit lcd_rs   = P27;  // 13  //4
sbit lcd_e    = P26;  //14    //6

void init_lcd();
void clr_array();
void lcd_pulse();
void dly_250m();
void dis_line_one();
void dis_line_two();
void setup_lcd_cmd();

unsigned int disp[17],dis_count ;
void init_lcd()
{
setup_lcd_cmd();
dly_250m();
lcdport = functionset;
```

```
lcd_pulse();
dly_250m();
lcdport = functionset;
lcd_pulse();
dly_250m();
lcdport = functionset;
lcd_pulse();
dly_250m();
lcdport = displayon;
lcd_pulse();
dly_250m();
lcdport = fentrymode;
lcd_pulse();
dly_250m();
lcdport = cleardisplay;
lcd_pulse();
}

void dly_250m()
{
unsigned int i;
for(i=0;i<=4500;i++)
{;}
}

void lcd_pulse()
{
unsigned int i;
lcd_e=1;
for(i=0;i<=100;i++)
{;}
lcd_e=0;
}
```

```
void setup_lcd_cmd()
{
lcd_rs=0;
//  lcd_rw=0;
}

void clr_array()
{
for(dis_count = 1; dis_count<=16;dis_count++)
disp[dis_count] =0x20 ;
}

void clr_display()
{
clr_array();
dis_line_one();
dis_line_two();
}

void  dis_line_one()
{
lcd_rs = 0;
lcdport = 0x80;
lcd_pulse();
lcd_rs = 1;
dly_250m();
for(dis_count = 1 ; dis_count <=16; dis_count++)
{
   lcdport = disp[dis_count];
   lcd_pulse();
}
clr_array();
lcd_rs = 0;
lcdport = 0x8f;
```

```
lcd_pulse();
lcd_rs = 0;
lcdport = 0xc0;
lcd_pulse();
lcd_rs =1;
}

void dis_line_two()
{
lcd_rs = 0;
lcdport = 0xc0;
lcd_pulse();
lcd_rs = 1;
dly_250m();
for(dis_count = 1 ; dis_count <=16; dis_count++)
{
  lcdport = disp[dis_count];
  lcd_pulse();
}
clr_array();
}
```

PROGRAM CODE FOR 89C2051

// Program for prepaid card programmer with security no: '22' //

```
#include<reg51.h>
#include<eeprom_pro.c>

void delay();
void get_data();
void initial();
void load_data();

int temp,val1,val2,sno ;

void main()
{
initial();
while(1)
{
get_data();                          // receive the card value from PC
load_data();                         // load value to card
}
}

void delay()
{
unsigned int loop, inner;
for(inner = 0;inner<=20;inner++)
{
for(loop=0;loop<=20000;loop++)
{}
}
}

void get_data()
```

```
{
do
{                                   // wait for initial ack signal from pc
RI=0;
Do
{ ; }
while(RI==0);
temp = SBUF;
RI=0;
}
while(temp != 0xaa);
TI=0;                               // replay for ack signal
SBUF = 0xab;
do{;}
while(TI==0);
TI=0;
RI=0;                               // receive the user serial no
do{;}
while(RI==0);
sno = SBUF;
RI =0;
TI=0;
SBUF = sno+1;                       // send receive ack to pc
do{;}
while(TI==0);
TI=0;
RI=0;                               // receive the higher byte
do{;}
while(RI==0);
val1 = SBUF;
RI =0;

TI=0;
SBUF = val1 +1;                     // send receive ack to pc
```

```
do{;}
while(TI==0);
TI=0;
RI=0;
do{;}
while(RI==0);                    // receive the lower byte
val2 = SBUF;
RI =0;
TI=0;
SBUF = val2+1;                   // send ack receive ack to pc
do{;}
while(TI==0);
TI=0;
}

void initial()
{
IE=0X90;
SCON = 0x50;                     // initialize SFR's for serial communication
TMOD=0x20;
TL1=0xe8;
TH1=0xe8;                        // B.R = 1200  @ 11.059MHz
TR1 =1;
TI =0;
RI =0;
ep[0] =0;
ep[1] =0;
}

void load_data()
{
ep[0] = val1;
ep[1] = val2;
ep[2] = sno;
```

```
word_add=0x11;                    // write  value to card 1
nof_data=3;
dev_add=0xa0;
eep_write();
word_add=0x11;
nof_data=3;
dev_add=0xac;                        // write  value to card 2
eep_write();
}
```

```
// security pc card  programming program//
#include <bios.h>
#include <conio.h>
#include <stdio.h>
#include <dos.h>
#include <time.h>
#include<string.h>
#include<ctype.h>
#include<stdlib.h>
#include<process.h>
//#define COM0  1
#define COM1  0
//#define   SETTINGS0   (_COM_1200|   _COM_CHR8   |   _COM_STOP1   |
_COM_NOPARITY)
#define   SETTINGS1   (_COM_1200|   _COM_CHR8   |   _COM_STOP1   |
_COM_NOPARITY)
//#define TRANS0 0x2f8
#define TRANS1 0x3F8
unsigned int value,temp,temp1,count;
unsigned int vc,timeout,count1,sno;
void main()
{
 _bios_serialcom(_COM_INIT,COM1,SETTINGS1);
 clrscr();
 textcolor(BLACK);
 textbackground(CYAN);
 outportb(TRANS1,0xaa);
 timeout = 0;
 count = 0;
  count1 = 0;
  vc = inportb(TRANS1);
  gotoxy(10,15);
  printf(" CONNECTING TO OUR HARDWARE....");
  do{
```

```
        count++;
        delay(10);
        if(count >= 40)
        {
            count1++;
            outportb(TRANS1,0xaa);
            count =0;
        }
       if(count1 >= 10)
       {
            gotoxy(10,15);
            printf(" HARDWARE NOT CONNECTED                    ");
            sound(1500);
            sleep(2);
            nosound();
            exit(0);
       }
       vc = inportb(TRANS1);
     }while(vc!=0xab );
  clrscr();
  gotoxy(25,10);
  printf(" PREPAID CARD PROGRAMMER");
  gotoxy(10,12);
  printf(" ENTER USER SERIAL NO (<255) :");
  scanf("%d",&sno);
  gotoxy(10,14);
  printf(" ENTER THE VALUE (0-9999)   :");
  scanf("%d",&value);
  if(value >=10000 || value < 0 || sno >=256)
  {
   clrscr();
   gotoxy(10,10);
   printf(" ENTER CORRECTLY ");
   sound(1500);
```

