DESIGN AND DEVELOPMENT OF A CONTROLLER FOR SWITCHING SOLAR BASED MULTIPLE PUMPS

A Project submitted to the

Dept. of Electrical & Electronic Engineering, BRAC University in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering

By

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Declaration

We do hereby declare that the project titled **"design and development of a controller for switching solar based multiple pumps"** is submitted to the Department of Electrical and Electronics Engineering of BRAC University in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronics Engineering. This is our original work and has not submitted elsewhere for the award of any other degree or diploma.

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Abstract

Conventional photovoltaic systems for pumping are designed with panel capacity over 30 to 40 percent so that pumping can be continued during low insulation. This adds much to the cost of such system. The new system eliminates over capacity requirement of PV modules by using a combination of pumps where load become variable with the change of PV power output. This developed system continues pumping even during low solar isolation. Directly fed DC motors drive the pumps to avoid design complexity and eliminate battery and its maintenance cost. The designed system is superior to existing system, increasing the water output for the same installed PV module capacity. The objective of this project is to develop a controller for switching the pumps for reasons described above. The controller will be designed with the microcontroller and electronic switch. The input of the controller will be the power from solarpanel and the output will be the number of pumps to be switched depending on the isolation.

Table of Contents

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Chapter1

Introduction

1.1Background

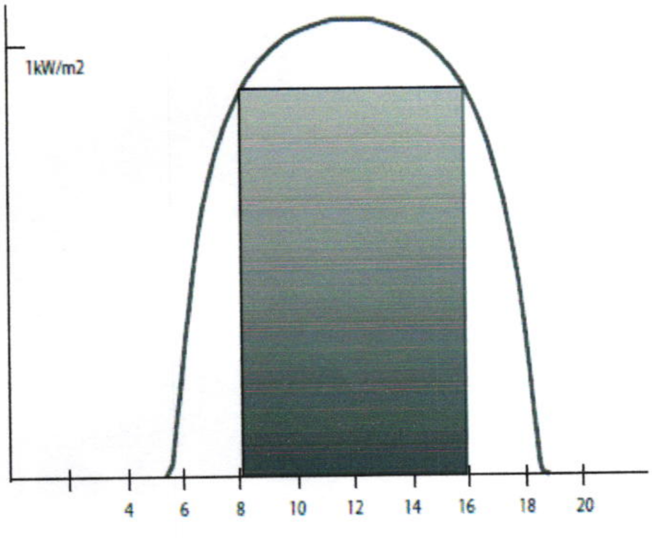
The operation of solar powered pump is more economical mainly due to lower operation and maintenance costs, most importantly more environment friendly than pumps powered by an internal combustion engine (ICE). This type of photovoltaic powered pumps especially very convenient for Bangladesh, a developing country of south east Asia with large population has agricultural economy. About fifty nine percent of cultivable lands need irrigation. During dry season and due to climate change demand of electricity for irrigation is increasing day by day. Grid current is also not available in many rural areas. Due to shortage of electricity it is difficult to meet the demand. Use of solar power is a good alternative to grid electricity.

Running DC pumpsin contrast to AC pumps using solar power is more convenient as from solar panel we get direct current. So, there is no need of AC to DC converter which effectively reduces the costs of the system and also the maintenance costs.

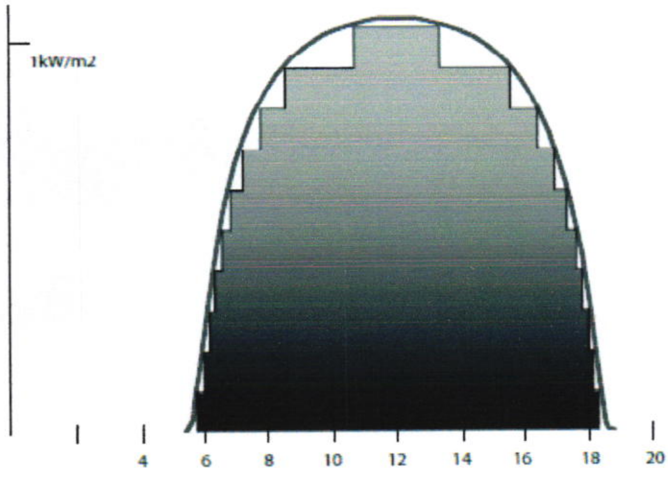
The Proposed System

Performance of a solar PV system is affected by availability of solar radiation. The available solar radiation is a function time of the day and the site selected. Optimal performance of a solar PV system depends upon how well these two factors are considered while designing the system. The hourly variation of irradiance at a site is represented by a bell shaped curve as shown in Fig. 1(a). In conventional solar irrigation system the pumps are selected according to the near-to-maximum sunshine availability Therefore, under low sun shine condition, the pumps stand as over rated, hence, can not be operated. On the other hand, during high sun shine the extra solar power is unutilized. The proposed system overcome the problem by using multiple pumps with different capacities and by switching the pumps intelligently. A simple rule based switching algorithm isdeveloped for the purpose. Based on the availability of sunshine the pump controller decides which set of pumps to operate. The availability of sunshine is measured indirectly by measuring the terminal voltage of the PV modules. The control algorithm requires that the combined pump-motor characteristics be known beforehand The concept may be clarified more through an example Considering a setup consisting of four pumps having rating of 1, 2, 4 and 8 hp. Depending on availability of solar power, e.g. in the early morning, only one pump with 1 hp motor may be operated. On the other hand at mid day when full sunshine may be available all four pumps having a total of 15 hp can be operated. In the intermediate conditions, the number of pumps of varying capacity may be operated depending on the solar power available at a particular time so that the photovoltaic output of solar panel is utilized to the maximum. This results in the maximum possible water being pumped. But with the conventional system, the pump can be operated only a portion of the day and if one wants toincrease the duration of use, one has to increase the panelsize. The solar energy utilization capability of theconventional and the proposed pumping system is shown Fig 1.

