CHAPTER 2
SYSTEM DESIGN

The schematic representation of the system to be designed is given below.

Figure 2.1: Schematic Diagram
2.1. MODULE DESCRIPTIONS

SOLAR PANEL

A solar cell (also called a photovoltaic cell) is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect. It is a form of photoelectric cell, in which its electrical characteristics like current, voltage or resistance, vary when light is incident upon it. When exposed to light, it can generate and support an electric current without being attached to any external voltage source. A solar panel consists of large number of solar cells arranged in series-parallel combinations.

The solar cell works in three steps:

1. Photons in sunlight hit the solar panel and are absorbed by semiconducting materials, such as silicon.
2. Electrons (negatively charged) are knocked loose from their atoms, causing an electric potential difference. Current starts flowing through the material to cancel the potential and this electricity is captured. Due to the special composition of solar cells, the electrons are only allowed to move in a single direction.
3. An array of solar cells converts solar energy into a usable amount of direct current (DC) electricity.

WIND ENERGY

As wind does not blow all the time, solar and wind power alone are poor power sources. Hybridizing solar and wind power sources together with storage batteries to cover the periods of time without sun or wind provides a realistic form of power generation.

This variable feature of wind-turbine power generation is different from conventional fossil fuel, nuclear, or hydro-based power generation. Wind energy has become the least expensive renewable energy technology in existence and has peaked the interest of scientists world over.
A simple relationship exists relating power generated by a wind turbine and wind parameters

\[ P = 0.5 A C_p v g b \]

Where

A = rotor swept area

\( C_p \) = coefficient of performance

v = wind speed in m/sec

\( g \) = generator efficiency

b = gear box/bearings efficiency

**CONTROL UNIT**

By the block of Control Unit, we meant the overall control of the output from the PV and the charging control of the battery. The solar charge controller used in this module is Maximum Power Point Tracking solar charge controllers (MPPT). MPPT are different than the traditional PWM solar charge controllers in that they are more efficient and in many cases more feature rich. MPPT solar charge controllers allow your solar panels to operate at their optimum power output voltage, improving their performance by as much as 30%. Traditional solar charge controllers reduce the efficiency of one part of your system in order to make it work with another.

**RECTIFIER**

For supplying power to the inverter and for keeping the battery bank charged, rectifier circuit is needed. A rectifier circuit is used to convert the ac line supply to dc and a phase controlled rectifier can be used for this purpose. When an electrical isolation from the mains is required, it is possible to use a dc-dc converter with a high-frequency isolation transformer.
BATTERIES

There are many different types of battery systems. Of these, the conventional lead-acid batteries are commonly used for the UPS applications. In the normal mode when the line voltage is present, the battery is trickly charged to offset the slight self-discharge by the battery. This requires that a constant trickle charge voltage be applied across the battery, and the battery continuously draws a small amount of current, thus maintaining itself in a fully charged state.

In the event of a line outage, the battery is expressed in ampere-hours, which is the product of a constant discharge current and the duration beyond which the battery voltage falls below the final discharge voltage. The battery voltage should not be allowed to fall below the final discharge voltage level; otherwise the battery life is shortened.

Once the line voltage is restored, the battery bank is brought back to its fully charged state. This causes the battery terminal voltage to increase to its trickle charge voltage level. Once it is reached the voltage applied is kept constant and the charging current finally decreases to the trickle charge current and stays at that level. It is possible to program the battery-charging characteristic to bring it to a full-charge state more quickly.

INVERTERS

It is desirable to use the PWM dc-to-ac inverters, with either a single-phase or three-phase ac output. An isolation transformer is generally used at the output.

FILTER

It is important to minimize the harmonics content of the inverter output. The filtered output of the inverter is normally specified to contain very little harmonic distortion, even though most loads are highly nonlinear and, hence, inject larger harmonic currents into charger circuit.
CHAPTER 3
CIRCUIT IMPLEMENTATION

The circuit mainly consists of microcontroller, power supply, LCD, charger, battery, and inverter section. We use PIC16F877A as microcontroller. Here the input is from main supply or from solar or from wind. Our aim is to charge the battery using solar. If the solar is not available, charge the battery using wind. If both are not available, then by main supply.

Microcontroller stores the program for selecting the charger input according to the availability, determines the mode of charging and checks the battery voltage. The LCD is used to display the voltage variations and the battery conditions. Here 2*16 LCD is used. When solar voltage is greater than a particular threshold, the battery will be charged using the solar energy. Is solar is not available, the battery will be charged using the wind. When none of the sources are available, then by main supply. Relay is used to switch the mode of charging. A relay is an electrically operated switch. Many relays use an electromagnet to operate a switching mechanism.

The circuit representation of the system includes two sections:

- Microcontroller Circuit
- Inverter Circuit
3.1. MICROCONTROLLER CIRCUIT

This circuit is intended to interface the LCD which shows the current status of the battery and available resources and to operate the relays correspondingly.

Figure 3.1: Microcontroller Circuit
3.2. INVERTER CIRCUIT

This circuit includes battery charging section and inverter section. The charger circuit gets excited according to the operated relay and thus stored power is inverted and the required ac supply is provided to the loads.

Figure 3.2: Inverter Circuit
CHAPTER 4
MICROCONTROLLER PROGRAMMING

The controller used is PIC16F877A. The program was burned in the microcontroller using PIC C and simulated in “PIC SIMULATOR IDE 6.83 PORTABLE”.