```
        sleep(2);
        nosound();
      }
     else
      {
        temp = value / 100;
        temp1 = value % 100;
        delay(100);
        outportb(TRANS1,sno);
        do{
        vc = inportb(TRANS1);
        }while(vc!=sno+1);
        delay(100);
        outportb(TRANS1,temp);
        do{
        vc = inportb(TRANS1);
        }while(vc!=temp+1);
        delay(100);
        outportb(TRANS1,temp1);
        do{
        vc = inportb(TRANS1);
        }while(vc!=temp1+1);
        printf("%d",vc);
      clrscr();
      gotoxy(10,10);
      printf(" CARD PROGRAM COMPLETE ");
      gotoxy(10,12);
      printf(" CARD VALUE IS = %d  " ,value);
      sleep(3);
     } // else
     exit(0);
}
```

APPENDIX-III

Features

- Compatible with MCS-51™ Products
- 4K Bytes of In-System Reprogrammable Flash Memory
  - Endurance: 1,000 Write/Erase Cycles
- Fully Static Operation: 0 Hz to 24 MHz
- Three-level Program Memory Lock
- 128 x 8-bit Internal RAM
- 32 Programmable I/O Lines
- Two 16-bit Timer/Counters
- Six Interrupt Sources
- Programmable Serial Channel
- Low-power Idle and Power-down Modes

8-bit Microcontroller with 4K Bytes Flash

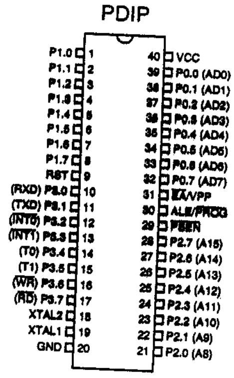
AT89C51

Description

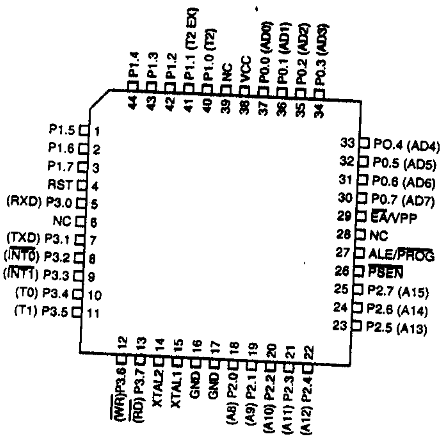
The AT89C51 is a low-power, high-performance CMOS 8-bit microcomputer with 4K bytes of Flash programmable and erasable read only memory (PEROM). The device is manufactured using Atmel's high-density nonvolatile memory technology and is compatible with the industry-standard MCS-51 instruction set and pinout. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional nonvolatile memory programmer. By combining a versatile 8-bit CPU with Flash on a monolithic chip, the Atmel AT89C51 is a powerful microcomputer which provides a highly-flexible and cost-effective solution to many embedded control applications.

Pin Configurations

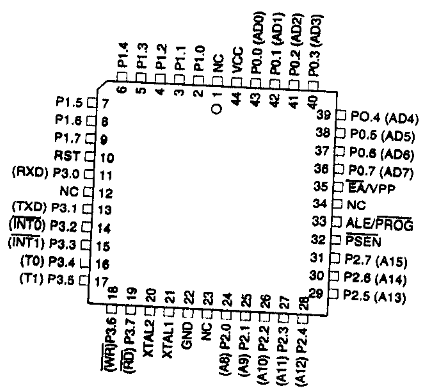
PDIP



PQFP/TQFP

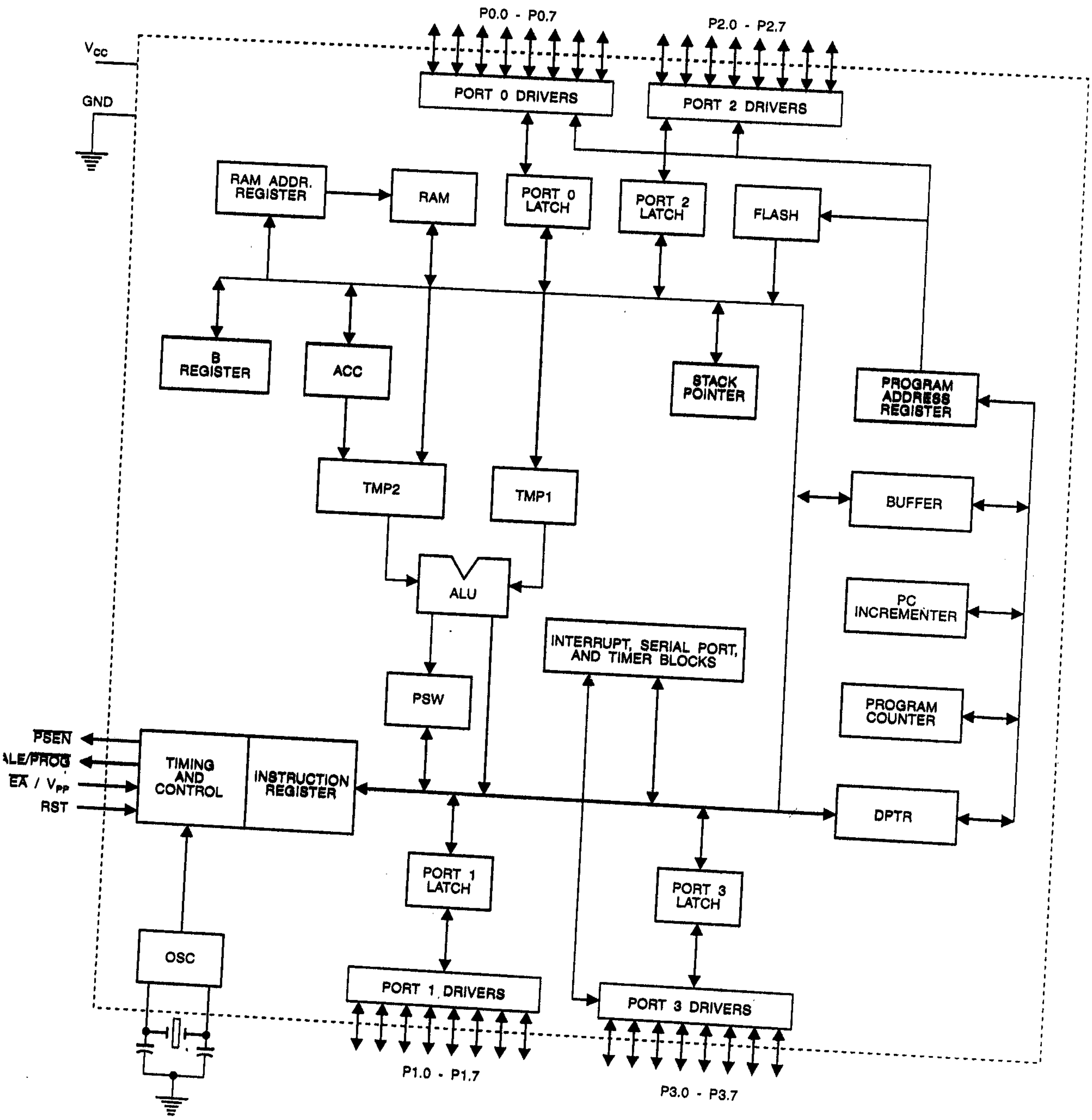


PLCC



Rev. 0265G–02/00

Block Diagram



The AT89C51 provides the following standard features: 4K bytes of Flash, 128 bytes of RAM, 32 I/O lines, two 16-bit timer/counters, a five vector two-level interrupt architecture, a full duplex serial port, on-chip oscillator and clock circuitry. In addition, the AT89C51 is designed with static logic for operation down to zero frequency and supports two software selectable power saving modes. The Idle Mode stops the CPU while allowing the RAM, timer/counters, serial port and interrupt system to continue functioning. The Power-down Mode saves the RAM contents but freezes the oscillator disabling all other chip functions until the next hardware reset.

Pin Description

VCC

Supply voltage.

GND

Ground.

Port 0

Port 0 is an 8-bit open-drain bi-directional I/O port. As an output port, each pin can sink eight TTL inputs. When 1s are written to port 0 pins, the pins can be used as high-impedance inputs.

Port 0 may also be configured to be the multiplexed low-order address/data bus during accesses to external program and data memory. In this mode P0 has internal pullups.

Port 0 also receives the code bytes during Flash programming, and outputs the code bytes during program verification. External pullups are required during program verification.

Port 1

Port 1 is an 8-bit bi-directional I/O port with internal pullups. The Port 1 output buffers can sink/source four TTL inputs. When 1s are written to Port 1 pins they are pulled high by the internal pullups and can be used as inputs. As inputs, Port 1 pins that are externally being pulled low will source current (I_{IL}) because of the internal pullups.

Port 1 also receives the low-order address bytes during Flash programming and verification.

Port 2

Port 2 is an 8-bit bi-directional I/O port with internal pullups. The Port 2 output buffers can sink/source four TTL inputs. When 1s are written to Port 2 pins they are pulled high by the internal pullups and can be used as inputs. As inputs, Port 2 pins that are externally being pulled low will source current (I_{IL}) because of the internal pullups.

