P-1431

DCS BASED TRANSFORMER MONITORING

A PROJECT REPORT

Submitted by

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in partial fulfillment for the award of the degree

of

BACHELOR OF ENGINEERING

in

ELECTRICAL & ELECTRONICS ENGINEERING

Under the guidance of

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APRIL – 2005

CERTIFICATE

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BONAFIDE CERTIFICATE

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College : **KUMARAGURU COLLEGE OF TECHNOLOGY**

Branch : **Electrical & Electronics Engineering**

Semester : **Eighth Semester**

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The report of the project work submitted by the above students in partial fulfillment for the award of Bachelor of Engineering degree in Electrical & Electronics Engineering of Anna University were evaluated and confirmed to be report of the work done by the above students.

(INTERNAL EXAMINER) **(EXTERNAL EXAMINER)**

DEDICATED TO OUR BELOVED PARENTS

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TABLE OF CONTENTS

TABLE OF CONTENTS

ABSTRACT

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To increase availability and to achieve optimized operating management, on-line condition monitoring for transformers is useful and necessary. Based on the experiences with a considerable amount of systems in operation, a generally applicable set-up of sensing circuits is proposed. By means of linear approximation techniques the acquired measured data are converted to useful information for a reliable condition diagnosis. The evaluation of data acquired on-site shows the capability to detect problems within active part, on-load tap changer and the oil before they could develop into major failures. By means of this method, it is possible to monitor and control all transformers that are connected in a network, from a control center with a single system, which is extremely cost-effective. The project also enables provisions for report generation of the operating conditions which can be useful for analyzing the performance of transformers on an every day basis.

LIST OF FIGURES

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES

Page No.

LIST OF ABBREVIATIONS

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1. DCS	-	Distributed Control System.
2. SCADA	-	Supervisory Control and Data Acquisition.
3. PLC	-	Programmable Logic Controllers.
4. TTL	-	Transistor Transistor Logic.
5. RS	-	Recommended Standards.
6. PIC	-	Peripheral Interface Controller.
7. Kbps	-	Kilo Bits Per Second.
8. Mbps	-	Mega Bits Per Second.
9. LED	-	Light Emitting Diode.
10. DGA	-	Dissolved Gas Analysis.
11. PPM	-	Parts Per Million.
12. SPDT	-	Single Pole Double Throw.
13. RAM	-	Random Access Memory.
14. EEPROM	-	Electrical Erasable Programmable Read Only Memory.
15. EPROM	-	Erasable Programmable Read Only Memory.
16. POR	-	Power on Reset.
17. USART	-	Universal synchronous asynchronous receiver transmitter.
18. LASER	-	Light Amplification by Simulated Emission of Radiations.
19. LSB	-	Least Significant Bit.
20. EIA	-	Electronics Industry Association.
21. CMOS	-	Complementary Metal Oxide Semiconductor.

INTRODUCTION

APPENDIX -2

National Semiconductor

December 1994

LM35/LM35A/LM35C/LM35CA/LM35D Precision Centigrade Temperature Sensors

General Description

The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in ° Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±1/4°C at room temperature and ±3/4°C over a full −55 to +150°C temperature range. Low cost is assured by trimming and calibration at the wafer level. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy. It can be used with single power supplies, or with plus and minus supplies. As it draws only 60 μA from its supply, it has very low self-heating, less than 0.1°C in still air. The LM35 is rated to operate over a −55° to +150°C temperature range, while the LM35C is rated for a −40° to +110°C range (−10° with improved accuracy). The LM35 series is available packaged in hermetic TO-46 transistor packages, while the LM35C, LM35CA, and LM35D are also available in the plastic TO-92 transistor package. The LM35D is also available in an 8-lead surface mount small outline package and a plastic TO-202 package.

Features

- Calibrated directly in ° Celsius (Centigrade)
- Linear + 10.0 mV/°C scale factor
- 0.5°C accuracy guaranteeable (at +25°C)
- Rated for full −55° to +150°C range
- Suitable for remote applications
- Low cost due to wafer-level trimming
- Operates from 4 to 30 volts
- Less than 60 μA current drain
- Low self-heating, 0.08°C in still air
- Nonlinearity only ±1/4°C typical
- Low impedance output, 0.1 Ω for 1 mA load

Connection Diagrams

TO-46
Metal Can Package*

TL/H/5516–1

*Case is connected to negative pin (GND)

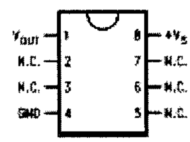
Order Number LM35H, LM35AH, LM35CH, LM35CAH or LM35DH
See NS Package Number H03H

TO-92
Plastic Package

TL/H/5516–2

Order Number LM35CZ, LM35CAZ or LM35DZ
See NS Package Number Z03A

SO-8
Small Outline Molded Package



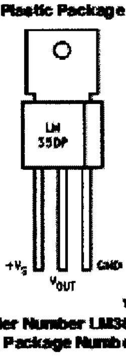
TL/H/5516–21

Top View

N.C. = No Connection

Order Number LM35DM
See NS Package Number M08A

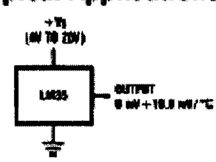
TO-202
Plastic Package



TL/H/5516–24

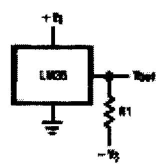
Order Number LM35DP
See NS Package Number P03A

Typical Applications



TL/H/5516–3

FIGURE 1. Basic Centigrade Temperature Sensor (+2°C to +150°C)



TL/H/5516–4

Choose $R_1 = -V_S/50\ \mu A$

$V_{OUT} = +1{,}500$ mV at $+150°C$

$= +250$ mV at $+25°C$

$= -550$ mV at $-55°C$

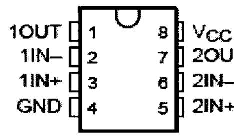
FIGURE 2. Full-Range Centigrade Temperature Sensor

LM158, LM158A, LM258, LM258A
LM358, LM358A, LM2904, LM2904Q
DUAL OPERATIONAL AMPLIFIERS

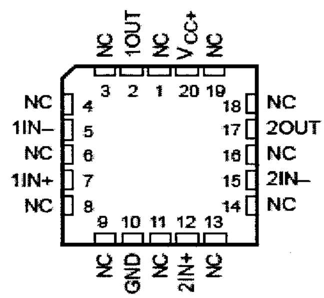
SLOS068E – JUNE 1976 – REVISED SEPTEMBER 2002

- **Wide Range of Supply Voltages:**
  - **Single Supply . . . 3 V to 30 V (LM2904 and LM2904Q . . . 3 V to 26 V) or**
  - **Dual Supplies**
- **Low Supply-Current Drain Independent of Supply Voltage . . . 0.7 mA Typ**
- **Common-Mode Input Voltage Range Includes Ground, Allowing Direct Sensing Near Ground**
- **Low Input Bias and Offset Parameters:**
  - **Input Offset Voltage . . . 3 mV Typ**
    A Versions . . . 2 mV Typ
  - **Input Offset Current . . . 2 nA Typ**
  - **Input Bias Current . . . 20 nA Typ**
    A Versions . . . 15 nA Typ
- **Differential Input Voltage Range Equal to Maximum-Rated Supply Voltage . . . ±32 V (LM2904 and LM2904Q . . . ±26 V)**
- **Open-Loop Differential Voltage Amplification . . . 100 V/mV Typ**
- **Internal Frequency Compensation**

LM158, LM158A . . . JG PACKAGE
LM258 . . . D OR P PACKAGE
LM258A . . . P PACKAGE
LM358 . . . D, P, PS, OR PW PACKAGE
LM358A . . . D OR P PACKAGE
LM2904 . . . D, P, PS, OR PW PACKAGE
LM2904Q . . . D PACKAGE
(TOP VIEW)



LM158, LM158A . . . FK PACKAGE
(TOP VIEW)



NC – No internal connection

description/ordering information

These devices consist of two independent, high-gain, frequency-compensated operational amplifiers designed to operate from a single supply over a wide range of voltages. Operation from split supplies also is possible if the difference between the two supplies is 3 V to 30 V (3 V to 26 V for the LM2904 and LM2904Q), and V_{CC} is at least 1.5 V more positive than the input common-mode voltage. The low supply-current drain is independent of the magnitude of the supply voltage.