4.1 PROGRAM CODE

```c
#include <stdio.h>
#include<string.h>
#include <lcd.c>

float solar1,mains1,battery1,mains2,s1,s2,m1,m2,b1,b2,wind1,w1,w2,op1,op2;
long int a=255;
int i;

void main()
{
    setup_adc_ports(ALL_ANALOG);
    setup_adc(ADC_CLOCK_INTERNAL);
    setup_psp(PSP_DISABLED);
    setup_spi(FALSE);
    setup_timer_0(RTCC_INTERNAL|RTCC_DIV_1);
}
```

setup_timer_1(T1_DISABLED);
setup_timer_2(T2_DIV_BY_16, 127, 1);
setup_ccp1(CCP_PWM);

SET_TRIS_B( 0x00 );//B0,B1,B2,B3,B4,B5,B6,B7 - OUTPUT PINS
lcd_init();
lcd_putchar("f HYBRID
\nSOLAR CHARGER");
delay_ms(1000);

while(1)
{
    set_pwm1_duty(a);
    set_adc_channel(0);
delay_ms( 10 );
mains1 = read_adc();
lcd_gotoxy(0,2);
printf(lcd_putchar,"f Mains V=%f",mains1);
delay_ms(1000);

set_adc_channel(1);
delay_ms( 10 );
wind1 = read_adc();
lcd_gotoxy(0,2);
printf(lcd_putchar,"f Wind V=%f",wind1);
delay_ms(1000);

set_adc_channel(2);
delay_ms(10);
solar1 = read_adc();

lcd_gotoxy(0,1);
printf(lcd_putchar,"f Solar V=%f",solar1);
delay_ms(1000);

set_adc_channel(3);
delay_ms(10);
battery1 = read_adc();

lcd_gotoxy(0,1);
printf(lcd_putchar,"f Battery V=%f",battery1);
delay_ms(1000);

set_adc_channel(5);
delay_ms(10);
op2 = read_adc();

if(s2>=15 && w2>=8)
{
    OUTPUT_B(0x08);
    lcd_putc("f CH by Solar ");
    delay_ms(1000);

    if(op1>12)
    {
        for(i=0;op1<=12;i++)
        {
            set_pwm1_duty(a=a-20);
        }
    }
    else if(op1<12)
    {
        for(i=0;op1>=12;i++)
        {
            set_pwm1_duty(a=a+20);
        }
    }
    else if(s2>=15 && w2<=8)
    {
        OUTPUT_B(0x08);
    }
lcd_putc("f CH by Solar ");

delay_ms(1000);

if(op1>12)
{
    for(i=0;op1<=12;i++)
    {
        set_pwm1_duty(a=a-20);
    }
}
else if(op1<12)
{
    for(i=0;op1>=12;i++)
    {
        set_pwm1_duty(a=a+20);
    }
}
else if(s2<=15 && w2>=8 )
{
    OUTPUT_B(0x90);
    lcdputc("f CH by Wind ");
}
```c
delay_ms(1000);

if(op1>12)
{
    for(i=0;op1<=12;i++)
    {
        set_pwm1_duty(a=a-20);
    }
}
else if(op1<12)
{
    for(i=0;op1>=12;i++)
    {
        set_pwm1_duty(a=a+20);
    }
}
}
else if(s2<=15 && w2<=8 && m2>=180)
{
    OUTPUT_B(0x44);
    lcd_putc("CH by Mains ");
    delay_ms(1000);
    if(op1>12)
    {
```

for(i=0;op1<=12;i++)
{
  set_pwm1_duty(a=a-20);
}

else if(op1<12)
{
  for(i=0;op1>=12;i++)
  {
    set_pwm1_duty(a=a+20);
  }
}

else if (b2>=12)
{
  lcd_puts("No Charging");
  delay_ms(1000);
}
else if(b2>6 && b2<=8)
{
  OUTPUT_B(0x08);
  lcd_puts("Low Battery");
  delay_ms(1000);
}
else if (b2<6)
{
    OUTPUT_B(0x22);
    lcd_putchar("f Shut Down ");
    delay_ms(1000);
}
}
CHAPTER 5

DESIGN CRITERIA

Photovoltaic (PV) systems have been used for many decades. Today, with the focus on greener sources of power, PV has become an important source of power for a wide range of applications. Improvements in converting light energy into electrical energy as well as the cost reductions have helped create this growth. Even with higher efficiency and lower cost, the goal remains to maximize the power from the PV system under various lighting conditions.

Here, it is planned to design a hybrid solar charger with wind energy as the alternate source. The charger is supposed to meet the loads of an industry warehouse consisting a total load of 1576 Watts. For this purpose the different loads and its specifications were tabulated and total connected load were found.

<table>
<thead>
<tr>
<th>APPLIANCES</th>
<th>NO.</th>
<th>POWER(watts)</th>
<th>HOURS PER DAY</th>
<th>TOTAL Wh /DAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Tube</td>
<td>10</td>
<td>40</td>
<td>10</td>
<td>4000</td>
</tr>
<tr>
<td>2. CFL</td>
<td>12</td>
<td>18</td>
<td>24</td>
<td>5184</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td></td>
<td>10</td>
<td>3600</td>
</tr>
<tr>
<td>3. Fan</td>
<td>8</td>
<td>50</td>
<td>14</td>
<td>5600</td>
</tr>
<tr>
<td>4. Exhaust fan</td>
<td>8</td>
<td>25</td>
<td>13</td>
<td>2600</td>
</tr>
</tbody>
</table>

Table 5.1: Unit Consumption By Warehouse Loads
5.1. INVERTER UNIT

The solar inverter is a critical component in a solar energy system. It performs the conversion of the variable DC output of the Photovoltaic (PV) module(s) into a clean sinusoidal 50- or 60 Hz AC current that is then applied directly to the commercial electrical grid or to a local, off-grid electrical network. Typically, communications capability is included so users can monitor the inverter and report on power and operating conditions, provide firmware updates and control the inverter grid connection.

At the heart of the inverter is a real-time microcontroller. The controller executes the very precise algorithms required to invert the DC voltage generated by the solar module into AC. This controller is programmed to perform the control loops necessary for all the power management functions necessary including DC/DC and DC/AC. The controller also maximizes the power output from the PV through complex algorithms called maximum power point tracking (MPPT). The PV maximum output power is dependent on the operating conditions and varies from moment to moment due to temperature, shading, cloud cover, and time of day so tracking and adjusting for this maximum power point is a continuous process. For systems with battery energy storage, the controller can control the charging as well as switch over to battery power once the sun sets or cloud cover reduces the PV output power.

The controller contains advanced peripherals like high precision PWM outputs and ADCs for implementing control loops. The ADC measures variables, such as the PV output voltage and current, and then adjusts the DC/DC or DC/AC converter by changing the PWM duty cycle.

The C2000 in particular is designed to read the ADC and adjust the PWM within a single clock cycle, so real time control is possible. Communications on a simple system can be handled by a single processor, more elaborate systems with complex displays and reporting on consumption and feed-in-tariff pay back may require a secondary processor, potentially with Ethernet capability like the Stellaris Cortex M3 parts. For safety reasons, isolation between the processor and the current
and voltage is also required, as well as on the communications bus to the outside world.