Port 2 emits the high-order address byte during fetches from external program memory and during accesses to external data memory that use 16-bit addresses (MOVX @ DPTR). In this application, it uses strong internal pullups when emitting 1s. During accesses to external data memory that use 8-bit addresses (MOVX @ RI), Port 2 emits the contents of the P2 Special Function Register.

Port 2 also receives the high-order address bits and some control signals during Flash programming and verification.

Port 3

Port 3 is an 8-bit bi-directional I/O port with internal pullups. The Port 3 output buffers can sink/source four TTL inputs. When 1s are written to Port 3 pins they are pulled high by the internal pullups and can be used as inputs. As inputs, Port 3 pins that are externally being pulled low will source current (I_{IL}) because of the pullups.

Port 3 also serves the functions of various special features of the AT89C51 as listed below:

Port Pin	Alternate Functions
P3.0	RXD (serial input port)
P3.1	TXD (serial output port)
P3.2	$\overline{INT0}$ (external interrupt 0)
P3.3	$\overline{INT1}$ (external interrupt 1)
P3.4	T0 (timer 0 external input)
P3.5	T1 (timer 1 external input)
P3.6	$\overline{WR}$ (external data memory write strobe)
P3.7	$\overline{RD}$ (external data memory read strobe)

Port 3 also receives some control signals for Flash programming and verification.

RST

Reset input. A high on this pin for two machine cycles while the oscillator is running resets the device.

ALE/$\overline{PROG}$

Address Latch Enable output pulse for latching the low byte of the address during accesses to external memory. This pin is also the program pulse input ($\overline{PROG}$) during Flash programming.

In normal operation ALE is emitted at a constant rate of 1/6 the oscillator frequency, and may be used for external timing or clocking purposes. Note, however, that one ALE pulse is skipped during each access to external Data Memory.

If desired, ALE operation can be disabled by setting bit 0 of SFR location 8EH. With the bit set, ALE is active only during a MOVX or MOVC instruction. Otherwise, the pin is weakly pulled high. Setting the ALE-disable bit has no effect if the microcontroller is in external execution mode.

PSEN

Program Store Enable is the read strobe to external program memory.

When the AT89C51 is executing code from external program memory, PSEN is activated twice each machine cycle, except that two PSEN activations are skipped during each access to external data memory.

EA/VPP

External Access Enable. EA must be strapped to GND in order to enable the device to fetch code from external program memory locations starting at 0000H up to FFFFH. Note, however, that if lock bit 1 is programmed, EA will be internally latched on reset.

EA should be strapped to V_{CC} for internal program executions.

This pin also receives the 12-volt programming enable voltage (V_{PP}) during Flash programming, for parts that require 12-volt V_{PP}.

XTAL1

Input to the inverting oscillator amplifier and input to the internal clock operating circuit.

XTAL2

Output from the inverting oscillator amplifier.

Oscillator Characteristics

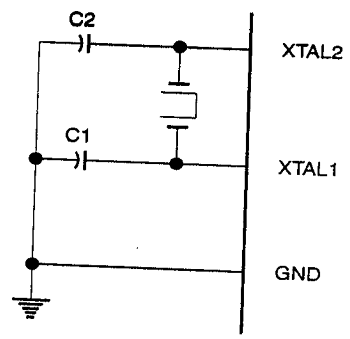
XTAL1 and XTAL2 are the input and output, respectively, of an inverting amplifier which can be configured for use as an on-chip oscillator, as shown in Figure 1. Either a quartz crystal or ceramic resonator may be used. To drive the device from an external clock source, XTAL2 should be left unconnected while XTAL1 is driven as shown in Figure 2. There are no requirements on the duty cycle of the external clock signal, since the input to the internal clocking circuitry is through a divide-by-two flip-flop, but minimum and maximum voltage high and low time specifications must be observed.

Idle Mode

In idle mode, the CPU puts itself to sleep while all the on-chip peripherals remain active. The mode is invoked by software. The content of the on-chip RAM and all the special functions registers remain unchanged during this mode. The idle mode can be terminated by any enabled interrupt or by a hardware reset.