This adds much to the cost of such systems. The project implemented with the financial support of Bangladesh Academy of Sciences in the place of land owner farmer Abdus Salam of Bamunsur near Ati Bazar Karaniganj. The established system eliminates over capacity requirements of PV modules by using a combination of pumps where the load become variable with the change of PV power output.



Figure(a)



(b)

Fig. 1 Solar energyy utilization of conventional and proposed pumping system (a) conventional, (b) proposed

The system setup of the proposed system is presented in Fig. 1.1. The proposed system depends for its performance on intelligent switching of multiple pumps. DC motors are used instead of ac motors as used in conventional solar irrigation system. Use of dc motors avoids system complexity by eliminating batteries and inverters. The motors are fed directly from the PV modules. The higher cost of dc motors over ac motors are more than compensated by the elimination of batteries and inverters. A microcontrollerbased switching circuit is used to switch the pumps on or based switching circuit is used to switch the pumps on or based switching circuit is used to switch the pumps on or off. With series parallel combination of solar panels, solar power at desired voltage and current is fed into the terminalof a switching device that switches on oroff the motors.

The system set up of the proposed system is presented in Figure 1

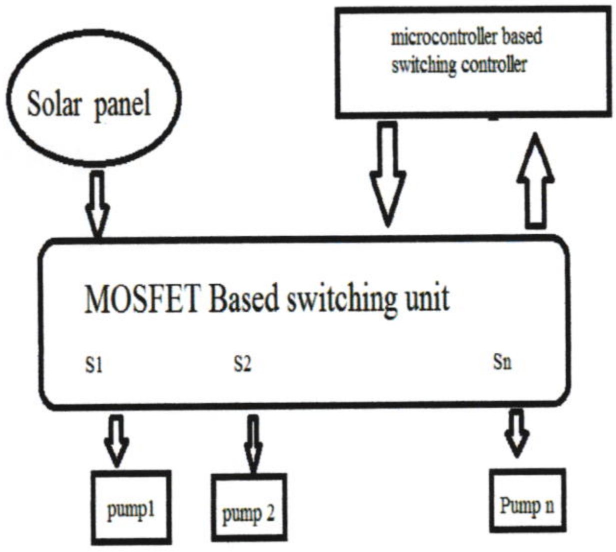


Figure 1.1

In this developing Project We have tried to develop a Microcontroller based Electronic Switch to turn off/on the motors which is done manually in this implemented project.

1.2 Literature Review

Bangladesh is suffering from acute shortage of electricity -to overcome the crisis, Government is mulling developing atomic energy and also utilizing other sources.

Under the crisis, an alternative source of energy is expanding in Bangladesh specially in rural Bangladesh -the solar energy in the absence and inadequacy of continuous supply of electricity to the rural people.

Solar energy is a renewable energy without causing pollution to the environment.

Present System

Solar PV modules produce direct current (DC) power. But alternating current (AC) motor-pumps are generally used for pumping purposes, therefore, a DC-AC converter called 'inverter' is needed to convert power of solar panel from DC to AC. PV power output is non-linear and time-dependent that changes with change in solar irradiance throughout a day, as well as solar cell temperature . The pump runs only when the available photovoltaic (PV) power is sufficient to drive the motor and compensate the loss of the inverters. If the generated PV output falls short of the power requirement by the motor due to a low light condition, the motors of the pumps stall. Since the optimal performance of a pumpdriven by a motor depends on the PV panel configurationan overcapacity of solar panels is generally maintained, even though it is by far the most expensive component in a PV pumping system. In such a system design, the excess solar power available at times is not generally utilized.

The proposed system uses multiple pumps of different dimensions, and utilizes intelligent switching to operate the pump motors so that the photovoltaic output of solar panel is utilized to the maximum.

The Present Fuzzy Based Switching Controller

Fuzzy theory is a science closely related to our lives. Because it describes things with language, it is easy to accept. In real life, most descriptions are fuzzy. For example, when we say “sweet fruit” or “drive fast” sweet and fast are not accurate values but simply a description of the degree. However, people can easily understand the meaning from the description.

The input of a common controller is a specific numeric value, but the knowledge base for fuzzy control is expressed with language. The system must turn numeric values into language and corresponding domains to allow the fuzzy interface engine to interface. This transformation is called fuzzification.

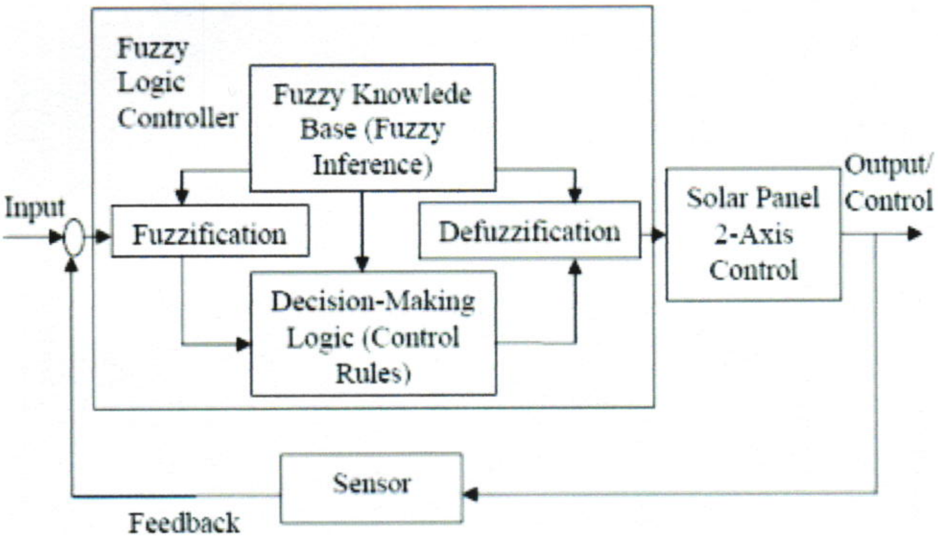


Fig Fuzzy Based Switching Controller

The present system is very complex and expensive comapared to our proposed microcontroller based switching controller.