5.2. CONSTANT VOLTAGE BATTERY CHARGING METHOD

Maximum power point tracking (MPPT) is a technique that grid-tie inverters, solar battery chargers and similar devices use to get the maximum possible power from one or more photovoltaic devices, typically solar panels, though optical power transmission systems can benefit from similar technology. Solar cells have a complex relationship between solar irradiation, temperature and total resistance that produces a non-linear output efficiency known as the I-V curve. It is the purpose of the MPPT system to sample the output of the cells and apply the proper resistance (load) to obtain maximum power for any given environmental conditions. MPPT devices are typically integrated into an electric power converter system that provides voltage or current conversion, filtering, and regulation for driving various loads, including power grids, batteries, or motors.

CONSTANT VOLTAGE METHOD

The term "constant voltage" in MPP tracking is used to describe different techniques, one in which the output voltage is regulated to a constant value under all conditions and one in which the output voltage is regulated based on a constant ratio to the measured open circuit voltage ($V_{OC}$). The latter technique is referred to in contrast as the "open voltage" method. If the output voltage is held constant, there is no attempt to track the maximum power point, so it is not a maximum power point tracking technique in a strict sense, though it does have some advantages in cases when the MPP tracking tends to fail, and thus it is sometimes used to supplement an MPPT method in those cases.
In the "constant voltage" MPPT method (also known as the "open voltage method"), the power delivered to the load is momentarily interrupted and the open-circuit voltage with zero current is measured.
The controller then resumes operation with the voltage controlled at a fixed ratio, such as 0.76, of the open-circuit voltage $V_{OC}$. This is usually a value which has been determined to be the maximum power point. The operating point of the PV array is thus kept near the MPP by regulating the array voltage and matching it to the fixed reference voltage $V_{ref}=kV_{OC}$. The value of $V_{ref}$ may be also chosen to give optimal performance relative to other factors as well as the MPP, but the central idea in this technique is that $V_{ref}$ is determined as a ratio to $V_{OC}$.

One of the inherent approximations to the "constant voltage" ratio method is that the ratio of the MPP voltage to $V_{OC}$ is only approximately constant, so it leaves room for further possible optimization. Here, the constant voltage method is adopted by means of MOSFET controlled PWM controller.
CHAPTER 6
PARAMETER DESIGN

Solar photovoltaic system or solar power system is one of renewable energy system which uses PV modules to convert sunlight into electricity. The electricity generated can be either stored or used directly, fed back into grid line or combined with one or more other electricity generators or more renewable energy sources.

Solar Preference Solar Charge Controller is needed to be connected for solar powering the batteries. There is a mains to battery charger inbuilt in Solar Inverter but it starts charging batteries only when the batteries get exhausted due to absence of solar power or anything else. When the batteries get exhausted, Solar Inverter shifts to mains mode and starts charging the batteries through mains while giving stabilized mains AC to the load at output. When the battery is fully charged through mains charger, the unit shifts back to battery, thus giving top preference to Solar Power.

Major system components:

Solar PV system includes different components that should be selected according to your system type, site location and applications. The major components for solar PV system are solar charge controller, inverter, battery bank, auxiliary energy sources and loads (appliances).

1. **PV module** – converts sunlight into DC electricity.
2. **Solar charge controller** – regulates the voltage and current coming from the PV panels going to battery and prevents battery overcharging and prolongs the battery life.
3. **Inverter** – converts DC output of PV panels or wind turbine into a clean AC current for AC appliances or fed back into grid line.
4. **Battery** – stores energy for supplying to electrical appliances when there is a demand.
5. **Load** – is electrical appliances that connected to solar PV system such as lights, radio, TV, computer, refrigerator, etc.

6. **Auxiliary energy sources** - is diesel generator or other renewable energy sources.

### 6.1. SOLAR PHOTOVOLTAIC SYSTEM DESIGNING

#### i. Determine power consumption demands

The first step in designing a solar PV system is to find out the total power and energy consumption of all loads that need to be supplied by the solar PV system as follows:

a. Calculate total Watt-hours per day for each appliance used.

Add the Watt-hours needed for all appliances together to get the total Watt-hours per day which must be delivered to the appliances.

b. Calculate total Watt-hours per day needed from the PV modules.

Multiply the total appliances Watt-hours per day times 1.3 (the energy lost in the system) to get the total Watt-hours per day which must be provided by the panels.

#### ii. Size the PV modules

Different size of PV modules will produce different amount of power. To find out the sizing of PV module, the total peak watt produced needs. The peak watt (Wp) produced depends on size of the PV module and climate of site location. We have to consider “panel generation factor” which is different in each site location. For Thailand, the panel generation factor is 3.43. To determine the sizing of PV modules, calculate as follows:

a. Calculate the total Watt-peak rating needed for PV modules

Divide the total Watt-hours per day needed from the PV modules from item i.b by 3.43 to get the total Watt-peak rating needed for the PV panels needed to operate the appliances.
b. Calculate the number of PV panels for the system

Divide the answer obtained in item ii.a by the rated output Watt-peak of the PV modules available to you. Increase any fractional part of result to the next highest full number and that will be the number of PV modules required.

Result of the calculation is the minimum number of PV panels. If more PV modules are installed, the system will perform better and battery life will be improved. If fewer PV modules are used, the system may not work at all during cloudy periods and battery life will be shortened.

6.2. INVERTER SIZING

An inverter is used in the system where AC power output is needed. The input rating of the inverter should never be lower than the total watt of appliances. The inverter must have the same nominal voltage as your battery.

For stand-alone systems, the inverter must be large enough to handle the total amount of Watts you will be using at one time. The inverter size should be 25-30% bigger than total Watts of appliances. In case of appliance type is motor or compressor then inverter size should be minimum 3 times the capacity of those appliances and must be added to the inverter capacity to handle surge current during starting.

For grid tie systems or grid connected systems, the input rating of the inverter should be same as PV array rating to allow for safe and efficient operation.