It should be noted that when idle is terminated by a hard ware reset, the device normally resumes program execution, from where it left off, up to two machine cycles before the internal reset algorithm takes control. On-chip hardware inhibits access to internal RAM in this event, but access to the port pins is not inhibited. To eliminate the possibility of an unexpected write to a port pin when idle is terminated by reset, the instruction following the one that invokes idle should not be one that writes to a port pin or to external memory.

Figure 1. Oscillator Connections

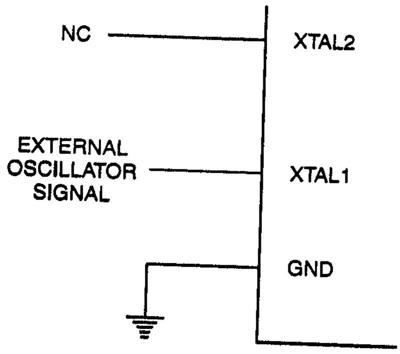


Note: C1, C2 = 30 pF ± 10 pF for Crystals
= 40 pF ± 10 pF for Ceramic Resonators

Status of External Pins During Idle and Power-down Modes

Mode	Program Memory	ALE	PSEN	PORT0	PORT1	PORT2	PORT3
Idle	Internal	1	1	Data	Data	Data	Data
Idle	External	1	1	Float	Data	Address	Data
Power-down	Internal	0	0	Data	Data	Data	Data
Power-down	External	0	0	Float	Data	Data	Data

Figure 2. External Clock Drive Configuration



Power-down Mode

In the power-down mode, the oscillator is stopped, and the instruction that invokes power-down is the last instruction executed. The on-chip RAM and Special Function Registers retain their values until the power-down mode is terminated. The only exit from power-down is a hardware reset. Reset redefines the SFRs but does not change the on-chip RAM. The reset should not be activated before V_{CC} is restored to its normal operating level and must be held active long enough to allow the oscillator to restart and stabilize.

Program Memory Lock Bits

On the chip are three lock bits which can be left unprogrammed (U) or can be programmed (P) to obtain the additional features listed in the table below.

When lock bit 1 is programmed, the logic level at the $\overline{EA}$ pin is sampled and latched during reset. If the device is powered up without a reset, the latch initializes to a random value, and holds that value until reset is activated. It is necessary that the latched value of $\overline{EA}$ be in agreement with the current logic level at that pin in order for the device to function properly.

Lock Bit Protection Modes

	Program Lock Bits			
	LB1	**LB2**	**LB3**	**Protection Type**
1	U	U	U	No program lock features
2	P	U	U	MOVC instructions executed from external program memory are disabled from fetching code bytes from internal memory, $\overline{EA}$ is sampled and latched on reset, and further programming of the Flash is disabled
3	P	P	U	Same as mode 2, also verify is disabled
4	P	P	P	Same as mode 3, also external execution is disabled

Features

- Compatible with MCS-51™ Products
- 2K Bytes of Reprogrammable Flash Memory
  - Endurance: 1,000 Write/Erase Cycles
- 2.7V to 6V Operating Range
- Fully Static Operation: 0 Hz to 24 MHz
- Two-level Program Memory Lock
- 128 x 8-bit Internal RAM
- 15 Programmable I/O Lines
- Two 16-bit Timer/Counters
- Six Interrupt Sources
- Programmable Serial UART Channel
- Direct LED Drive Outputs
- On-chip Analog Comparator
- Low-power Idle and Power-down Modes

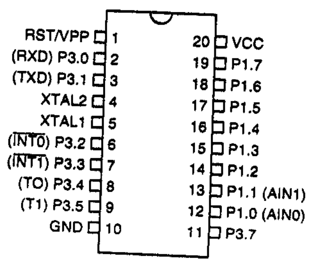
Description

The AT89C2051 is a low-voltage, high-performance CMOS 8-bit microcomputer with 2K bytes of Flash programmable and erasable read only memory (PEROM). The device is manufactured using Atmel's high-density nonvolatile memory technology and is compatible with the industry-standard MCS-51 instruction set. By combining a versatile 8-bit CPU with Flash on a monolithic chip, the Atmel AT89C2051 is a powerful microcomputer which provides a highly-flexible and cost-effective solution to many embedded control applications.

The AT89C2051 provides the following standard features: 2K bytes of Flash, 128 bytes of RAM, 15 I/O lines, two 16-bit timer/counters, a five vector two-level interrupt architecture, a full duplex serial port, a precision analog comparator, on-chip oscillator and clock circuitry. In addition, the AT89C2051 is designed with static logic for operation down to zero frequency and supports two software selectable power saving modes. The Idle Mode stops the CPU while allowing the RAM, timer/counters, serial port and interrupt system to continue functioning. The power-down mode saves the RAM contents but freezes the oscillator disabling all other chip functions until the next hardware reset.