The Proposed Microcontroller Based switching Controller

Now a days use of microcontroller in various projects is increasing because of its availability, low cost and easy application.

A huge range of different microcontrollers are available in the market of different companies from where we can choose the right one.Application of all kinds microcontrollers are more or less similar. So if one has idea about one kind of microcontroller , he or she should not face any problem to work with different types of microcontroller. To develop this electronic switch we have used very common electrical equipments like relay, regulators which made this project easy to understand for engineers.

For the simulation Purpose we used a small 10 watt solar panels. The specifications are-

Peak power at 16.4(min pdl)-10w.

- Voltage(v mp)-17v
- Current(I mp)-0.6amp
- Open circuit voltage-21.8V
- Short circuit current-0.7A.
- Minimum bypass diode-1A
- series fuse Max -1A

1.3 Objectives

We have worked on developing a microcontroller based electronic switching system to turn on/ off the DC motors based on solar isolation. In the implemented project **"**A Low Cost Multiple Motor Switched PV **Powered Irrigation System"** described in previous chapter (1.1), according to the solar isolation, switching of the DC motors had been done manually using man power whereas in this developed project switching of motors will be done automatically by an electronic switch which have been developed in this project work. During the whole process , our main objective was keeping the project simple , decreasing the cost and make it environment friendly. We used components like solar panel, microcontrollers which are easily available now-a-days. The uprising electronic switch is designed for irrigation purpose , our main concentration was on lowering the cost as much as possible, as most of our farmers are very poor so that they can afford it . Moreover, no use of grid electricity and use of renewable energy adds much to the national economy and pollution free environment.

Chapter _ 02

2.1 Methodology

2.1.1 Component Used

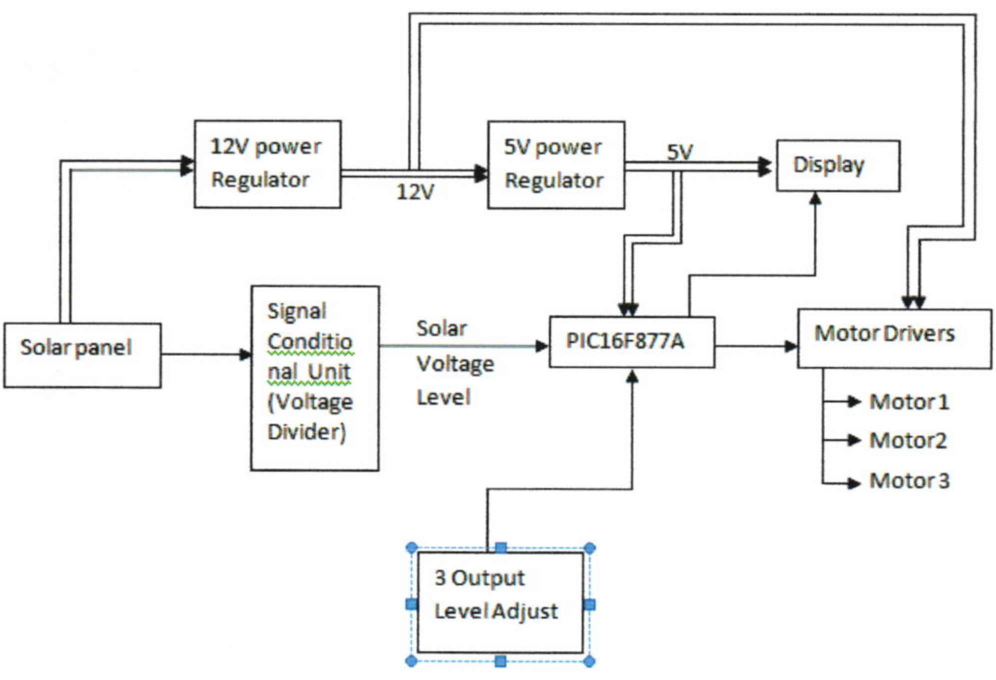
10 W Solar panel, LCD display, electronic Relay Module, three 12v DC motors ,potentiometer, regulators, passive components, bread board etc.

All components of the proposed system arepurchased locally.

2.1.2 Circuit design

For simulation purpose we have used 10 watt solar panel to run three 12V DC motors .12 v DC motors are used as the alternative or dc pumps in the lab. In the field DC pumps will be used. The proposed system is shown in Figure 2.1

The Block Diagram



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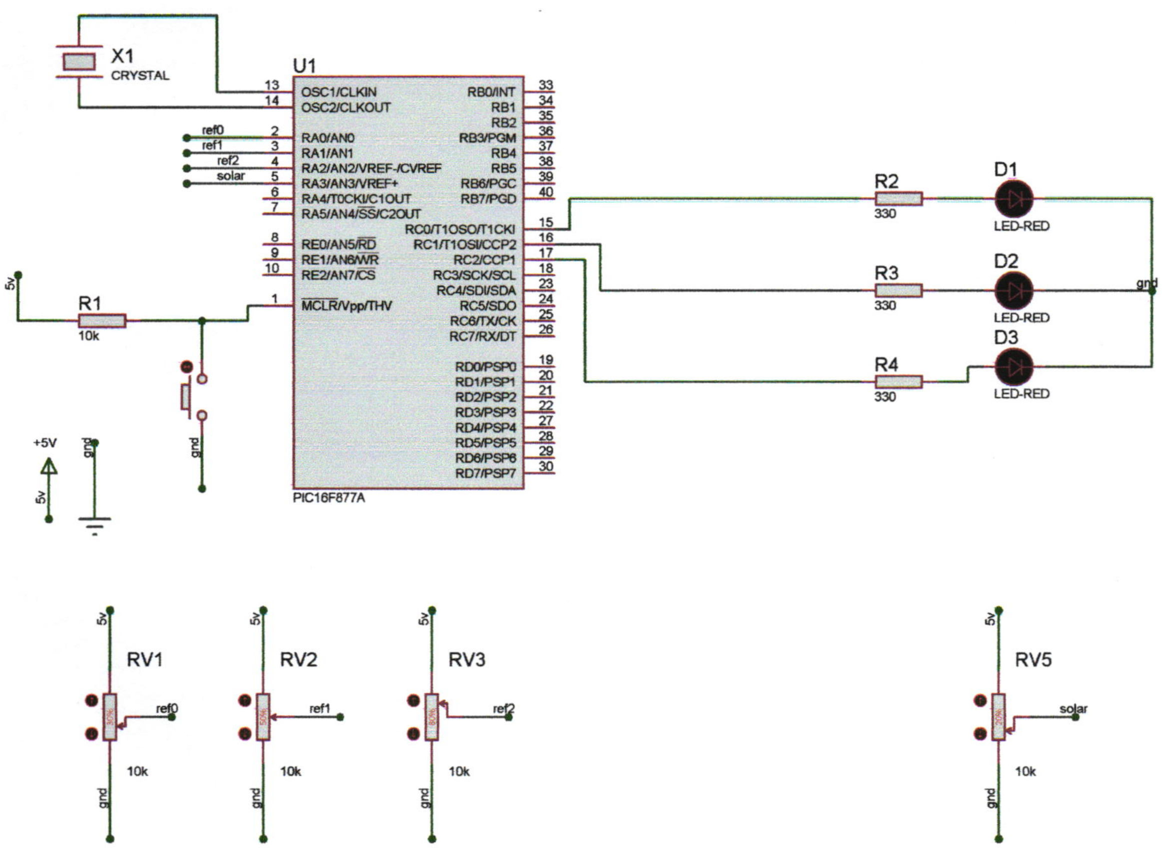