6.3. BATTERY SIZING

The battery type recommended for using in solar PV system is deep cycle battery. Deep cycle battery is specifically designed for to be discharged to low energy level and rapid recharged or cycle charged and discharged day after day for years. The battery should be large enough to store sufficient energy to operate the appliances at night and cloudy days. To find out the size of battery, calculate as follows:
a. Calculate total Watt-hours per day used by appliances.

b. Divide the total Watt-hours per day used by 0.85 for battery loss.

c. Divide the answer obtained in item b by 0.6 for depth of discharge.

d. Divide the answer obtained in item c by the nominal battery voltage.

e. Multiply the answer obtained in item d with days of autonomy (the number of days that you need the system to operate when there is no power produced by PV panels) to get the required Ampere-hour capacity of deep-cycle battery.

Battery Capacity (Ah) = \frac{\text{Total Watt-hours per day used by appliances}}{0.85} \times \frac{1}{0.6} \times \text{nominal battery voltage} \times \text{Days of autonomy}

Figure 6.1: Hybrid Source Battery Charging

6.4. SOLAR CHARGE CONTROLLER SIZING

The solar charge controller is typically rated against Amperage and Voltage capacities. Select the solar charge controller to match the voltage of PV array and batteries and then identify which type of solar charge controller is right for your application. Make sure that solar charge controller has enough capacity to handle the current from PV array.
For the controller type, the sizing of controller depends on the total PV input current which is delivered to the controller and also depends on PV panel configuration (series or parallel configuration).

According to standard practice, the sizing of solar charge controller is to take the short circuit current (Isc) of the PV array, and multiply it by 1.3

Solar charge controller rating = Total short circuit current of PV array x 1.3

6.5. EXAMPLE

Let us consider a small industrial warehouse. It has the following electrical appliance usage:

- Twelve 18 Watt fluorescent lamps with electronic ballast used 24 hours per day.
- Twenty 18 Watt fluorescent lamps with electronic ballast used 10 hours per day.
- Ten 40 watt tube light used for 10 hours per day.
- Eight 25 watt exhaust fan used for 13 hours per day.
- Eight 50 Watt Ceiling fans used for 14 hours per day.

The system will be powered by 12 Vdc, 110 Wp PV module.

1. Determine power consumption demands

Total appliance usage = (40 W x 10 hours x 10) + (18 W x 24 hours x 12) + (18 W x 10 hours x 20) + (50 W x 14 hours x 8) + (25 W x 13 hours x 8)

= 20.97 KWh per day

Total PV panels energy needed = 20.97 x 1.3 KWh per day
= 27.77 KWh per day

2.1 Total Wp of PV panel = 27.77 KWh / 3.4

Capacity needed = 7950.44 Wp

2.2 Number of PV panels needed = 7950.44 / 110
= 72 modules
2. Size the PV panel
   Actual requirement = 72 modules
   So this system should be powered by at least 72 modules of 110 Wp PV module.

3. Inverter sizing
   Total Watt of all appliances = 1576 Watts
   For safety, the inverter should be considered 25-30% bigger size.
   The inverter size should be about 1970 W or greater.

4. Battery sizing
   Total appliances use = 20.97 KWh per day
   Nominal battery voltage = 24 V
   Days of autonomy = 0.5 days

   Battery capacity = \( \frac{20.97 \times 1000 \times 0.5}{0.85 \times 0.6 \times 24} \) = 856.62 Ah

   Total Ampere-hours required 856.62 Ah
   So the battery should be rated 24 V 1000Ah for half day autonomy.

5. Solar charge controller sizing
   PV module specification
   Pm = 110 Wp
   Vm = 16.7 Vdc
   Im = 6.6 A
   Voc = 20.7 A
   Isc = 7.5 A
   Solar charge controller rating = (4 strings x 7.5 A) x 1.3 = 39 A
   So the solar charge controller should be rated 40 A at 12 V or greater.
CHAPTER 7
SOFTWARE SIMULATION

The circuit was simulated in “Proteus 7 Professional“ and was found to work satisfactorily.

Figure 7.1: Proteus Simulation Window
CHAPTER 8

HARDWARE IMPLEMENTATION

The 20 Volt 5 Watt Solar Panel, 7.5 Ah 12 Volt Battery, battery charging circuit board, microcontroller circuit board and inverter circuit board constitute the hardware model. The LCD displays the current status of the battery and the mode of battery charging.

Figure 8.1: Hardware Model
CHAPTER 9

CONCLUSION

Hybrid energy systems rely on two or more sources of energy for electrical generation and are configured so that the loads can be served directly or indirectly by one or more of these sources. By providing battery storage, a steady constant supply is able to be given to the loads even at the time of power outages, thereby assuring protection against power outages and voltage regulation during under voltage and over voltage conditions. These are largely useful in the places where power outages cannot be tolerated. For example, computers used for controlling important processes, medical equipments and laboratories, etc.

Wind and solar hybrid energy systems offer a unique way to offset a home's electrical bills or, in some cases, take a home off of the power grid completely. By utilizing both wind turbines and solar arrays to generate electricity and battery storage, hybrid systems are able to overcome some of the disadvantages of using just one form of renewable energy (i.e., the system may be more able to reliably generate electricity).

A key objective of the project is to improve the living standards in underprivileged remote villages by increasing the uptake of alternative energy technology. This project acts as a reference point from which the social, environmental and economic benefits of such a technology are demonstrated. This can be achieved to some extend by our proposed project, of designing a “Hybrid Solar Charger”.
The main advantages of such a system are:

- Power back up solution.
- Renewable generation.
- Additional charging facility.
- Better protection from battery overcharging.
- Steady supply to the loads.
- Maximum utilization of "solar energy", an infinite resource.
- Optimum investment and maximum output.
REFERENCES


DATASHEETS
CD4047BM/CD4047BC Low Power Monostable/Astable Multivibrator

General Description
CD4047B is capable of operating in either the monostable or astable mode. It requires an external capacitor (between pins 1 and 3) and an external resistor (between pins 2 and 5) to determine the output pulse width in the monostable mode, and the output frequency in the astable mode. Astable operation is enabled by a high level on the astable input or low level on the astable input. The output frequency at 50% duty cycle at Q and Q outputs is determined by the timing components. A frequency twice that of Q is available at the Oscillator Output; a 50% duty cycle is not guaranteed.

Monostable operation is obtained when the device is triggered by low-to-high transition at + trigger input or high-to-low transition at - trigger input. A delay is provided by a simultaneous low-to-high transition to both the + trigger and retrigger inputs.

A high level on Reset input resets the outputs Q to low, Q to high.