Pin Configuration

PDIP/SOIC

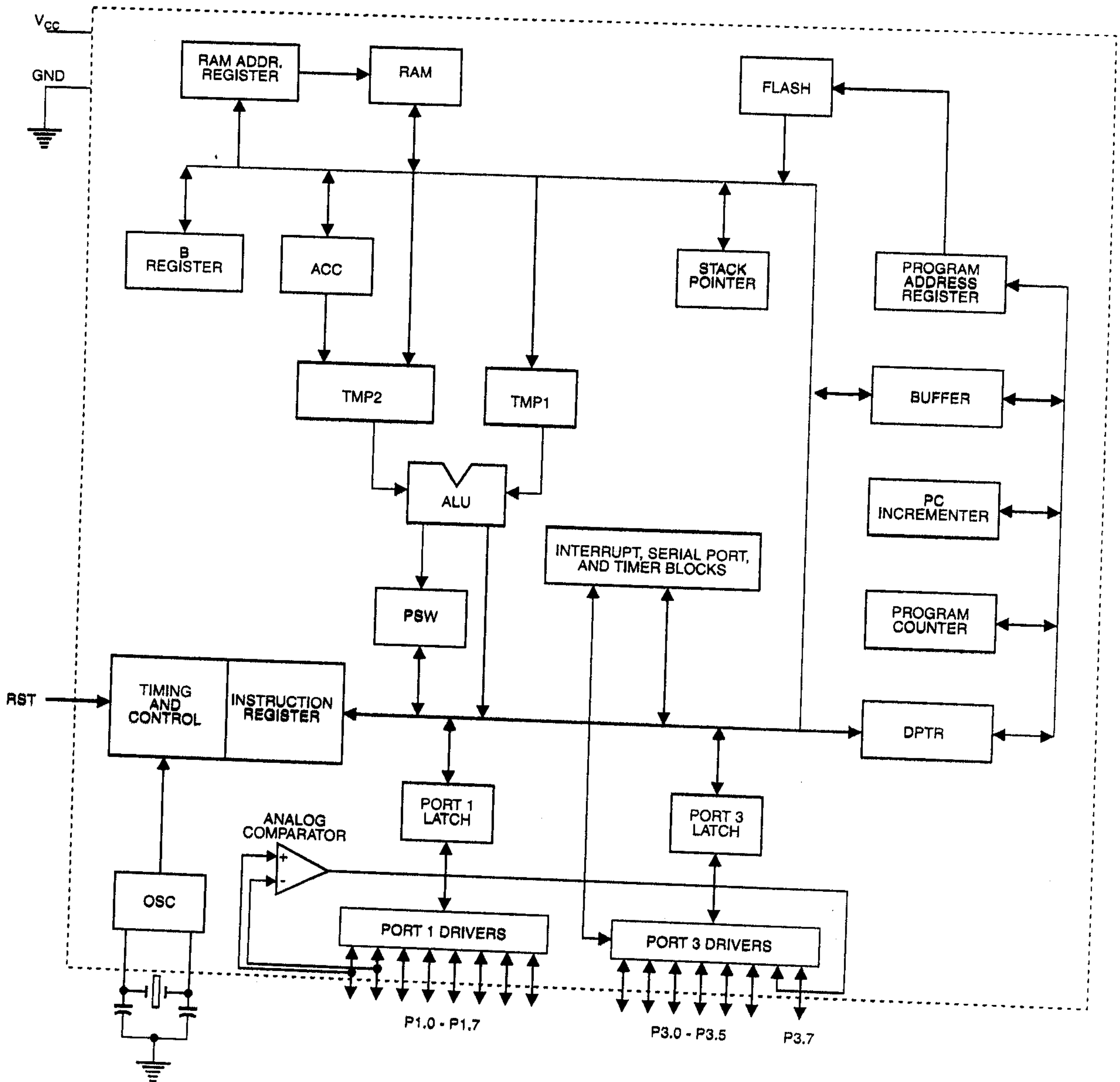


8-bit Microcontroller with 2K Bytes Flash

AT89C2051

Rev. 0368E–02/00

Block Diagram



Features

- Low-voltage and Standard-voltage Operation
  - 5.0 (V_{CC} = 4.5V to 5.5V)
  - 2.7 (V_{CC} = 2.7V to 5.5V)
  - 2.5 (V_{CC} = 2.5V to 5.5V)
  - 1.8 (V_{CC} = 1.8V to 5.5V)
- Internally Organized 128 x 8 (1K), 256 x 8 (2K), 512 x 8 (4K), 1024 x 8 (8K) or 2048 x 8 (16K)
- 2-wire Serial Interface
- Schmitt Trigger, Filtered Inputs for Noise Suppression
- Bi-directional Data Transfer Protocol
- 100 kHz (1.8V, 2.5V, 2.7V) and 400 kHz (5V) Compatibility
- Write Protect Pin for Hardware Data Protection
- 8-byte Page (1K, 2K), 16-byte Page (4K, 8K, 16K) Write Modes
- Partial Page Writes are Allowed
- Self-timed Write Cycle (10 ms max)
- High-reliability
  - Endurance: 1 Million Write Cycles
  - Data Retention: 100 Years
- Automotive Grade and Extended Temperature Devices Available
- 8-lead JEDEC SOIC, 8-pin PDIP and 8-lead TSSOP Packages

2-wire Serial EEPROM

1K (128 x 8)

2K (256 x 8)

4K (512 x 8)

8K (1024 x 8)

16K (2048 x 8)

AT24C01A
AT24C02
AT24C04
AT24C08
AT24C16

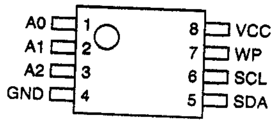
Description

The AT24C01A/02/04/08/16 provides 1024/2048/4096/8192/16384 bits of serial electrically erasable and programmable read-only memory (EEPROM) organized as 128/256/512/1024/2048 words of 8 bits each. The device is optimized for use in many industrial and commercial applications where low-power and low-voltage operation are essential. The AT24C01A/02/04/08/16 is available in space-saving 8-pin PDIP, (AT24C01A/02/04/08/16), 8-lead TSSOP (AT24C01A/02/04/08/16) and 8-lead JEDEC SOIC (AT24C01A/02/04/08/16) packages and is accessed via a 2-wire serial interface. In addition, the entire family is available in 5.0V (4.5V to 5.5V), 2.7V (2.7V to 5.5V), 2.5V (2.5V to 5.5V) and 1.8V (1.8V to 5.5V) versions.

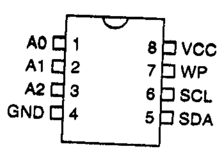
Pin Configurations

Pin Name	Function
A0 - A2	Address Inputs
SDA	Serial Data
SCL	Serial Clock Input
WP	Write Protect
NC	No Connect

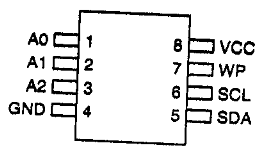
8-lead TSSOP



8-pin PDIP



8-lead SOIC



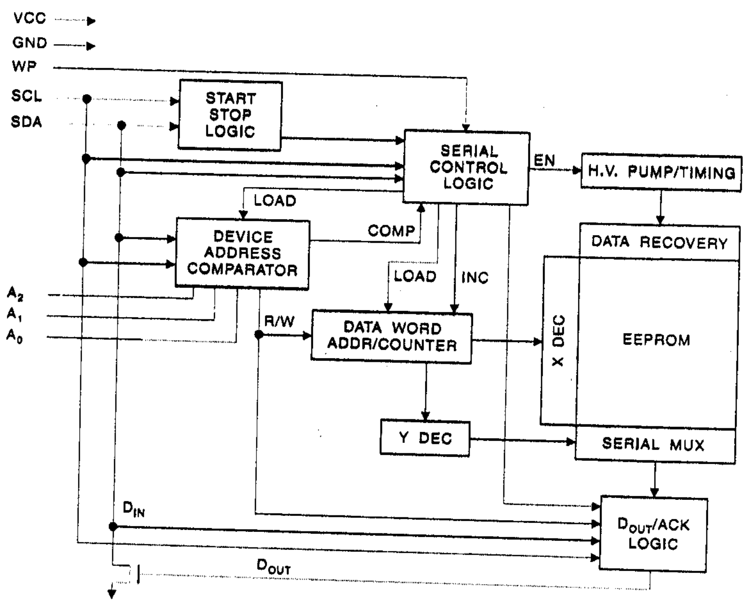
Rev. 0180F–06/01

Absolute Maximum Ratings

Operating Temperature	-55°C to +125°C
Storage Temperature	-65°C to +150°C
Voltage on Any Pin with Respect to Ground	-1.0V to +7.0V
Maximum Operating Voltage	6.25V
DC Output Current	5.0 mA

*NOTICE: Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Block Diagram



Pin Description

SERIAL CLOCK (SCL): The SCL input is used to positive edge clock data into each EEPROM device and negative edge clock data out of each device.

SERIAL DATA (SDA): The SDA pin is bi-directional for serial data transfer. This pin is open-drain driven and may be wire-ORed with any number of other open-drain or open-collector devices.

DEVICE/PAGE ADDRESSES (A2, A1, A0): The A2, A1 and A0 pins are device address inputs that are hard wired for the AT24C01A and the AT24C02. As many as eight 1K/2K devices may be addressed on a single bus system (device addressing is discussed in detail under the Device Addressing section).

The AT24C04 uses the A2 and A1 inputs for hard wire addressing and a total of four 4K devices may be addressed on a single bus system. The A0 pin is a no connect.

The AT24C08 only uses the A2 input for hardwire addressing and a total of two 8K devices may be addressed on a single bus system. The A0 and A1 pins are no connects.

The AT24C16 does not use the device address pins, which limits the number of devices on a single bus to one. The A0, A1 and A2 pins are no connects.