Solar panel open circuit voltage 21.6V . Solar panel provides signal to the signal conditional unit(voltage divider). This signal conditioning unit(voltage divider) is used to scale down the panel voltage which is used as source of signal flow for the microcontroller.

Voltage Divider Rule:

voltage divider (also known as a **potential divider**) **Voltage division** refers to the partitioning of a voltage among the components of the divider. An example of a voltage divider consists of two resistors in series or a potentiometer. It is commonly used to create a reference voltage, or to get a low voltage signal proportional to the voltage to be measured.

For these case we have used combination of two resistances which is 10 K and 47 k which are scaling down the panel voltage into 3.68 V serving as a signal source of the PIC16F877A microcontroller. So microcontroller is taking eighty percent Voltage from voltage divider as it can take highest 5 Volts .During Peak hours we are taking 20V input from solar panel and three out level set points of from the potentiometer through ADC channel of the microcontroller.

In this case, we are using a LM7805 and LM7812, which outputs 5 volts and 12V respectively. In order for the regulator to output 12 volts, the voltage entering is around 20 volts which comes from solar panel during peak hours. The output 12volts coming from LM7812 acts as a input for LM7805.

If we give direct power from solar to 5 V regulator, power loss will be higher. To avoid high power loss, we used 2 regulators 7812 and 7805.We add them in series to reduce power dissipation. The output of the 7805 regulator supplies power flow to the LCD to display voltages visually.

Again, The output of the 7805 regulator supplies power the motor driver (relays) to run the three DC motors. We are also using Three potentiometer to adjust the set points voltage level of the bands.

A **potentiometer** informally a **pot**, is a three-terminal resistor with a sliding or rotating contact that forms an adjustable voltage divider.[1] If only two terminals are used, one end and the wiper, it acts as a ***variable resistor*** or ***rheostat***

A potentiometer measuring instrument is essentially a voltage divider used for measuring electric potential (voltage); the component is an implementation of the same principle

The main challenging thing of this project is the power source (Solar panel) and voltage level the set points of the bands both are variable. We didn't put any built in set points in the microcontroller programming. The sets point of three voltage levels will be done automatically according to the reference point which comes from solar panel. We have done these using three potentiometers.

2.1.3 Microcontroller

A **microcontroller** (sometimes abbreviated **μC**, **uC** or **MCU**) is a small computer on a single integrated circuitcontaining a processor core, memory, and programmable input/output peripherals. Program memory in the form of NOR flash or OTP ROM is also often included on chip, as well as a typically small amount of RAM. Microcontrollers are designed for embedded applications, in contrast to themicroprocessors used in personal computers or other general purpose applications.

The proposed switching controller samples voltage from the terminal of solar panel and depending upon the voltage level number of pumps are turned on or switched off. For this proposed project we have used PIC 16F877A to introduce our electronic switching circuit.

PIC 16F877A 256 bytes EEPROM ,368 byte RAM, up to 8K * 14 words of flash program memory, 8 channel 10 bit ADC.

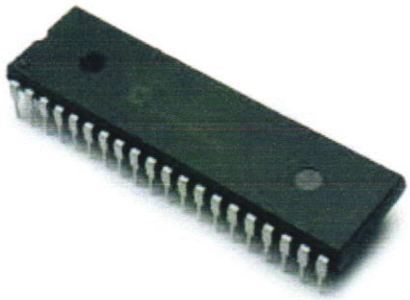


Fig 2.1- PIC 16F877a

PIC is a family of modified Harvard architecture microcontrollers made by microchip technology ,derived from 1650 originally developed by general instrument microelectronic division. The name PIC initially referred to "Peripheral Interface Controller" . Now it is PIC only.

PICS are both popular with industrial developers and hobbyists alike due to their low costs, large user base, extensive collection of application notes, availability of low cost or free development tools and serial programming (and re programming flash memory capability.

For " The design and development of a controller for switching multiple pumps" we have used PIC 16F877A microcontroller which is one of the popular PIC microcontroller and it has many internal peripherals.

The 40 pin make it easier to use the peripherals as the function are spread out over the pins. It make it easier to decide which external device to attach without worrying too much as there is enough pins to do the job. One of the main advantage is that each pin is only shared between only two or three functions so its easier to decide what the pin function whereas other device has up to 5 function for a pin.