Applications include transducer amplifiers, dc amplification blocks, and all the conventional operational amplifier circuits that now can be implemented more easily in single-supply-voltage systems. For example, these devices can be operated directly from the standard 5-V supply used in digital systems and easily provide the required interface electronics without additional ±5-V supplies.

The LM2904Q is manufactured to demanding automotive requirements.

INTRODUCTION

Transformer outages have a considerable economic impact on the operation of an electrical network. Therefore our aim is to ensure an accurate assessment of the transformer condition. Techniques that allow diagnosing the integrity through non-intrusive tests can be used to optimize the maintenance effort and to ensure maximum availability and reliability. With the increasing average age of transformer population, there is an increasing need to know the internal condition. For this purpose, on- and off- line methods and systems have been developed in recent years. On-line monitoring of transformers can be used continuously during the operation of transformers and offers in that way a possibility to record different relevant stresses, which can affect the lifetime. The automatic evaluation of these data allows the early detection of an oncoming fault. In order to enable a consistent utilization of the technically possible load capacity of the transformer, statements regarding the current over-load capacity, for examples can be made.

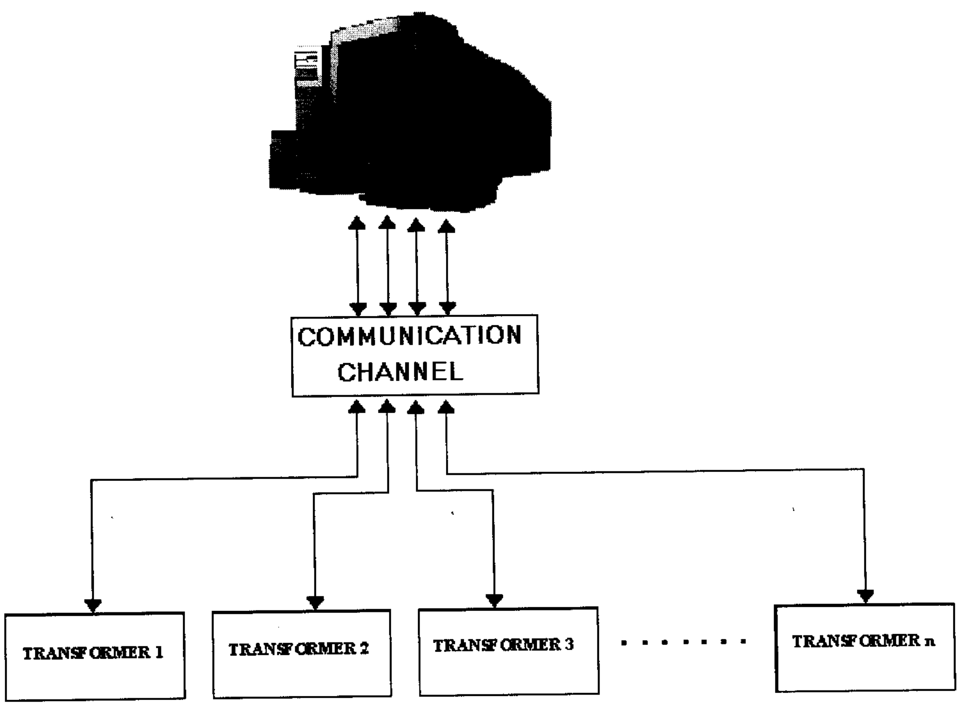
1.1 DISTRIBUTED CONTROL SYSTEM

A large-scale process control system characterized by a distributed network of processors and I/O subsystems that encompass control user interfacing, data collection, and system management. Distributed Control System enables us to manage the process as a complete system with control over the inter-relationship of various subsystems. Distributed Control System is used in applications to monitor and control distributed equipment with remote human intervention. When using a provides the means for effectively monitoring and controlling the process or facility.

1.1.1 ADVANTAGES OF DCS

- Integrity: Small process time than SCADA or PLC.
- PLC or SCADA is hard to design for large configurations.
- Total integration of various subsystems into one complete system that performs the complete functions is possible only in Distributed Control System.