WRITE PROTECT (WP): The AT24C01A/02/04/16 has a Write Protect pin that provides hardware data protection. The Write Protect pin allows normal read/write operations when connected to ground (GND). When the Write Protect pin is connected to V_{CC}, the write protection feature is enabled and operates as shown in the following table.

HD44780U (LCD-II)

(Dot Matrix Liquid Crystal Display Controller/Driver)

HITACHI

Description

The HD44780U dot-matrix liquid crystal display controller and driver LSI displays alphanumerics, Japanese kana characters, and symbols. It can be configured to drive a dot-matrix liquid crystal display under the control of a 4- or 8-bit microprocessor. Since all the functions such as display RAM, character generator, and liquid crystal driver, required for driving a dot-matrix liquid crystal display are internally provided on one chip, a minimal system can be interfaced with this controller/driver.

A single HD44780U can display up to one 8-character line or two 8-character lines.

The HD44780U has pin function compatibility with the HD44780S which allows the user to easily replace an LCD-II with an HD44780U. The HD44780U character generator ROM is extended to generate 208 5 × 8 dot character fonts and 32 5 × 10 dot character fonts for a total of 240 different character fonts.

The low power supply (2.7V to 5.5V) of the HD44780U is suitable for any portable battery-driven product requiring low power dissipation.

Features

- 5 × 8 and 5 × 10 dot matrix possible
- Low power operation support:
  - 2.7 to 5.5V
- Wide range of liquid crystal display driver power
  - 3.0 to 11V
- Liquid crystal drive waveform
  - A (One line frequency AC waveform)
- Correspond to high speed MPU bus interface
  - 2 MHz (when V_{cc} = 5V)
- 4-bit or 8-bit MPU interface enabled
- 80 × 8-bit display RAM (80 characters max.)
- 9,920-bit character generator ROM for a total of 240 character fonts
  - 208 character fonts (5 × 8 dot)
  - 32 character fonts (5 × 10 dot)

- 64 × 8-bit character generator RAM
  - 8 character fonts (5 × 8 dot)
  - 4 character fonts (5 × 10 dot)
- 16-common × 40-segment liquid crystal display driver
- Programmable duty cycles
  - 1/8 for one line of 5 × 8 dots with cursor
  - 1/11 for one line of 5 × 10 dots with cursor
  - 1/16 for two lines of 5 × 8 dots with cursor
- Wide range of instruction functions:
  - Display clear, cursor home, display on/off, cursor on/off, display character blink, cursor shift, display shift
- Pin function compatibility with HD44780S
- Automatic reset circuit that initializes the controller/driver after power on
- Internal oscillator with external resistors
- Low power consumption

Ordering Information

Type No.	Package	CGROM
HD44780UA00FS	FP-80B	Japanese standard font
HCD44780UA00	Chip	
HD44780UA00TF	TFP-80F	
HD44780UA02FS	FP-80B	European standard font
HCD44780UA02	Chip	
HD44780UA02TF	TFP-80F	
HD44780UBxxFS	FP-80B	Custom font
HCD44780UBxx	Chip	
HD44780UBxxTF	TFP-80F	

Note: xx: ROM code No.

ABSOLUTE MAXIMUM RATINGS—MAX225/MAX244–MAX249

Supply Voltage (V_{CC}) ....-0.3V to +6V
Input Voltages
 T_{IN}, ENA, ENB, ENR, ENT, ENRA, ENRB, ENTA, ENTB....................-0.3V to (V_{CC} + 0.3V)
 R_{IN} ....±25V
 T_{OUT} (Note 3)....................±15V
 R_{OUT} ....-0.3V to (V_{CC} + 0.3V)
Short Circuit (one output at a time)
 T_{OUT} to GND....................Continuous
 R_{OUT} to GND....................Continuous

Continuous Power Dissipation (T_A = +70°C)
 28-Pin Wide SO (derate 12.50mW/°C above +70°C)............1W
 40-Pin Plastic DIP (derate 11.11mW/°C above +70°C)...611mW
 44-Pin PLCC (derate 13.33mW/°C above +70°C) 1.07W
Operating Temperature Ranges
 MAX225C_ _, MAX24_C_ _ ....0°C to +70°C
 MAX225E_ _, MAX24_E_ _ ....-40°C to +85°C
Storage Temperature Range....................-65°C to +160°C
Lead Temperature (soldering,10sec)....................+300°C

Note 4: Input voltage measured with transmitter output in a high-impedance state, shutdown, or V_{CC} = 0V.

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS—MAX225/MAX244–MAX249

(MAX225, V_{CC} = 5.0V ±5%; MAX244–MAX249, V_{CC} = +5.0V ±10%, external capacitors C1–C4 = 1µF; T_A = T_{MIN} to T_{MAX}; unless otherwise noted.)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