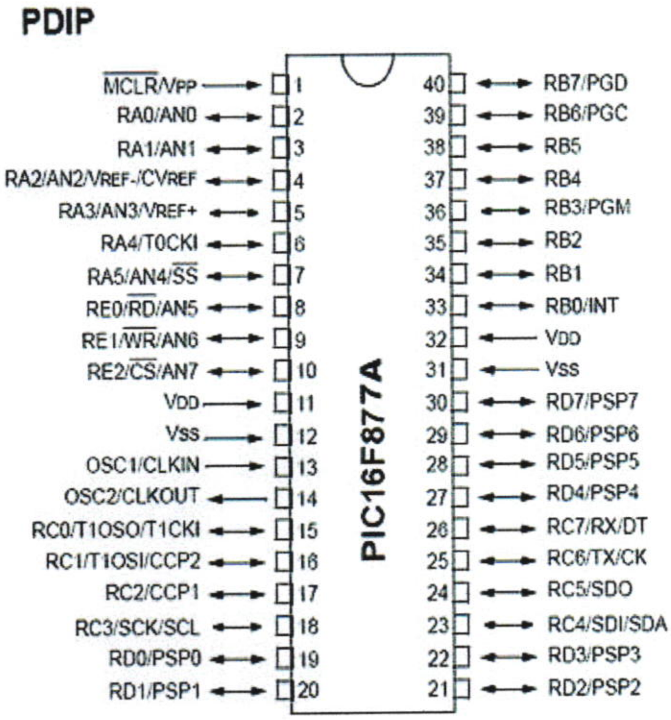


Fig 2.2(Pin Out Diagram of PIC 16F877A)

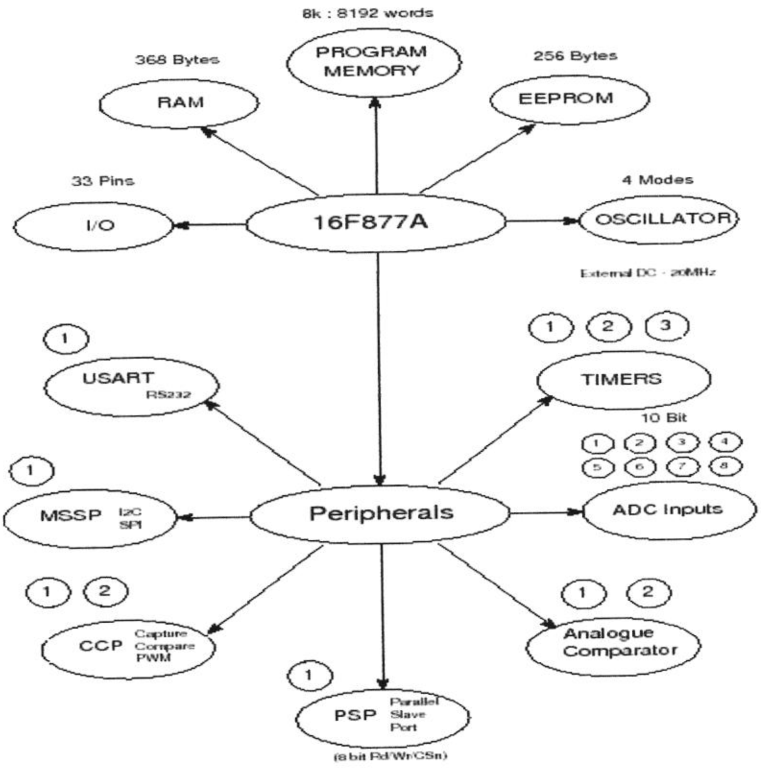


Figure : peripherals of a microcontroller

We are using Solar energy as power supply which give analog signal but Microcontrollers understands only digital signal. We don't need much computing power for the respective project. Lastly, as it is a undergraduate thesis project not done by the professionals modifications are needed to be done several times. Keeping these points in our mind, the main criteria for choosing microcontroller were-

- ✓ **Ac to DC converter (to convert analog to digital signal)**
- ✓ **Flash memory**

PIC 16F877a fulfills all the features mentioned above. It has 10 bit analog to digital converter (8 input channels) .

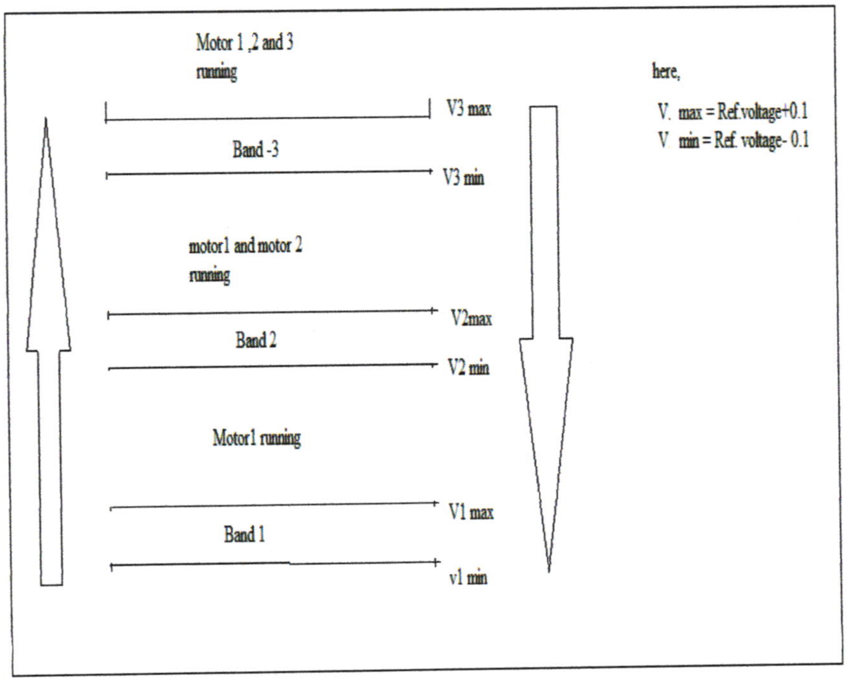
2.1.4 Microcontroller Programming

The microcontroller PIC16F877A programmed in Mic**roC. MicroC/OS-II** (commonly termed as **μC/OS-II** or **uC/OS-II**), is the acronym for Micro-Controller Operating Systems Version 2. It is a priority-based pre-emptive real-time multitasking operating system kernel for microprocessors, written mainly in theC programming language. It is intended for use in embedded systems. Its features are:

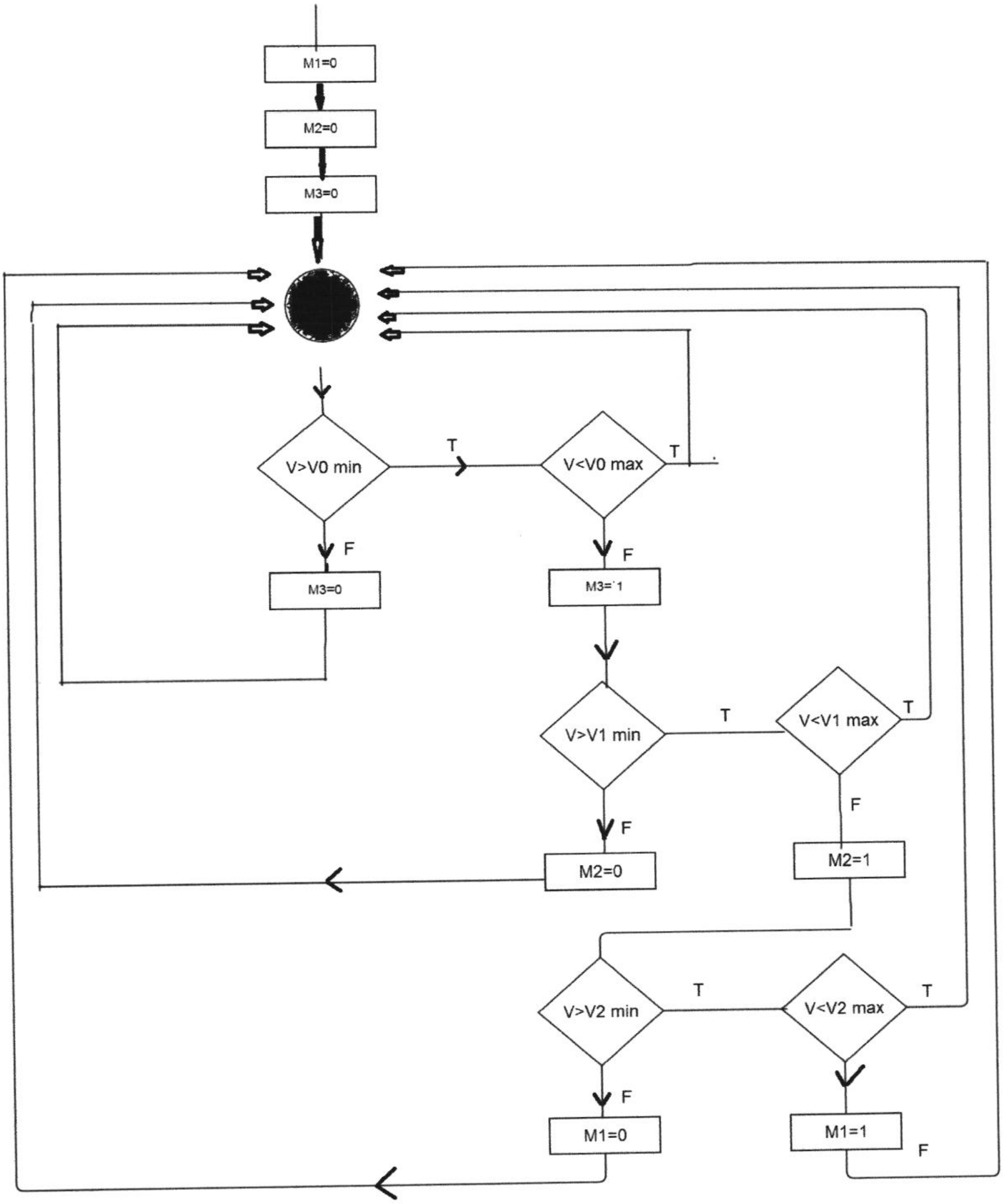
- It is a very small real-time kernel.
- Memory footprint is about 20KB for a fully functional kernel.
- Source code is written mostly in ANSI C.
- Highly portable, ROMable, very scalable, preemptive real-time, deterministic, multitasking kernel.

- It can manage up to 64 tasks (56 user tasks available).
- It has connectivity with μC/GUI and μC/FS (GUI and File Systems for μC/OS II).
- It is ported to more than 100 microprocessors and microcontrollers.
- It is simple to use and simple to implement but very effective compared to the price/performance ratio.
- It supports all type of processors from 8-bit to 64-bit.

In the respective project , multiple motors are operated based on power we get from solar panel. While programming the microcontroller we used the concept of bands instead of constant voltage to avoid jittering affect . Without these concept of bands switching of the motors will be so rapid which could cause harm both microcontroller and the motors. We didn't put any built in values for the set point of the bands. The programming is done in a way that the set points of the voltage levels will be set automatically according to the reference voltage comes from solar panel.



Inside the bands the number of motor running is constant. For example , when the reference voltage is between band 1 no motor will be zero. Again, when the reference voltage remain in band two number or motor working is one not two. When, the voltage level would be high from the range of band 2 , two motors will be turned on. Same principle works for switching three motors and vice versa. To conclude, inside the bands the number of motor running are constant.



M1=0
M2=0
M3=0
V>V0 min
T
V<V0 max
T
F
M3=0
F
M3=`1
V>V1 min
T
V<V1 max
T
F
F
M2=0
M2=1
V>V2 min
T
V<V2 max
T
F
M1=0
M1=1
F

2.1.5 Relay connections

We have measured the power from solar panel gives severel times during day time.Normal DC gear-head motors requires current greater than 250mA. ICs like 555 timer, ATmega16 Microcontroller, 74 series ICs cannot supply this amount of current. If we directly connect motors to the output of any of the above IC's, they might get damaged.