Features
- Wide supply voltage range 3.0V to 15V
- High noise immunity 0.45 Vpp (typ.)
- Low power TTL Fan out of 2 driving 74L
  or 1 driving 74LS
- SPECIAL FEATURES
  - Low power consumption: special CMOS oscillator configuration
  - Monostable (one-shot) or astable (free-running) operation
  - True and complemented buffered outputs
  - Only one external R and C required

Applications
- Frequency discriminators
- Timing circuits
- Time-delay applications
- Envelope detection
- Frequency multiplication
- Frequency division

Block and Connection Diagrams
### Absolute Maximum Ratings (Notes 1 and 2)
If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.
- DC Supply Voltage ($V_{DD}$) $-0.5V$ to $+18V_{DC}$
- Input Voltage ($V_{IN}$) $-0.5V$ to $V_{DD} + 0.5V_{DC}$
- Storage Temperature Range ($T_{S}$) $-65°C$ to $+150°C$
- Power Dissipation ($P_{D}$)
  - Dual-In-Line: 700 mW
  - Small Outline: 500 mW
- Load Temperature ($T_{L}$)
  - Soldering, 10 seconds: $260°C$

### DC Electrical Characteristics CD4047BM (Note 2)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>$-55°C$</th>
<th>$25°C$</th>
<th>$125°C$</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$V_{DD} = 5V$</td>
<td>Min</td>
<td>Max</td>
<td>Min</td>
<td>Max</td>
</tr>
<tr>
<td>I_{DD}</td>
<td>Quiescent Device Current</td>
<td>$V_{DD} = 5V$</td>
<td>5</td>
<td>5</td>
<td>5</td>
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<tr>
<td></td>
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<td>$V_{DD} = 10V$</td>
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<td>10</td>
<td>10</td>
<td>300</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_{DD} = 15V$</td>
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<td>20</td>
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<td>400</td>
</tr>
<tr>
<td>V_{OL}</td>
<td>Low Level Output Voltage</td>
<td>$I_{OL} &lt; 1 \mu A$</td>
<td>0.05</td>
<td>0</td>
<td>0.05</td>
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<tr>
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<tr>
<td></td>
<td></td>
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<td>3.5</td>
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<td>or $4.5V$</td>
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<tr>
<td></td>
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<td>or $13.5V$</td>
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<td>11.0</td>
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<td>0.64</td>
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<td>0.9</td>
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<td>1.6</td>
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<td>0.9</td>
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<tr>
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<td>High Level Output Current</td>
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<td>(Note 2)</td>
<td>$V_{OL} = 0.5V$</td>
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<td>-0.9</td>
</tr>
<tr>
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<td>or $0.6V$</td>
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<td>Input Current</td>
<td>$V_{DD} = 15V, V_{IN} = 0V$</td>
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<td>-0.1</td>
<td>-0.1</td>
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<tr>
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<td></td>
<td>$V_{DD} = 15V, V_{IN} = 15V$</td>
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<td>0.1</td>
<td>0.1</td>
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### DC Electrical Characteristics CD4047BC (Note 2)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>$-40°C$</th>
<th>$25°C$</th>
<th>$85°C$</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>$V_{DD} = 5V$</td>
<td>Min</td>
<td>Max</td>
<td>Min</td>
<td>Max</td>
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<tr>
<td>I_{DD}</td>
<td>Quiescent Device Current</td>
<td>$V_{DD} = 5V$</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>150</td>
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<tr>
<td></td>
<td></td>
<td>$V_{DD} = 10V$</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>300</td>
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<tr>
<td></td>
<td></td>
<td>$V_{DD} = 15V$</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>600</td>
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<tr>
<td>V_{OL}</td>
<td>Low Level Output Voltage</td>
<td>$I_{OL} &lt; 1 \mu A$</td>
<td>0.05</td>
<td>0</td>
<td>0.05</td>
<td>0.05</td>
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<tr>
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<td>$V_{OL} = 10V$</td>
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<tr>
<td>V_{OH}</td>
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<td>4.95</td>
<td>4.95</td>
<td>4.95</td>
<td>4.95</td>
</tr>
<tr>
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<td>$V_{OH} = 5V$</td>
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<td>4.95</td>
<td>4.95</td>
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<tr>
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<td>$V_{OH} = 10V$</td>
<td>9.95</td>
<td>9.95</td>
<td>9.95</td>
<td>9.95</td>
</tr>
<tr>
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<td></td>
<td>$V_{OH} = 15V$</td>
<td>14.95</td>
<td>14.95</td>
<td>14.95</td>
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</table>
## DC Electrical Characteristics

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>-40°C</th>
<th>25°C</th>
<th>85°C</th>
<th>Units</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Min</td>
<td>Max</td>
<td>Min</td>
<td>Typ</td>
</tr>
<tr>
<td>V_{IL}</td>
<td>Low Level Input Voltage</td>
<td>V_{DD} = 5V, V_{O} = 0.5V or 4.5V</td>
<td>1.5</td>
<td>3.0</td>
<td>2.25</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>V_{DD} = 10V, V_{O} = 1V or 9V</td>
<td>3.0</td>
<td>4.0</td>
<td>4.5</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>V_{DD} = 15V, V_{O} = 1.5V or 13.5V</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>V_{IH}</td>
<td>High Level Input Voltage</td>
<td>V_{DD} = 5V, V_{O} = 0.5V or 4.5V</td>
<td>3.5</td>
<td>3.5</td>
<td>2.75</td>
<td>3.5</td>
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<tr>
<td></td>
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<td>V_{DD} = 10V, V_{O} = 1V or 9V</td>
<td>7.0</td>
<td>7.0</td>
<td>5.6</td>
<td>7.0</td>
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<tr>
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<td>V_{DD} = 15V, V_{O} = 1.5V or 13.5V</td>
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<td>11.0</td>
<td>8.25</td>
<td>11.0</td>
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<tr>
<td>I_{CL}</td>
<td>Low Level Output Current</td>
<td>V_{DD} = 5V, V_{O} = 0.4V</td>
<td>0.52</td>
<td>0.44</td>
<td>0.38</td>
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<tr>
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<td>1.3</td>
<td>1.1</td>
<td>0.9</td>
<td>0.9</td>
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<tr>
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<td></td>
<td>V_{DD} = 15V, V_{O} = 1.5V</td>
<td>3.5</td>
<td>3.0</td>
<td>2.4</td>
<td>2.4</td>
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<td>I_{CH}</td>
<td>High Level Output Current</td>
<td>V_{DD} = 5V, V_{O} = 0.4V</td>
<td>-0.52</td>
<td>-0.44</td>
<td>-0.36</td>
<td>-0.36</td>
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<tr>
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<td></td>
<td>V_{DD} = 10V, V_{O} = 0.5V</td>
<td>-1.3</td>
<td>-1.1</td>
<td>-0.9</td>
<td>-0.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>V_{DD} = 15V, V_{O} = 1.5V</td>
<td>-2.8</td>
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<td>-2.4</td>
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<tr>
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<td>Input Current</td>
<td>V_{DD} = 15V, V_{O} = 0V</td>
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<td>10^-5</td>
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<td>1.0</td>
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<tr>
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<td>V_{DD} = 15V, V_{O} = 15V</td>
<td>0.2</td>
<td>10^-5</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