SCHEMATIC DIAGRAM OF DISTRIBUTED CONTROL SYSTEM



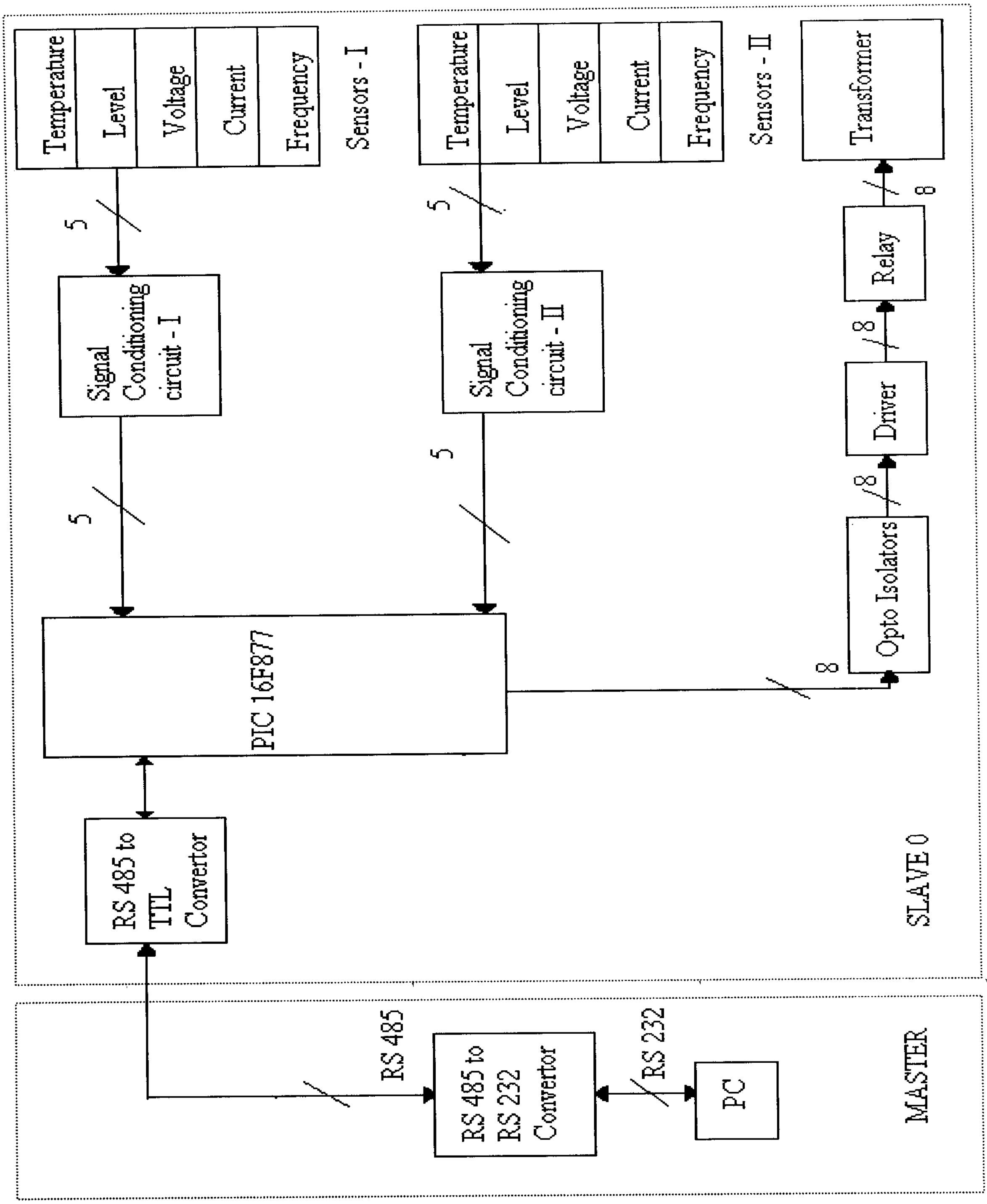
1.2 TRANSFORMERS

A transformer is a static device comprising of coils coupled through a magnetic medium connecting two ports at different voltage levels in an electric system allowing the interchange of electrical energy between the ports in either direction via the magnetic field. The transformer is one of the most important components of variety of electrical circuits ranging from low-power, low current electronic and control circuits to ultra high-voltage power systems. Transformers are built in an astonishing range of sizes from the tiny units used in communication systems to monsters used in high-voltage transmission systems, weighing hundreds of tons. A circuit model and performance analysis of transformers is necessary for understanding of many electronic and control systems and almost all power systems. The most important tasks performed by transformers are:

i. Changing voltage and current levels in electric power systems,
ii. Matching source and load impedances for maximum power transfer in electronic circuitry, and
iii. Electrical isolation

BLOCK DIAGRAM

BLOCK DIAGRAM



The block diagram of Distributed Control System based Transformer monitoring comprises of two units.

a. Master unit

b. Slave unit

2.1 MASTER UNIT

The RS 232 channel and PC together makes the master unit.

2.1.1 RS 232 CHANNEL

In RS 232, the data communication between the elements is single ended. Data transmission is said to be single ended if data can either be transmitted or received, at a relatively slow data rates (up to 20 kbps) and short distances (up to 50 feet at the maximum data rate). This channel is bi-directional and allows point-to-point communication.

2.1.2 PERSONAL COMPUTER

All the transformer parameters are continuously monitored and displayed in the PC. For any change in the value of the parameters, there is a corresponding change in the value displayed. The datas are transmitted or received by the personal computer through the communication channel.

2.2 SLAVE UNIT

The slave unit comprises of

i. Sensing circuits
ii. Signal conditioning circuits
iii. PIC 16F877
iv. RS 485 Channel
v. Tapping and Tripping Circuit

2.2.1 SENSING CIRCUITS

The sensing circuit senses those parameters that have to be monitored. The parameters that have to be monitored are,

a) Temperature
b) Level
c) Voltage
d) Current
e) Frequency

2.2.2 SIGNAL CONDITIONING CIRCUITS

The signal conditioning circuits amplify the output of the sensing circuit. The amplified value is then fed as an input to the PIC 16F877. The signal conditioning circuit also converts the output to the desired form so that it is accepted by the next stage, i.e. PIC 16F877.

2.2.3 PIC 16F877

The Peripheral Interface Controller that we use in Distributed Control System transformer Monitoring is 16F877.It is having higher memory and is capable of performing Serial Communication along with A-D Conversion.

2.2.4 RS 485 CHANNEL

Multi point communication in a network is possible in RS485 and the standard specifies up to 32 drivers and 32 receivers on a single two wire bus. With the introduction of 'automatic' repeaters and high impedance drivers/receivers, this 'limitation' can be extended to hundreds of nodes on a network. The baud rate that the 485 channels can transfer is 10Mbps to 100kbps and the maximum cable length is 4000ft.

2.2.5 TAPPING AND TRIPPING CIRCUIT

We have employed opto-isolator cum high speed switching relay, which is connected to the secondary of the transformer. Clicking the corresponding tap buttons in the front-end display the tap position can be changed.

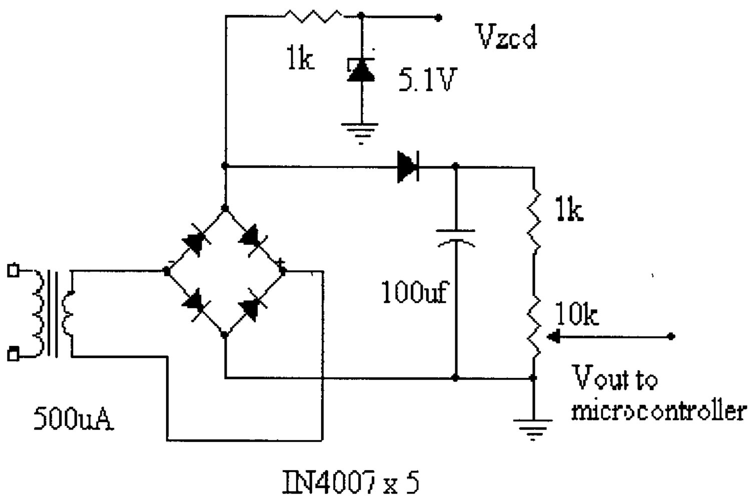
HARDWARE

HARDWARE

3.1 ELECTRICAL PARAMETER MEASUREMENT

3.1.1 VOLTAGE MEASUREMENT

The circuit includes a potential transformer whose primary winding is connected across the line carrying the voltage to be stepped down. The secondary is connected to the bridge rectifier. The loading of a potential transformer is usually small, sometimes only a few VA. The pulsating output is stabilized using a capacitor C1 of 100µf. The pulsating output (Vzcd) is also used for power factor manipulation. The output of this circuit (Vout) is given to Microcontroller and a linear programming is executed in the controller to manipulate and acquire original voltage of the transformer.

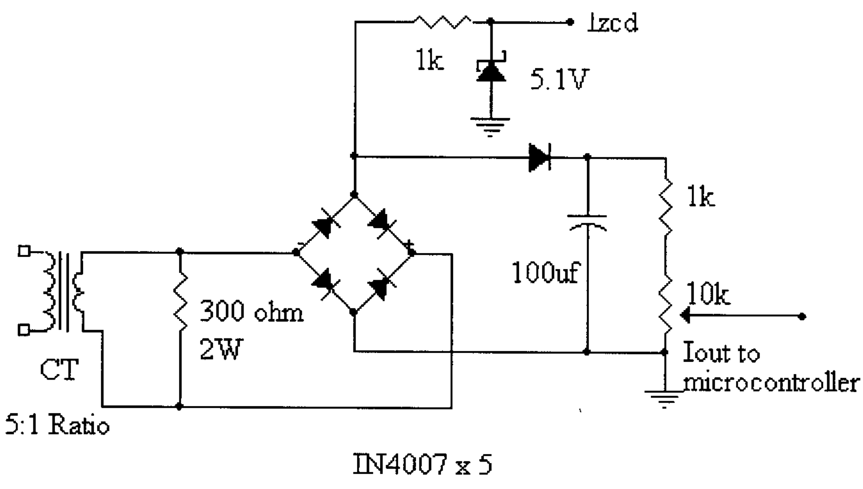


VOLTAGE MEASUREMENT CIRCUIT

3.1.2 CURRENT MEASUREMENT

The current measurement circuit consists of Current transformer of turns ratio 5:1.The Current Transformer's primary winding is connected in series with the line. The secondary of the Current Transformer is connected to a bridge network. The pulsating output (Izcd) is utilized

- To calculate power factor and
- It is stabilized using the capacitor and the output is then manipulated to get the actual value of the current.