RS-232 TRANSMITTERS						
Input Logic Threshold Low						
Input Logic Threshold High				1.4	0.8	V
Logic Pull-Up/Input Current	Tables 1a–1d	Normal operation	2	1.4		V
		Shutdown		10	50	µA
Data Rate	Tables 1a–1d, normal operation			±0.01	±1	µA
Output Voltage Swing	All transmitter outputs loaded with 3kΩ to GND			120	64	kbits/sec
			±5	±7.5		V
Output Leakage Current (shutdown)	Tables 1a–1d	ENA, ENB, ENT, ENTA, ENTB = V_{CC}, V_{OUT} = ±15V		±0.01	±25	µA
		V_{CC} = 0V, V_{OUT} = ±15V		±0.01	±25	µA
Transmitter Output Resistance	V_{CC} = V+ = V- = 0V, V_{OUT} = ±2V (Note 4)		300	10M		Ω
Output Short-Circuit Current	V_{OUT} = 0V		±7	±30		mA
RS-232 RECEIVERS						
RS-232 Input Voltage Operating Range						
RS-232 Input Threshold Low	V_{CC} = 5V				±25	V
RS-232 Input Threshold High	V_{CC} = 5V		0.8	1.3		V
RS-232 Input Hysteresis	V_{CC} = 5V			1.8	2.4	V
RS-232 Input Resistance			0.2	0.5	1.0	V
TTL/CMOS Output Voltage Low	I_{OUT} = 3.2mA		3	5	7	kΩ
TTL/CMOS Output Voltage High	I_{OUT} = -1.0mA			0.2	0.4	V
TTL/CMOS Output Short-Circuit Current	Sourcing V_{OUT} = GND		3.5	V_{CC} - 0.2		V
	Shrinking V_{OUT} = V_{CC}		-2	-10		mA
			10	30		mA
TTL/CMOS Output Leakage Current	Normal operation, outputs disabled, Tables 1a–1d, 0V ≤ V_{OUT} ≤ V_{CC}, $\overline{ENR\_}$ = V_{CC}			±0.05	±0.10	µA

19-4323; Rev 9; 5/00

MAXIM

+5V-Powered, Multichannel RS-232 Drivers/Receivers

General Description

The MAX220–MAX249 family of line drivers/receivers is intended for all EIA/TIA-232E and V.28/V.24 communications interfaces, particularly applications where ±12V is not available.

These parts are especially useful in battery-powered systems, since their low-power shutdown mode reduces power dissipation to less than 5μW. The MAX225, MAX233, MAX235, and MAX245/MAX246/MAX247 use no external components and are recommended for applications where printed circuit board space is critical.

Applications

Portable Computers

Low-Power Modems

Interface Translation

Battery-Powered RS-232 Systems

Multidrop RS-232 Networks

Features

Superior to Bipolar

- ♦ **Operate from Single +5V Power Supply (+5V and +12V—MAX231/MAX239)**
- ♦ **Low-Power Receive Mode in Shutdown (MAX223/MAX242)**
- ♦ **Meet All EIA/TIA-232E and V.28 Specifications**
- ♦ **Multiple Drivers and Receivers**
- ♦ **3-State Driver and Receiver Outputs**
- ♦ **Open-Line Detection (MAX243)**

Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE
MAX220CPE	0°C to +70°C	16 Plastic DIP
MAX220CSE	0°C to +70°C	16 Narrow SO
MAX220CWE	0°C to +70°C	16 Wide SO
MAX220C/D	0°C to +70°C	Dice*
MAX220EPE	-40°C to +85°C	16 Plastic DIP
MAX220ESE	-40°C to +85°C	16 Narrow SO
MAX220EWE	-40°C to +85°C	16 Wide SO
MAX220EJE	-40°C to +85°C	16 CERDIP
MAX220MJE	-55°C to +125°C	16 CERDIP

Ordering Information continued at end of data sheet.

Contact factory for dice specifications.

Selection Table

Part Number	Power Supply (V)	No. of RS-232 Drivers/Rx	No. of Ext. Caps	Nominal Cap. Value (μF)	SHDN & Three-State	Rx Active in SHDN	Data Rate (kbps)	Features
MAX220	+5	2/2	4	0.1	No	—	120	Ultra-low-power, industry-standard pinout
MAX222	+5	2/2	4	0.1	Yes	—	200	Low-power shutdown
MAX223 (MAX213)	+5	4/5	4	1.0 (0.1)	Yes	✔	120	MAX241 and receivers active in shutdown
MAX225	+5	5/5	0	—	Yes	✔	120	Available in SO
MAX230 (MAX200)	+5	5/0	4	1.0 (0.1)	Yes	—	120	5 drivers with shutdown
MAX231 (MAX201)	+5 and +7.5 to +13.2	2/2	2	1.0 (0.1)	No	—	120	Standard +5/+12V or battery supplies; same functions as MAX232
MAX232 (MAX202)	+5	2/2	4	1.0 (0.1)	No	—	120 (64)	Industry standard
MAX232A	+5	2/2	4	0.1	No	—	200	Higher slew rate, small caps
MAX233 (MAX203)	+5	2/2	0	—	No	—	120	No external caps
MAX233A	+5	2/2	0	—	No	—	200	No external caps, high slew rate
MAX234 (MAX204)	+5	4/0	4	1.0 (0.1)	No	—	120	Replaces 1488
MAX235 (MAX205)	+5	5/5	0	—	Yes	—	120	No external caps
MAX236 (MAX206)	+5	4/3	4	1.0 (0.1)	Yes	—	120	Shutdown, three state
MAX237 (MAX207)	+5	5/3	4	1.0 (0.1)	No	—	120	Complements IBM PC serial port
MAX238 (MAX208)	+5	4/4	4	1.0 (0.1)	No	—	120	Replaces 1488 and 1489