### Notes:
1. “Absolute Maximum Ratings” are those values beyond which the safety of the device cannot be guaranteed. They are not meant to imply that the device should be operated at these limits. The table of “Recommended Operating Conditions” and “Electrical Characteristics” provides conditions for actual device operation.
2. V_{DD} = 0V unless otherwise specified.
3. All ICs are tested one output at a time.

## AC Electrical Characteristics

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>V_{DD} = 5V</td>
<td>200</td>
<td>400</td>
<td>ns</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>V_{DD} = 10V</td>
<td>100</td>
<td>200</td>
<td>ns</td>
<td></td>
</tr>
<tr>
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<td></td>
<td>V_{DD} = 15V</td>
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<td>160</td>
<td>ns</td>
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<tr>
<td></td>
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<td>V_{DD} = 5V</td>
<td>550</td>
<td>900</td>
<td>ns</td>
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<td>V_{DD} = 10V</td>
<td>250</td>
<td>500</td>
<td>ns</td>
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<td>V_{DD} = 15V</td>
<td>200</td>
<td>400</td>
<td>ns</td>
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<td>600</td>
<td>ns</td>
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<td>480</td>
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<td>V_{DD} = 5V</td>
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<td>600</td>
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<td>V_{DD} = 15V</td>
<td>150</td>
<td>250</td>
<td>ns</td>
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<tr>
<td></td>
<td></td>
<td>V_{DD} = 5V</td>
<td>000</td>
<td>000</td>
<td>ns</td>
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<td>125</td>
<td>250</td>
<td>ns</td>
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<td>100</td>
<td>200</td>
<td>ns</td>
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<tr>
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<td>V_{DD} = 5V</td>
<td>100</td>
<td>200</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td></td>
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<td>V_{DD} = 10V</td>
<td>50</td>
<td>100</td>
<td>ns</td>
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</tr>
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<td>80</td>
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<td>Minimum Input Pulse Duration</td>
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<td>1000</td>
<td>ns</td>
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<td>200</td>
<td>400</td>
<td>ns</td>
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<td></td>
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<td>320</td>
<td>ns</td>
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<tr>
<td></td>
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<td>V_{DD} = 5V</td>
<td>15</td>
<td>μs</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>V_{DD} = 10V</td>
<td>5</td>
<td>μs</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>V_{DD} = 15V</td>
<td>5</td>
<td>μs</td>
<td></td>
<td></td>
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<tr>
<td>C_{IN}</td>
<td>Average Input Capacitance</td>
<td>Any Input</td>
<td>5</td>
<td>7.5</td>
<td>pF</td>
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</table>

*AC Parameters are guaranteed by DC correlated testing.*
Logic Diagram

Truth Table

<table>
<thead>
<tr>
<th>Function</th>
<th>Terminal Connections</th>
<th>Output Pulse From</th>
<th>Typical Output Period or Pulse Width</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>To V_{DD}</td>
<td>To V_{SS}</td>
<td>Input Pulse To</td>
</tr>
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<td>Astable Multivibrator</td>
<td>4, 5, 6, 14</td>
<td>7, 8, 9, 12</td>
<td>5</td>
</tr>
<tr>
<td>Free-Running</td>
<td>4, 5, 14</td>
<td>7, 8, 9, 12</td>
<td>10, 11, 13</td>
</tr>
<tr>
<td>True Gating</td>
<td>6, 14</td>
<td>5, 7, 8, 9, 12</td>
<td>10, 11, 13</td>
</tr>
<tr>
<td>Compliment Gating</td>
<td>4, 5, 6, 14</td>
<td>7, 8, 9, 12</td>
<td>5</td>
</tr>
<tr>
<td>Monostable Multivibrator</td>
<td>4, 14</td>
<td>5, 6, 7, 9</td>
<td>5, 7, 9, 12</td>
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<tr>
<td>Positive-Edge Trigger</td>
<td>4, 14</td>
<td>5, 6, 7, 9</td>
<td>6</td>
</tr>
<tr>
<td>Negative-Edge Trigger</td>
<td>4, 14</td>
<td>5, 6, 7, 9</td>
<td>6</td>
</tr>
<tr>
<td>Retriggerable</td>
<td>4, 14</td>
<td>5, 6, 7, 9</td>
<td>6</td>
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<tr>
<td>External Countdown*</td>
<td>14</td>
<td>5, 6, 7, 8, 9, 12</td>
<td>(See Figure)</td>
</tr>
</tbody>
</table>

Note: External resistor between terminals 2 and 3. External capacitor between terminals 1 and 3.

*Typical Implementation of External Countdown Option

\[ t_{\text{EXIT}} = (N - 1) t_a + t_m + t_a/2 \]
LIFE SUPPORT POLICY

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1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform, when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.
LM317
3-Terminal Positive Adjustable Regulator

Features
• Output Current In Excess of 1.5A
• Output Adjustable Between 1.2V and 37V
• Internal Thermal Overload Protection
• Internal Short Circuit Current Limiting
• Output Transistor Safe Operating Area Compensation
• TO-220 Package

Description
This monolithic integrated circuit is an adjustable 3-terminal positive voltage regulator designed to supply more than 1.5A of load current with an output voltage adjustable over a 1.2V to 37V. It employs internal current limiting, thermal shut-down and safe area compensation.