CURRENT MEASURING CIRCUIT

3.1.3 POWER FACTOR MEASUREMENT

The pulsating output of the voltage and current measurement circuits are given to two Schmitt trigger pins of microcontroller, whose output will be a square wave. The XOR operation between these two signals is done internally in the PIC coding. The truth table of XOR gate is

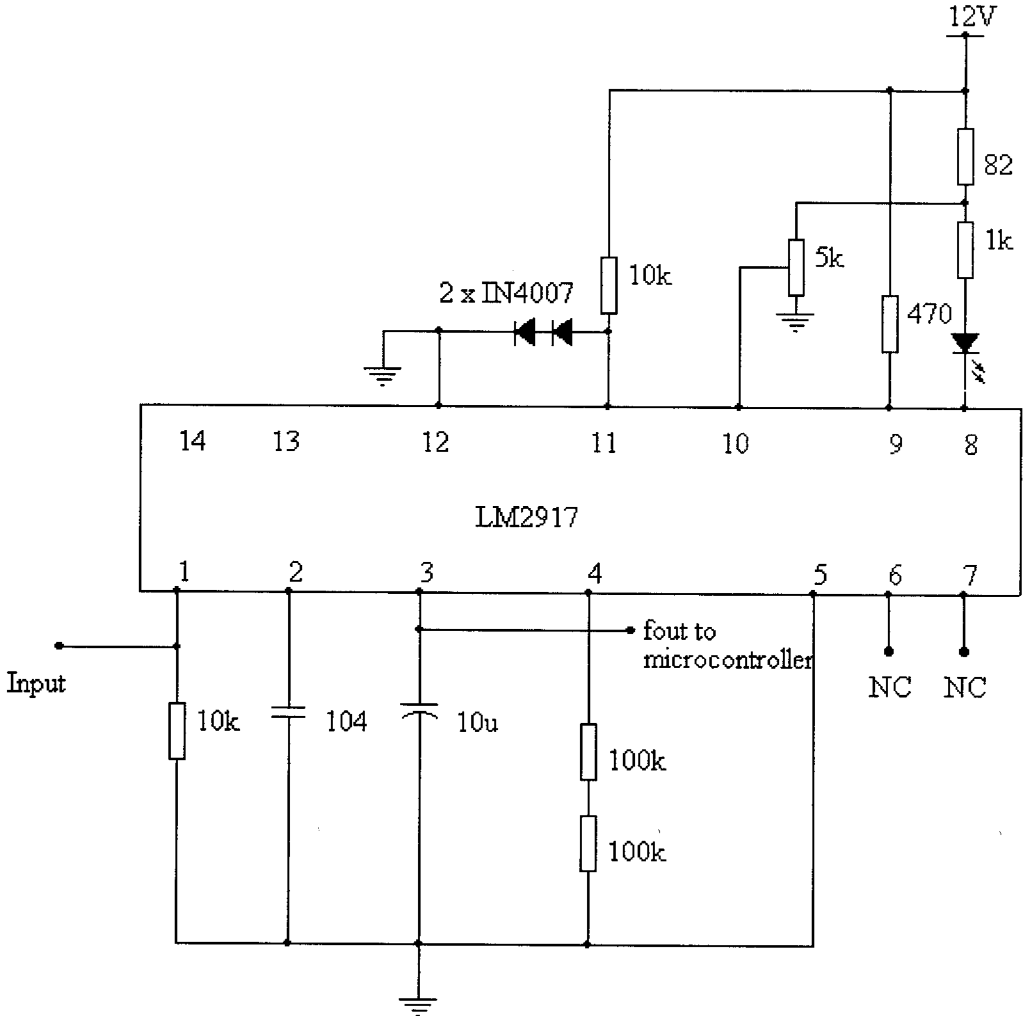
$$F = XY' + X'Y$$

X	Y	F
L	L	L
L	H	H
H	L	H
H	H	L

The XOR gate output will be high during the non-overlapping period of voltage and current, which is the indirect measure of lag or lead between voltage and current. A timer is incremented during the non-overlapping period; its value in millisecond is equivalent to corresponding phase angle in degrees. Leading or lagging power factor is determined based on the timer value.

3.1.4 FREQUENCY MEASUREMENT

The frequency is measured using the frequency to voltage converter, LM2917. The voltage whose frequency is to be measured is given as an input to the LM2917. It senses frequency of the applied voltage and generates corresponding output voltage. This output is then fed to the microcontroller and the exact value of frequency is manipulated in the front end display.



FREQUENCY TO VOLTAGE CONVERTERS

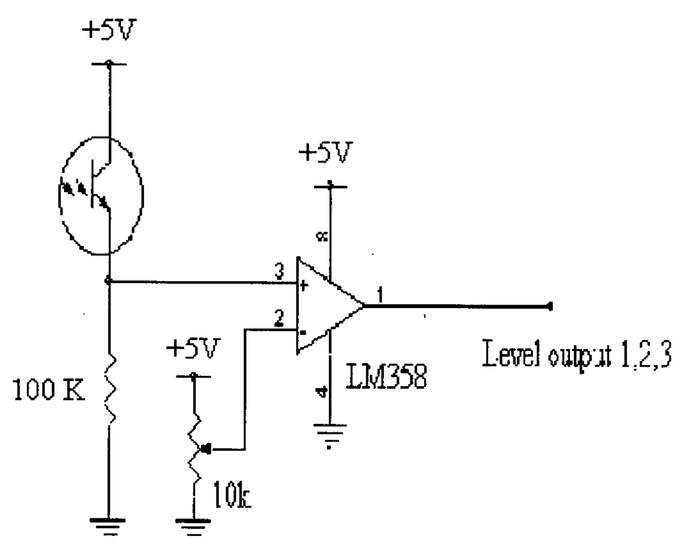
3.2 OIL PARAMETER MEASUREMENT

3.2.1 LEVEL DETECTION CIRCUIT

The level of the transformer oil is measured using the circuit shown below. The level of the oil in a transformer is very important, because when the oil level in the transformer is less, it may lead to some adverse effects leading to improper functioning of the transformer. Hence it is necessary to monitor the level of the oil continuously. Our project detects the level of the transformer oil in a small module .The level detecting circuit includes

- Transmitter
- Receiver

The transmitter that we have employed is a LASER source. When there is oil in the transformer, the oil refracts the laser beam and hence the photo transducer does not receive any signal. This is then sent as an input to the Microcontroller whose output is then sent to the front end in order to display the level of the oil in the transformer.

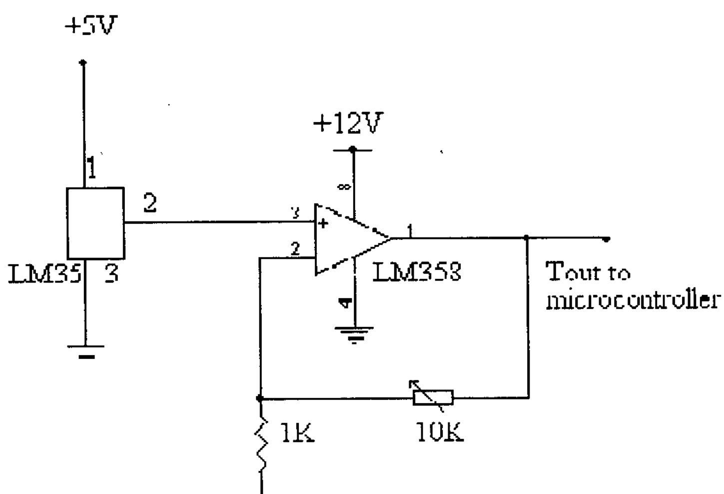


LEVEL DETECTOR

3.2.2 TEMPERATURE SENSING CIRCUIT

The circuit continuously monitors the temperature of the transformer oil. The monitored value is continuously displayed to the user via the personal computer.