There is a need of a circuitry that can act as a bridge between the above mentioned ICs and the motors. There are several ways of making it, some of them are mentioned below.

Using Transistor

Using L293D/L298

Using relays.

We have used 4 channel relay module board.

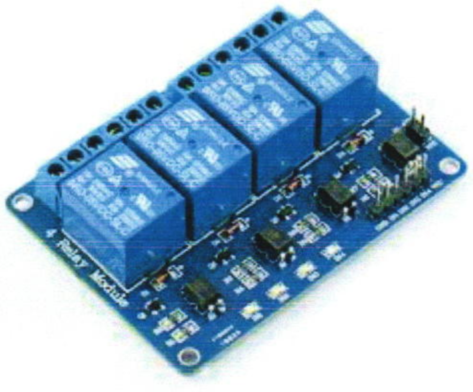
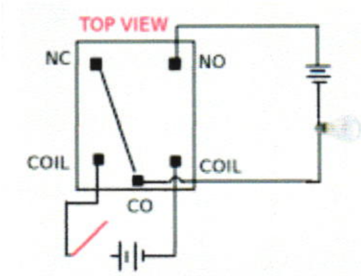


Fig: Relay module

Relays are electromechanical switches. They have very high current rating and both AC and DC motors can be controlled through them because motor will be completely isolated from the remaining circuit.

Working of a relay : Relays consist of a electromagnet, armature, spring and electrical contacts. The spring holds the armature at one electrical contact and as soon as a voltage is applied across the electromagnet, it coils the armature, changes its contact and moves to another electrical contact. The figure below describes its working.



Working of relay

Terms associated with relays:

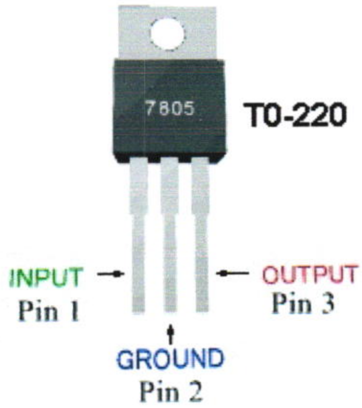
- **Normally Open (NO):** contacts connect the circuit when the relay is activated; the circuit is disconnected when the relay is inactive.
- **Normally Closed(NC):** contacts disconnect the circuit when the relay is activated; the circuit is connected when the relay is inactive.
- **Change Over (CO):** Its the common contact.
- **COIL:** Its the electromagnet coil inside relay.

Relay connection

- Vcc and ground for power supply for relay.
- For driving 3 motor we used channel 1, channel 2, channel 3. When we give 0, common point and no change ports are shorted. That means relay is OFF. When we give 1, no and common points are shorted. Which make the relay on. And according to the power supply motor started driving. According to the specification of the motor, the length of wine will be increase or decrease.

2.1.6 Regulators

Depending on the voltage regulator in use, we can get a regulated positive or negative voltage, at whichever voltage we want. The LM78XX voltage regulators are a popular kind for regulating and outputting positive voltage, while the LM79XX are a popular series of regulators for negative voltage. In this project, we used two positive voltage regulators, which output 5V, the LM7805 regulator and 12V , the LM7812 regulator.



A voltage regulator is a 3-terminal device.

Pin 1 is the Input Pin. The output voltage of whatever voltage source we want to regulate down (whether it's a transformer, battery, solar panel etc.) is fed into this pin. So for instance, if 10 volts coming from a transformer that we want regulated down to 5 volts, the output of the transformer (the 10 volts) is fed into the regulator input (pin 1) so that the regulator can regulate it down to wanted voltage (5 volts). The voltage regulator should always be fed as smooth of a DC signal as possible (which gives the best regulated output) so it can regulate it down to its specified voltage. The input voltage has to be larger than the voltage that the regulator regulates out.

Pin 2 is Ground. It hooks up to the ground in our circuit. Without ground, the circuit couldn't be complete because the voltage wouldn't have electric potential and the circuit wouldn't have a return path. Ground is essential.

Pin 3 is the Output Pin.

In this case, we are using a LM7805 and LM7812, which outputs 5 volts and 12V respectively. In order for the regulator to output 12 volts, the voltage entering is around 20 volts which comes from solar panel during peak hours. The output 12volts coming from LM7812 acts as a input for LM7805.

2.1.7 Printed Circuit board

Finally we have Designed a Printed Circuit Board for more permanent look.

A **printed circuit board (PCB)** mechanically supports and electrically connects electronic components using conductive tracks, pads and other features etched from copper sheets laminated onto a non-conductive substrate. PCBs can be *single sided* (one copper layer), *double sided* (two copper layers) or *multi-layer*. Conductors on different layers are connected with plated-through holes calledvias. Advanced PCBs may contain components - capacitors, resistors or active devices - embedded in the substrate.

Printed circuit boards are used in all but the simplest electronic products. Alternatives to PCBs include wire wrap and point-to-point construction. PCBs require the additional design effort to lay out the circuit but manufacturing and assembly can be automated. Manufacturing circuits with PCBs is cheaper and faster than with other wiring methods as components are mounted and wired with one single part. Furthermore, operator wiring errors are eliminated.

inputs and guidance are most critical at the beginning of the layout process. The more information one can provide, and the more involvement are throughout the layout process, the better the board will turn out. Giving the designer interim completion points—at which we want to be notified of the layout progress for a quick review. This "loop closure" prevents a layout from going too far astray and will minimize reworking the board layout.

We have designed the PCB using Proteus software.