Internal Block Diagram
**Absolute Maximum Ratings**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input-Output Voltage Differential</td>
<td>$V_{I} - V_{O}$</td>
<td>40</td>
<td>V</td>
</tr>
<tr>
<td>Lead Temperature</td>
<td>$T_{LEAD}$</td>
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<td>°C</td>
</tr>
<tr>
<td>Power Dissipation</td>
<td>$P_{D}$</td>
<td>Internally limited</td>
<td>W</td>
</tr>
<tr>
<td>Operating Junction Temperature Range</td>
<td>$T_{j}$</td>
<td>0 ~ +125</td>
<td>°C</td>
</tr>
<tr>
<td>Storage Temperature Range</td>
<td>$T_{STG}$</td>
<td>-65 ~ +125</td>
<td>°C</td>
</tr>
<tr>
<td>Temperature Coefficient of Output Voltage</td>
<td>$\Delta V_o/\Delta T$</td>
<td>±0.02</td>
<td>%/°C</td>
</tr>
</tbody>
</table>

**Note 1:** Absolute Maximum Ratings: are those values beyond which the safety of the device cannot be guaranteed. The device should not be operated at these limits. The parametric values defined in the Electrical Characteristics tables are not guaranteed at the absolute maximum ratings. The “Recommended Operating Conditions” table will define the conditions for actual device operation.

**Electrical Characteristics**

(V$_I$-V$_O$ = 5V, I$_O$ = 0.5A, 0°C ≤ $T_j$ ≤ +125°C, I$_{MAX}$ = 1.5A, $P_{D MAX}$ = 20W, unless otherwise specified)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line Regulation (Note2)</td>
<td>$R_{LINE}$</td>
<td>$T_a = +25^\circ C$</td>
<td>0.01</td>
<td>0.04</td>
<td>-</td>
<td>%/V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3V ≤ $V_I - V_O$ ≤ 40V</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>%/V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_O &gt; 5$</td>
<td>0.02</td>
<td>0.07</td>
<td>-</td>
<td>%/V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_O ≥ 5$</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>%/V</td>
</tr>
<tr>
<td>Load Regulation (Note2)</td>
<td>$R_{LOAD}$</td>
<td>$T_a = +25^\circ C$, 10mA ≤ $I_O$ ≤ $I_{MAX}$</td>
<td>-</td>
<td>-</td>
<td>25</td>
<td>mV/Vo</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_O &lt; 5$</td>
<td>18</td>
<td>25</td>
<td>0.5</td>
<td>mV/Vo</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_O ≥ 5$</td>
<td>-</td>
<td>70</td>
<td>1.5</td>
<td>mV/Vo</td>
</tr>
<tr>
<td>Adjustable Pin Current</td>
<td>$I_{ADJ}$</td>
<td>-</td>
<td>-</td>
<td>46</td>
<td>100</td>
<td>μA</td>
</tr>
<tr>
<td>Adjustable Pin Current Change</td>
<td>$\Delta I_{ADJ}$</td>
<td>3V ≤ $V_I - V_O$ ≤ 40V</td>
<td>-</td>
<td>2.0</td>
<td>5</td>
<td>μA</td>
</tr>
<tr>
<td>Reference Voltage</td>
<td>$V_{REF}$</td>
<td>3V ≤ $V_{IN} - V_O$ ≤ 40V</td>
<td>1.20</td>
<td>1.25</td>
<td>1.30</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10mA ≤ $I_O$ ≤ $I_{MAX}$</td>
<td>1.20</td>
<td>1.25</td>
<td>1.30</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$P_D ≤ P_{MAX}$</td>
<td>1.20</td>
<td>1.25</td>
<td>1.30</td>
<td>V</td>
</tr>
<tr>
<td>Temperature Stability</td>
<td>$S_T$</td>
<td>-</td>
<td>-</td>
<td>0.7</td>
<td>-</td>
<td>%/Vo</td>
</tr>
<tr>
<td>Minimum Load Current to Maintain</td>
<td>$I_{(MIN)}$</td>
<td>$V_I - V_O$ = 40V</td>
<td>3.5</td>
<td>12</td>
<td>-</td>
<td>mA</td>
</tr>
<tr>
<td>Regulation</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>%/Vo</td>
</tr>
<tr>
<td>Maximum Output Current</td>
<td>$I_{(MAX)}$</td>
<td>$V_I - V_O$ ≤ 15V, $P_D ≤ P_{MAX}$</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_I - V_O$ ≤ 40V, $P_D ≤ P_{MAX}$</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$T_a$ = 25°C</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>A</td>
</tr>
<tr>
<td>RMS Noise, % of VOUT</td>
<td>$e_n$</td>
<td>$T_a$ = +25°C, 10Hz ≤ $f$ ≤ 10kHz</td>
<td>-</td>
<td>0.003</td>
<td>0.01</td>
<td>%/Vo</td>
</tr>
<tr>
<td>Ripple Rejection</td>
<td>$RR$</td>
<td>$V_O = 10V$, $f = 120Hz$ without $C_{ADJ}$</td>
<td>60</td>
<td>60</td>
<td>-</td>
<td>dB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$C_{ADJ} = 10\mu F$ (Note3)</td>
<td>75</td>
<td>75</td>
<td>-</td>
<td>dB</td>
</tr>
<tr>
<td>Long-Term Stability, $T_J$ = $T_{HIGH}$</td>
<td>ST</td>
<td>$T_a$ = +25°C for end point measurements, 1000HR</td>
<td>0.3</td>
<td>1</td>
<td>-</td>
<td>%</td>
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<tr>
<td>Thermal Resistance Junction to Case</td>
<td>$R_{JC}$</td>
<td>-</td>
<td>-</td>
<td>5</td>
<td>-</td>
<td>°C/W</td>
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</tbody>
</table>

**Note 2:** Load and line regulation are specified at constant junction temperature. Change in $V_O$ due to heating effects must be taken into account separately. Pulse testing with low duty is used. ($P_{MAX}$ = 20W)

**Note 3:** $C_{ADJ}$, when used, is connected between the adjustment pin and ground.
Typical Performance Characteristics

Figure 1. Load Regulation

Figure 2. Adjustment Current

Figure 3. Dropout Voltage

Figure 4. Reference Voltage
Typical Application

![LM317 Diagram](image)

\[ V_0 = 1.25V \left( 1 + \frac{R_2}{R_1} \right) + I_{ADJ}R_2 \]