Temperature sensing is done by integrated circuit temperature sensor LM35. The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius temperature. Its output is 10mV/degree Celsius. The LM35's low output impedance, linear output and precise inherent calibration make interfacing to read out or control circuitry especially easy. It can be used with single power supplies or with positive and negative supplies. As it draws only 60µA from its supply, it has very low self-heating, less than 0.1°C in still air. The LM35 is rated to operate over a -55°C to +150°C temperature range, while the LM35C is rated for a -40°C to +110°C range (-10°C with improved accuracy). The LM35 generates an electrical analogous of the surrounding temperature and the output of LM35 is amplified and fed to the microcontroller.



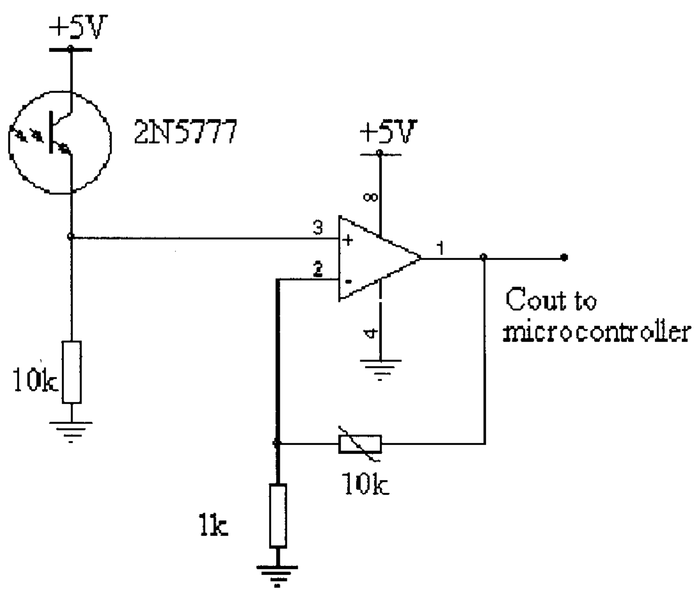
3.2.3 CONTAMINATION CIRCUIT

Transformer oil or Ascerol is a vegetable oil, which degrades over a period of time under working condition. This will affect the transformer durability. Hence oil play an important role and it has to be removed periodically so that it produces only positive or beneficial impact on the transformer. Our project determines the degradation level of the oil by measuring the contamination. Contamination detecting circuit is an optical circuit consisting of two sections,

a. Transmitter

b. Receiver

Transmitter includes laser beam and its accessories and receiver is a photo transducer with amplifier assembler. Based on the intensity of the beam falling over the transducer, it generates corresponding voltage, which indicates the contamination level of oil.



CONTAMINATION CIRCUIT

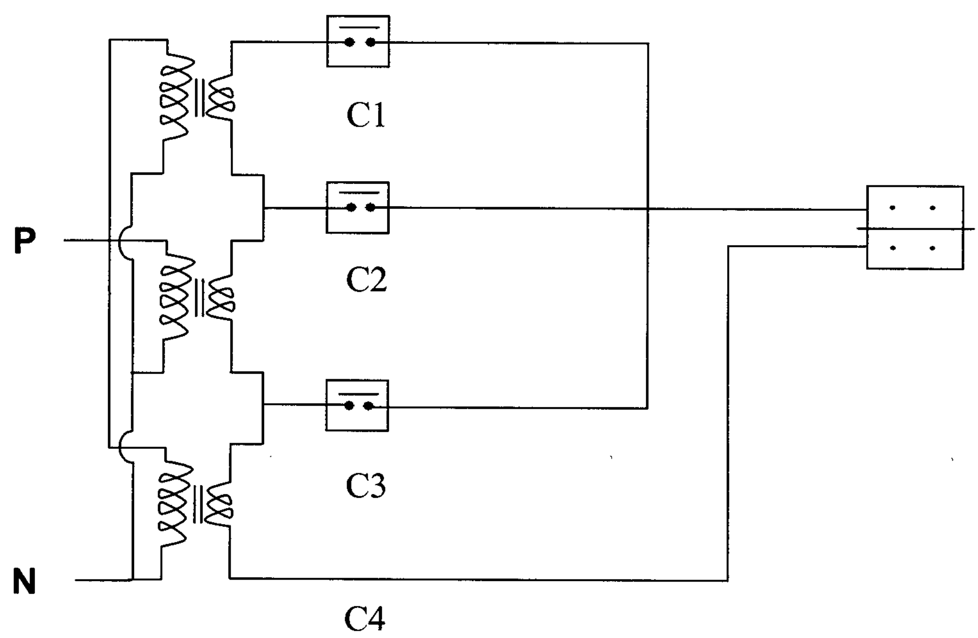
3.3 CONTROLLING

Control circuit enables efficient operation of transformer and protects the transformer during the occurrence of fault. Control circuits of our project are

1. Tap Changer circuit
2. Tripping Circuit

3.3.1 TAP CHANGER CIRCUIT

Tap changer circuit controls the opening or closing of contactor switches through high speed switching relay. The schematic diagram of contacts of relay is shown below



TAP CHANGER CIRCUIT

The contact C1, C2, C3 and C4 position is controlled using the signal from Microcontroller. The contact is closed manually by selecting an option button in Visual Basic display.

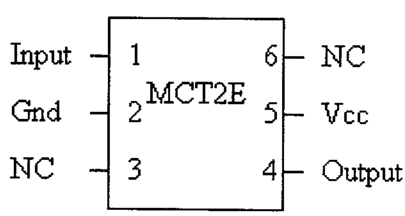
3.3.2 TRIPPING CIRCUIT

In the case of occurrence of fault and any abnormal conditions, it is necessary to isolate the transformer from the line. Hence tripping circuits are required. In the above circuit when all the contactors are in open position it indicates that the circuit is tripped.

3.3.3 OPTO COUPLER

The proper isolation between input and output becomes very important in several digital and analog applications. The traditional method of isolation involves the use of devices such as capacitors, relays, transformers and opto couplers. Of these, the opto coupler provides an ideal combination of speed, OC response for both analog and digital applications in industrial, medical and military products. Examples are logic isolations, line receivers, sensing circuits, power supply, feed back, high voltage current monitoring, and telephones lines and so on.

Opto coupler consists of an LED emitter and a photo sensor of transistor or diode type. Our project employs transistor type photo sensor.



DGA

4.1 NEED FOR DISSOLVED GAS ANALYSIS

During normal use there is usually a slow degradation of the mineral oil to yield certain gases that collect in the oil. However, when there is an electrical fault within the transformer, gases are generated at a much more rapid rate. There are four major types of electrical faults they are

TYPES OF FAULTS	MAJORITY GASES FORMED IN OIL
Arcing	Hydrogen, Acetylene, Carbon dioxide
Corona	Hydrogen, Methane
Sparking	Hydrogen, Methane, Ethane
Overheating	Ethylene, Methane

Types of faults and the gases evolved

These faults differ in its severity. The least severe is a partial discharge or corona, localized hot spots are next in severity, and the most severe is arcing. There are typically nine fault gases that are analyzed and each of the above faults generates certain key gases and a distribution pattern of these gases. Thus by determining the various gases present and their amounts, one can infer the nature of the fault giving rise to them.