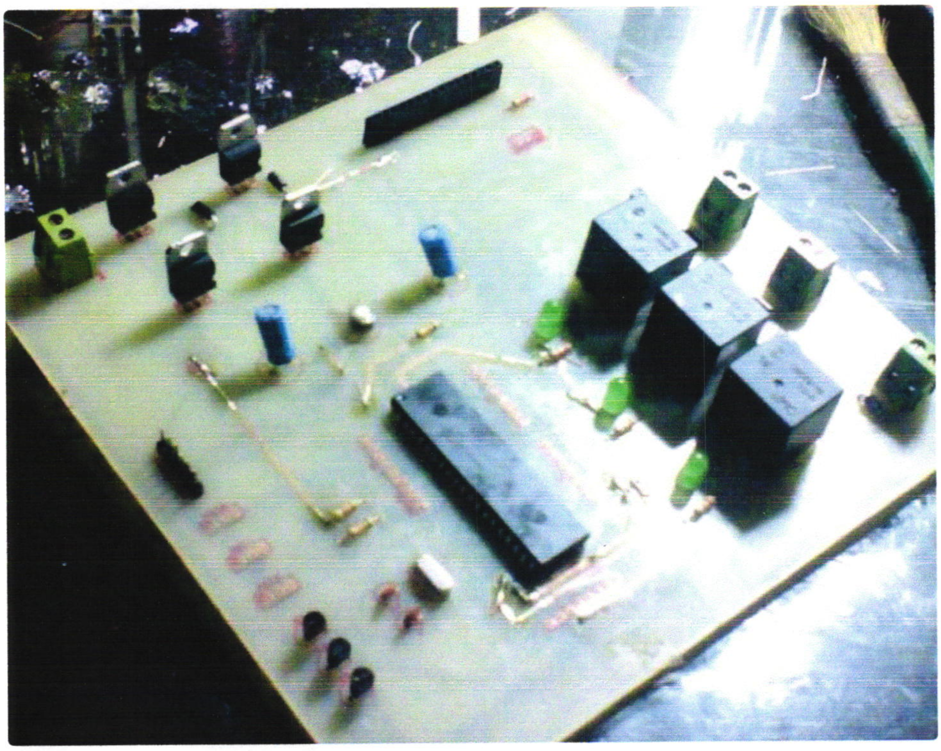


Figure : The printed Circuit Board

Chapter3

3.1 Conclusion:

A laboratory Model has been developed using Microcontroller for switching solar based multiple pumps. We have tried our best to demonstrate the concepts and its easy to visualize for engineers for implementing in real life.

3.2 Suggestions for further work

a. We have developed a laboratory model. This model can be implemented in real life.
b. We have used regulators to adjust voltage levels which causes some loss. Implement of Buck boost converter might give better results.

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[13]Microchip press release. "Microchip Technology Delivers 12 Billionth PIC® Microcontroller to Leading Motor Manufacturer, Nidec Corporation". 2013.

APPENDIX

Programming in C

```
// LCD module connections
sbit LCD_RS at RB4_bit;
sbit LCD_EN at RB5_bit;

sbit LCD_D4 at RB0_bit;
sbit LCD_D5 at RB1_bit;
sbit LCD_D6 at RB2_bit;
sbit LCD_D7 at RB3_bit;
```

```
sbit LCD_RS_Direction at TRISB4_bit;

sbit LCD_EN_Direction at TRISB5_bit;

sbit LCD_D4_Direction at TRISB0_bit;

sbit LCD_D5_Direction at TRISB1_bit;

sbit LCD_D6_Direction at TRISB2_bit;

sbit LCD_D7_Direction at TRISB3_bit;

// End LCD module connections


#define motor0 RC0_bit

#define motor1 RC1_bit

#define motor2 RC2_bit


#define motor_on 1

#define motor_off 0


#define max_solar_volt 21




void main(){
```

```
char ref0_txt[10];

char ref1_txt[10];

char ref2_txt[10];

char solar_txt[10];

char txt[10];


unsigned int ref0_adc, ref1_adc, ref2_adc, solar_adc;

float ref0_volt, ref1_volt, ref2_volt, solar_volt;

unsigned int band0_low,band0_high, band1_low,band1_high, band2_low,band2_high,
false_solar_adc;

unsigned int offset = 20;

int temp;


TRISC = 0;

PORTC = 0xff;


ADC_Init();

Lcd_Init();

Lcd_Cmd(_LCD_CURSOR_OFF);
```

```
while(1) {
  ref0_adc = ADC_Read(0);
  ref1_adc = ADC_Read(1);
  ref2_adc = ADC_Read(2);
  solar_adc = ADC_Read(3);

  ref0_volt = (float)(ref0_adc*max_solar_volt)/1023;
  ref1_volt = (float)(ref1_adc*max_solar_volt)/1023;
  ref2_volt = (float)(ref2_adc*max_solar_volt)/1023;
  solar_volt = (float)(solar_adc*max_solar_volt)/754;

 //display the voltages on lcd
************************************************************
   FloatToStr(ref0_volt, ref0_txt);
   FloatToStr(ref1_volt, ref1_txt);
   FloatToStr(ref2_volt, ref2_txt);
   FloatToStr(solar_volt, solar_txt);

 //for ref0
```

```
Lcd_Out(1,1, "First Threshold");

Lcd_Out(2,2, ref0_txt);

Delay_ms(800);


//for ref1

Lcd_Out(1,1, "Second Threshold");

Lcd_Out(2,2, ref1_txt);

Delay_ms(800);

Lcd_Cmd(_LCD_CLEAR);

Delay_ms(10);


  //for ref2

Lcd_Out(1,1, "Third Threshod");

Lcd_Out(2,2, ref2_txt);

Delay_ms(800);

Lcd_Cmd(_LCD_CLEAR);

Delay_ms(10);


//for solar

Lcd_Out(1,1, "Panel Voltage");
```

```
Lcd_Out(2,2, solar_txt);

Delay_ms(800);

Lcd_Cmd(_LCD_CLEAR);

Delay_ms(10);


//band calculation

//has to be in terms of ADC value

band0_low     = (ref0_adc - offset);

band0_high    = (ref0_adc + offset);

band1_low     = (ref1_adc - offset);

band1_high    = (ref1_adc + offset);

band2_low     = (ref2_adc - offset);

band2_high    = (ref2_adc + offset);
```