MAX239 (MAX209)	+5 and +7.5 to +13.2	3/5	2	1.0 (0.1)	No	—	120	Standard +5/+12V or battery supplies; single-package solution for IBM PC serial port
MAX240	+5	5/5	4	1.0	Yes	—	120	DIP or flatpack package
MAX241 (MAX211)	+5	4/5	4	1.0 (0.1)	Yes	—	120	Complete IBM PC serial port
MAX242	+5	2/2	4	0.1	Yes	✔	200	Separate shutdown and enable
MAX243	+5	2/2	4	0.1	No	—	200	Open-line detection simplifies cabling
MAX244	+5	8/10	4	1.0	No	—	120	High slew rate
MAX245	+5	8/10	0	—	Yes	✔	120	High slew rate, int. caps, two shutdown modes
MAX246	+5	8/10	0	—	Yes	✔	120	High slew rate, int. caps, three shutdown modes
MAX247	+5	8/9	0	—	Yes	✔	120	High slew rate, int. caps, nine operating modes
MAX248	+5	8/8	4	1.0	Yes	✔	120	High slew rate, selective half-chip enables
MAX249	+5	6/10	4	1.0	Yes	✔	120	Available in quad flatpack package

For free samples and the latest literature, visit www.maxim-ic.com or phone 1-800-998-8800. For small orders, phone 1-800-835-8769.

National Semiconductor

August 2000

LM158/LM258/LM358/LM2904 Low Power Dual Operational Amplifiers

General Description

The LM158 series consists of two independent, high gain, internally frequency compensated operational amplifiers which were designed specifically to operate from a single power supply over a wide range of voltages. Operation from split power supplies is also possible and the low power supply current drain is independent of the magnitude of the power supply voltage.

Application areas include transducer amplifiers, dc gain blocks and all the conventional op amp circuits which now can be more easily implemented in single power supply systems. For example, the LM158 series can be directly operated off of the standard +5V power supply voltage which is used in digital systems and will easily provide the required interface electronics without requiring the additional ±15V power supplies.

The LM358 is also available in a chip sized package (8-Bump micro SMD) using National's micro SMD package technology.

Unique Characteristics

- In the linear mode the input common-mode voltage range includes ground and the output voltage can also swing to ground, even though operated from only a single power supply voltage.
- The unity gain cross frequency is temperature compensated.
- The input bias current is also temperature compensated.

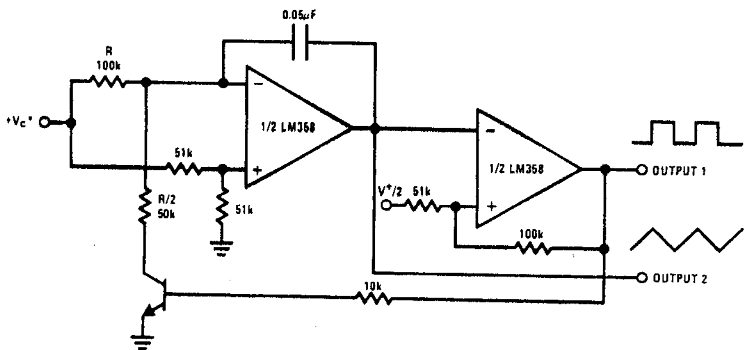
Advantages

- Two internally compensated op amps
- Eliminates need for dual supplies
- Allows direct sensing near GND and V_{OUT} also goes to GND
- Compatible with all forms of logic
- Power drain suitable for battery operation
- Pin-out same as LM1558/LM1458 dual op amp

Features

- Available in 8-Bump micro SMD chip sized package, (See AN-1112)
- Internally frequency compensated for unity gain
- Large dc voltage gain: 100 dB
- Wide bandwidth (unity gain): 1 MHz (temperature compensated)
- Wide power supply range:
  - Single supply: 3V to 32V
  - or dual supplies: ±1.5V to ±16V
- Very low supply current drain (500 µA)—essentially independent of supply voltage
- Low input offset voltage: 2 mV
- Input common-mode voltage range includes ground
- Differential input voltage range equal to the power supply voltage
- Large output voltage swing: 0V to $V^+ - 1.5V$

Voltage Controlled Oscillator (VCO)



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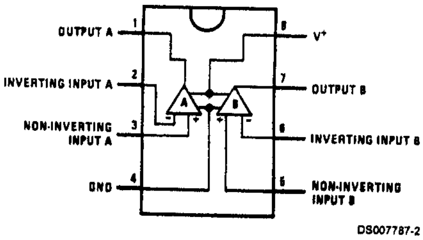
Connection Diagrams (Continued)

DIP/SO Package



Top View

Ordering Information

Package	Temperature Range				NSC Drawing
	−55°C to 125°C	−25°C to 85°C	0°C to 70°C	−40°C to 85°C	
SO-8			LM358AM LM358AMX LM358M LM358MX	LM2904M	M08A
8-Pin Molded DIP			LM358AN LM358N	LM2904N	N08E
8-Pin Ceramic DIP	LM158AJ/883(Note 11) LM158J/883(Note 11) LM158J LM158AJLQML(Note 12) LM158AJQMLV(Note 12)				J08A
TO-5, 8-Pin Metal Can	LM158AH/883(Note 11) LM158H/883(Note 11) LM158AH LM158H LM158AHLQML(Note 12) LM158AHLQMLV(Note 12)	LM258H	LM358H		H08C
8-Bump micro SMD			LM358BP LM358BPX		BPA08AAA

Note 11: LM158 is available per SMD #5962-8771001
LM158A is available per SMD #5962-8771002

Note 12: See STD Mil DWG 5962L87710 for Radiation Tolerant Devices