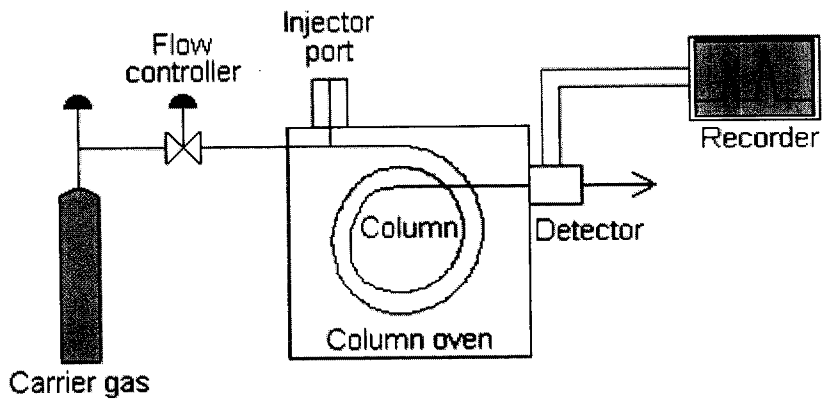
4.2 DGA

Dissolved gas analysis is probably the most widely used preventative maintenance technique in use today to monitor the operation of transformers. Properly used it can be a powerful tool in a well disciplined maintenance program. Depending on the location of a transformer and the nature of its usage, an appropriate dissolved gas analysis schedule can be set up. The more critical the unit is, the more frequently it should be sampled. When an adverse situation is detected the sampling frequency should also be increased. This latter philosophy allows one to determine how rapidly the gases are being generated and thus how serious the problem might be so that proper action can be taken before the unit suffers additional damage. It is also quite important to maintain a history of each unit so that one can determine if any gases are residual ones from a previous fault or are they due to a newly developing situation.

4.3 CHROMATOGRAPHY

Chromatography involves a sample (or sample extract) being dissolved in a *mobile phase* (which may be a gas, a liquid or a supercritical fluid). The mobile phase is then forced through an immobile, immiscible *stationary phase.* This stationary phase is packed densely and uniformly in a coiled tubing of specific length and diameter called the 'column'. The mobile gas phase called the "carrier" flows at a constant rate through this column. The phases are chosen such that components of the sample have differing solubilities in each phase. A component which is quite soluble in the stationary phase will take longer to travel through it than a component which is not very soluble in the stationary phase but very soluble in the mobile phase. As a result of these differences in mobilities, sample components will become separated from each other as they travel through the stationary phase. The instrument that does such mentioned processes is called "**gas chromatograph**"

SCHEMATIC DIAGRAM OF CHROMOTOGRAPH



4.4 WORKING

The dissolved gases in the transformer oil are removed and it is injected into the chromatograph through an injector port. This mixture of gas is mixed with carrier gas such as nitrogen, helium etc., Now the combined gas is passed through the column that separates the gases according to its molecular weight. A voltage equivalent of PPM of each gas is determined in the detector. This is then fed to the computer for calculation of area of individual gases. The PPM of the gases is determined by comparing it with standard gases whose PPM is known. Once the PPM of the individual gases is known, the type of fault that has occurred in the transformer can be determined using ROGERS RATIO ANALYSIS

4.5 ROGERS RATIO ANALYSIS

In our project we have employed Rogers analysis using four SPDT switches. Making any of the above sequence will trip the transformer and the reason for tripping will be displayed in the VB.

Rogers Ratio Analysis

CH_4/H_2	C_2H_6/CH_4	C_2H_4/C_2H_6	C_2H_2/C_2H_4	EVALUATION
0	0	0	0	NORMAL
1	0	0	0	Slight over heating <150 Deg C
1	1	0	0	Slight over heating 150-200 Deg C
0	1	0	0	Overheating 200-300 Deg C
0	1	1	0	General Conductor Overheating
1	0	1	0	Circulating currents & Overheated joints
0	0	0	1	Flash over with Power follow through
0	1	0	1	Tap changer selector Breaking Current
0	0	1	1	Arc with power follow through or Persistent sparking

MICROCONTROLLER

MICROCONTROLLER

5.1 KEY FEATURES OF PIC 16F877

- High-performance RISC CPU.
- Only 35 single instructions to learn.
- All single instructions except for program branches are two cycles.
- Operating speed: DC – 20MHz clock input
  DC - 200 ns instruction cycle.
- Up to 8K X 14 words of FLASH Program Memory
  Up to 368X 8 bytes of Data Memory (RAM).
  Up to 256 X 8 bytes of EEPROM data memory.
- Power on Reset (POR).
- Power saving SLEEP mode.
- 10 - Bit multi channel Analog-to-Digital converter.
- Universal synchronous asynchronous receiver transmitter. (USART) with 9-bit address detection.
- Brownout Reset (BOR).
- 3 Timers and 5 Ports (port A, B, C, D, and E).

5.2 I/O PORTS

PORTS A, B, C, D are used in which PORT A is a 6 bit wide bi-directional port whereas PORTS B, C are 8 bit bi-directional ports and PORT D is an 8-bit port with Schmitt trigger input buffers. The corresponding directional registers for PORT A, B, C are TRIS A, TRIS B, TRIS C respectively. Setting the directional register bit (=1) will make the corresponding PORT pin as input and clearing the bit (=0) will make the corresponding PORT pin as output.

ASSIGNMENT OF PORTS

PIN	NAME	FUNCTION
2	RA0	VOLTAGE
3	RA1	CURRENT
4	RA2	TEMPERATURE
5	RA3	FREQUENCY
7	RA5	CONTAMINATION
19	RD0	Vzcd
20	RD1	Izcd
25	RC6	TRANSMISSION
26	RC7	RECEPTION
27-29	RD4-RD6	LEVEL 1,2,3
33-36	RB0-RB3	TAP CONTROL
37-40	RB4-RB7	ROGERS RATIO