Figure 5. Programmable Regulator

- \( C_1 \) is required when regulator is located an appreciable distance from power supply filter.
- \( C_0 \) is not needed for stability, however, it does improve transient response.
- Since \( I_{ADJ} \) is controlled to less than 100\( \mu \)A, the error associated with this term is negligible in most applications.
## Ordering Information

<table>
<thead>
<tr>
<th>Product Number</th>
<th>Package</th>
<th>Operating Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>LM317T</td>
<td>TO-220 (Single Gauge)</td>
<td>0°C to +125°C</td>
</tr>
</tbody>
</table>

---

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PIC16F87XA

28/40/44-Pin Enhanced Flash Microcontrollers

Devices Included in this Data Sheet:
- PIC16F873A
- PIC16F874A
- PIC16F876A
- PIC16F877A

High-Performance RISC CPU:
- Only 35 single-word instructions to learn
- All single-cycle instructions except for program branches, which are two-cycle
- Operating speed: DC – 20 MHz clock input
  DC – 200 ns instruction cycle
- Up to 8k x 14 words of Flash Program Memory,
Up to 368 x 8 bytes of Data Memory (RAM),
Up to 256 x 8 bytes of EEPROM Data Memory
- Pinout compatible to other 28-pin or 40/44-pin PIC16CXXX and PIC16FXXX microcontrollers

Analog Features:
- 10-bit, up to 8-channel Analog-to-Digital Converter (A/D)
- Brown-out Reset (BOR)
- Analog Comparator module with:
  - Two analog comparators
  - Programmable on-chip voltage reference (VREF) module
  - Programmable input multiplexing from device inputs and internal voltage reference
  - Comparator outputs are externally accessible

Special Microcontroller Features:
- 100,000 erase/write cycle Enhanced Flash program memory typical
- 1,000,000 erase/write cycle Data EEPROM memory typical
- Data EEPROM Retention > 40 years
- Self-reprogrammable under software control
- In-Circuit Serial Programming™ (ICSP™) via two pins
- Single-supply 5V In-Circuit Serial Programming
- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Programmable code protection
- Power saving Sleep mode
- Selectable oscillator options
- In-Circuit Debug (ICD) via two pins

CMOS Technology:
- Low-power, high-speed Flash/EEPROM technology
- Fully static design
- Wide operating voltage range (2.0V to 5.5V)
- Commercial and industrial temperature ranges
- Low-power consumption

<table>
<thead>
<tr>
<th>Device</th>
<th>Program Memory (Bytes)</th>
<th>SRAM (Bytes)</th>
<th>EEPROM (Bytes)</th>
<th>I/O</th>
<th>CCP (PWM)</th>
<th>MSSP</th>
<th>USART</th>
<th>Timers</th>
<th>Comparators</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIC16F873A</td>
<td>7.2K</td>
<td>4096</td>
<td>192</td>
<td>128</td>
<td>22</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>2/1</td>
</tr>
<tr>
<td>PIC16F874A</td>
<td>7.2K</td>
<td>4096</td>
<td>192</td>
<td>128</td>
<td>33</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>2/1</td>
</tr>
<tr>
<td>PIC16F876A</td>
<td>14.3K</td>
<td>3142</td>
<td>308</td>
<td>256</td>
<td>22</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>2/1</td>
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<tr>
<td>PIC16F877A</td>
<td>14.3K</td>
<td>3142</td>
<td>308</td>
<td>256</td>
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<td>Yes</td>
<td>2/1</td>
</tr>
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</table>

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1.0 DEVICE OVERVIEW

This document contains device specific information about the following devices:

- PIC16F873A
- PIC16F874A
- PIC16F876A
- PIC16F877A

PIC16F873A/876A devices are available only in 28-pin packages, while PIC16F874A/877A devices are available in 40-pin and 44-pin packages. All devices in the PIC16F87XA family share common architecture with the following differences:

- The PIC16F873A and PIC16F874A have one half of the total on-chip memory of the PIC16F876A and PIC16F877A.
- The 28-pin devices have three I/O ports, while the 40/44-pin devices have five.
- The 28-pin devices have fourteen interrupts, while the 40/44-pin devices have fifteen.
- The 28-pin devices have five A/D input channels, while the 40/44-pin devices have eight.
- The Parallel Slave Port is implemented only on the 40/44-pin devices.

The available features are summarized in Table 1.1.

<table>
<thead>
<tr>
<th>Key Features</th>
<th>PIC16F873A</th>
<th>PIC16F874A</th>
<th>PIC16F876A</th>
<th>PIC16F877A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Frequency</td>
<td>DC – 20 MHz</td>
<td>DC – 20 MHz</td>
<td>DC – 20 MHz</td>
<td>DC – 20 MHz</td>
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<tr>
<td>Reset (and Hold)</td>
<td>POR, BOR (PWRT, OST)</td>
<td>POR, BOR (PWRT, OST)</td>
<td>POR, BOR (PWRT, OST)</td>
<td>POR, BOR (PWRT, OST)</td>
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<tr>
<td>Flash Program Memory (14-bit words)</td>
<td>4K</td>
<td>4K</td>
<td>8K</td>
<td>8K</td>
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<tr>
<td>Data Memory (bytes)</td>
<td>192</td>
<td>192</td>
<td>368</td>
<td>368</td>
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<td>EEPROM Data Memory (bytes)</td>
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<td>256</td>
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<tr>
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<td>15</td>
<td>14</td>
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<tr>
<td>Capture/Compare/PWM modules</td>
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<tr>
<td>Serial Communications</td>
<td>MSSP, USART</td>
<td>MSSP, USART</td>
<td>MSSP, USART</td>
<td>MSSP, USART</td>
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<tr>
<td>Parallel Communications</td>
<td>--</td>
<td>PSP</td>
<td>--</td>
<td>PSP</td>
</tr>
<tr>
<td>10-bit Analog-to-Digital Module</td>
<td>5 input channels</td>
<td>8 input channels</td>
<td>5 input channels</td>
<td>8 input channels</td>
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<tr>
<td>Analog Comparators</td>
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<td>2</td>
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<tr>
<td>Instruction Set</td>
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<tr>
<td>Packages</td>
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<td>40-pin PDIP</td>
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<td>28-pin SSOP</td>
<td>44-pin FLC</td>
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<td>44-pin QFN</td>
<td>28-pin QFN</td>
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