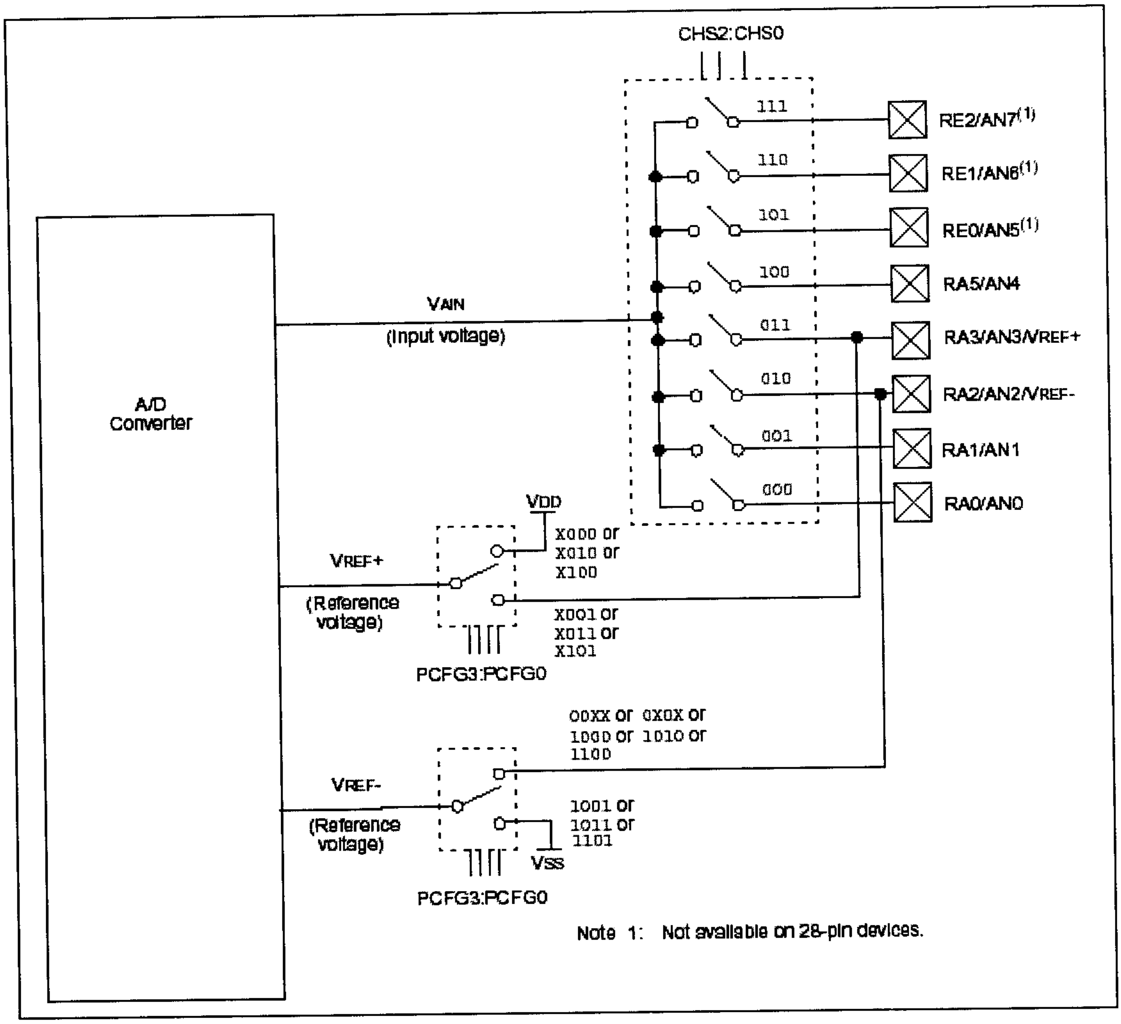
5.3 ANALOG TO DIGITAL CONVERTER (A/D)

The analog-to-digital (A/D) converter module has five inputs for the 28-pin devices. The analog input charges a sample and hold capacitor. The output of the sample and hold capacitor is the input into the converter. The converter then generates a digital result of this analog level via successive approximation. This A/D conversion, of the analog input signal, results in a corresponding 10-bit digital number .The A/D converter has a unique feature of being able to operate while the device is in SLEEP mode. To operate in sleep, the A/D clock must be derived from the A/D's internal RC oscillator. The A/D module has four registers. These registers are:

- A/D Result High Register (ADRESH)
- A/D Result Low Register (ADRESL)
- A/D Control Register0 (ADCON0)
- A/D Control Register1 (ADCON1)

The ADCON0 register controls the operation of the A/D module. The ADCON1 register configures the functions of the port pins. The port pins can be configured as analog inputs (RA3 can also be the voltage reference) or as digital I/O. The ADRESH: ADRESL registers contain the 10-bit result of the A/D conversion. When the A/D conversion is complete, the result is loaded into this A/D result register pair, the GO/DONE bit (ADCON0<2>) is cleared, and A/D interrupt flag bit ADIF is set. After the A/D module has been configured as desired, the selected channel must be acquired before the conversion is started. The analog input channels must have their corresponding TRIS bits selected as inputs. After

A/D BLOCK DIAGRAM



5.4 USART

The Universal Synchronous Asynchronous Receiver Transmitter (USART) module is one of the two serial I/O modules. (USART is also known as a Serial Communications Interface or SCI). The USART can be configured as a full duplex asynchronous system that can communicate with peripheral devices such as CRT terminals and personal computers, or it can be configured as a half duplex synchronous system that can communicate with peripheral devices such as A/D or D/A integrated circuits, Serial EPROM etc.

The USART can be configured in the following modes:

- Asynchronous (full duplex)
- Synchronous - Master (half duplex)
- Synchronous - Slave (half duplex)

Bit SPEN (RCSTA<7>), and bits TRISC<7:6>, has to be set in order to configure pins RC6/TX/CK and RC7/ RX/DT as the Universal Synchronous Asynchronous Receiver Transmitter. The USART module also has a multi-processor communication capability using 9-bit address detection.

In this project USART in Asynchronous mode (full duplex) is used for data transmission and reception. In this mode, the USART uses standard non return-to zero (NRZ) format (one start bit, eight or nine data bits and one stop bit). The most common data format is 8-bits. An on-chip dedicated 8-bit baud rate generator can be used to derive standard baud rate frequencies from the oscillator. The USART transmits and receives the LSB but use the same data format and baud rate. The baud rate generator produces a clock either x16 or x64 of the bit shift rate, depending on bit BRGH (TXSTA<2>). Parity is not supported by the hardware, but can be implemented in software (and stored as the ninth data bit). Synchronous mode is stopped during SLEEP. Asynchronous mode is selected by clearing bit SYNC (TXSTA<4>). The USART module has a special provision for multiprocessor communication. When the RX9 bit is set in the RCSTA register, 9-bits are received and the ninth bit is placed in the RX9D status bit of the RSTA register .The port can be programmed such that when the stop bit is received, the serial port interrupt will only be activated if the RX9D bit = 1. Setting the ADDEN bit CSTA <3> in the RCSTA register enables this feature.

5.5 TIMER

PIC 16F877 supports three timers – TIMER0, TIMER1, TIMER2. In the project TIMER 0 is employed.

TIMER 0

The Timer0 module timer / counter has the following features:

- 8-bit timer/counter
- Readable and writable
- Internal or external clock select
- Edge select for external clock
- 8-bit software programmable prescaler
- Interrupt on overflow from FFh to 00h

Timer0 can operate as a timer or as a counter. Timer mode is

Timer0 module will increment every instruction cycle (without prescaler). If the TMR0 register is written, the increment is inhibited for the following two instruction cycles. The user can work around this by writing an adjusted value to the TMR0 register. The TMR0 interrupt is generated when the TMR0 register overflows from FFh to 00h. This overflow sets bit T0IF (INTCON<2>). The interrupt can be masked by clearing bit T0IE (INTCON<5>).>). Bit T0IF must be cleared in software by the Timer0 module interrupt service routine before re-enabling this interrupt. The TMR0 interrupt cannot awaken the processor from SLEEP since the timer is shut off during SLEEP.

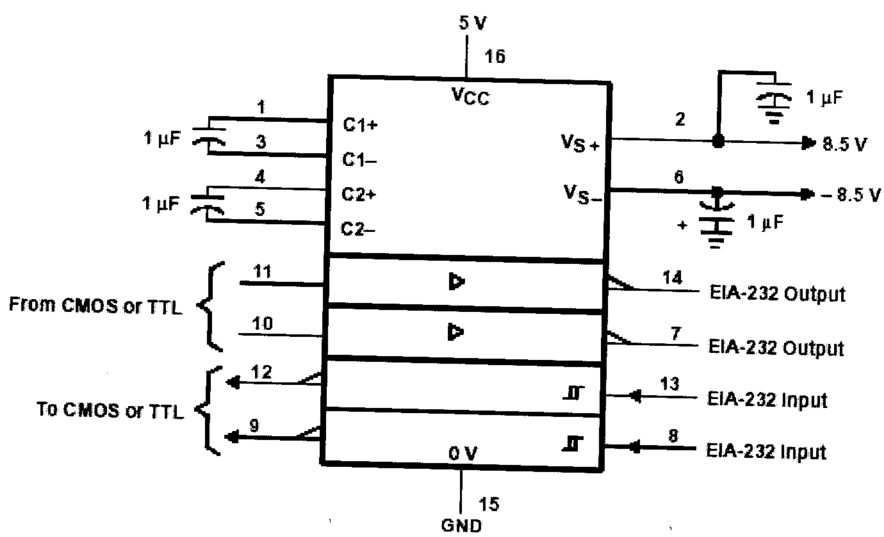
COMMUNICATION

COMMUNICATION

6.1 RS 232

The most common communication interface for short distance is RS 232. This defines a serial communication for one device to one computer communication port, with speeds up to 19,200 baud. Typically 7 or 8 bits (on/off) signal is transmitted to represent a character or digit. The 9-pin connector is used.

6.2 MAX 232:



Typical operating circuit

The MAX232 device is a dual driver/receiver that includes a capacitive voltage generator to supply EIA-232 voltage levels from a single levels. These receivers have a typical threshold of 1.3 V and a typical hysteresis of 0.5 V, and can accept ±30-V inputs. Each driver converts TTL/CMOS input levels into EIA-232 levels.

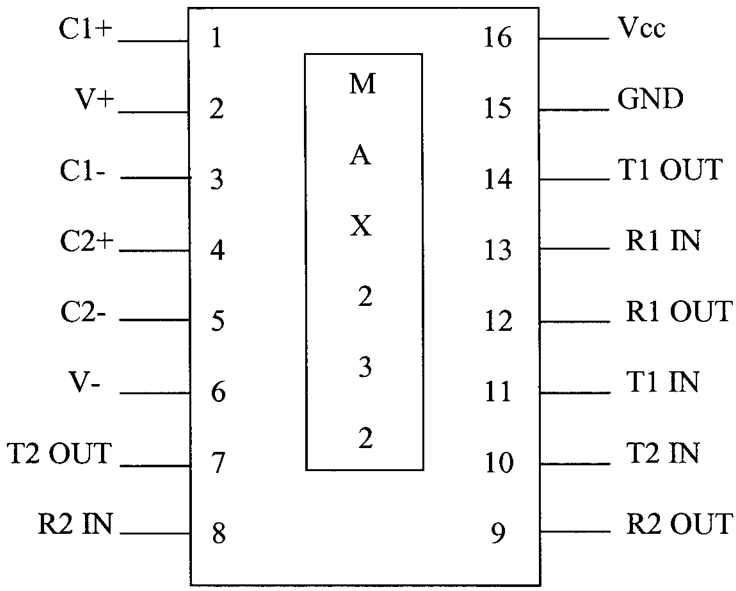
Each of the two transmitters is a CMOS inverter powered by +10v internally generated supply. The input is TTL and CMOS compatible with a threshold of about 26% of Vcc. The input if an unused transmitter section can be left unconnected, an internal 400kΩ pull up resistor connected between transistor input and Vcc will pull the input high forming the unused transistor output low.

The open circuit output voltage swing is guaranteed to meet RS 232 specification +5V output swing under the worst of both transmitter driving he 3kΩ minimum load impedance, the Vcc input at 4.5V and maximum allowable ambient temperature typical voltage with 5kΩ and Vcc = +9V.

6.2.1 RECEIVER SECTION:

The two receivers fully conform to RS232 specifications. Their input impedance is between 3kΩ either with or without 5V power applied and their switching threshold is within the +3V of RS232 specification. To ensure compatibility with either RS232 or TTL/CMOS input. The MAX 232 receivers have VIL of 0.8V and VHL of 2.4V. The receivers have 0.5V of hysteresis to improve noise rejection. The TTL/CMOS compatible output of receiver output will be high when input is floating or driven between +0.8V and 30V.

PIN DIAGRAM OF MAX 232



6.2.2 ELECTRICAL CHARACTERISTICS OF MAX 232

Vcc = 6V.

V+ = 12V.

V- = 12V.

INPUT VOLTAGE

T1 in, T2 in = -0.3 to (Vcc + 0.3V)

R1 in, R2 in = +30V or –30V.

OUTPUT VOLTAGE

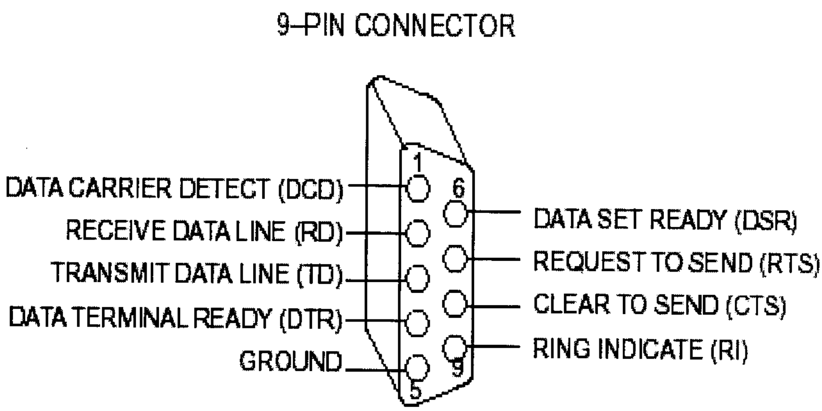
TI out, T2 out = ((V+) + 0.3V) to ((V-) + 0.3V).

R1 out, R2 out = -0.3V to (Vcc + 0.3V).

Power dissipation = 375 mW.

Output resistance = 300Ω.

The RS 232 can communicate with PC through a D9 pin connector.



6.3 RS 485

Electronic data communications between elements will generally fall into two categories

- Single ended data transmission.
- Differential data transmission.

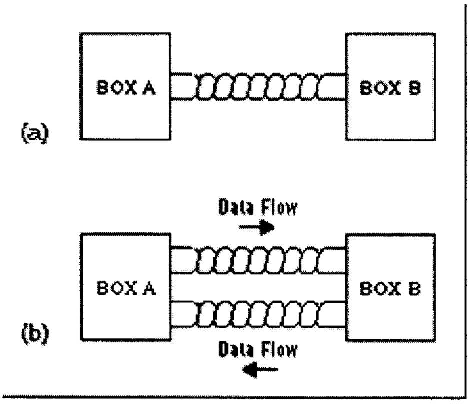
When communicating at high baud data rates, or over long distances in real world environments, single ended methods are often inadequate. Differential data transmission offers superior performance in most applications. Differential signals can help to nullify the effects of ground shifts and induced noise signals that can appear as common mode voltages on a network.

RS 485 meets the requirements for a truly multi-point communications network and the standard specifies up to 32 drivers and 32 receivers on a single bus. With the introduction of automatic repeaters and high impedance drivers/receivers this limitation can be extended to hundreds of nodes on a network.

This project employs communication of data between the master and the slave unit by means of full-duplex RS 485 system.

A full-duplex system allows communication in both directions simultaneously whereas in half-duplex system only one transmitter can be active at a time. Full-duplex system designed with RS 485 requires two twisted pair cables running between the transmitter and receiver. One twisted pair is dedicated to transmit information in one direction and the other twisted pair is dedicated to transmit data in opposite direction.

HALF AND FULL DUPLEX RS 485 SYSTEMS:



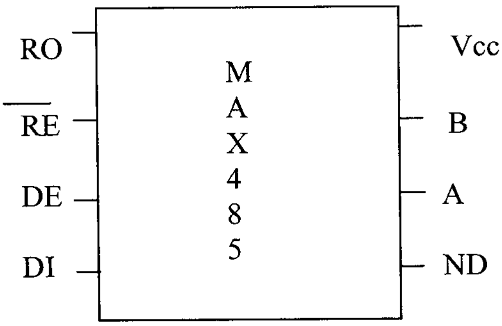
Half-duplex RS-485 system (a); full-duplex RS-485 system (b)

6.4 MAX 485

The MAX485 is a low-power transceiver for RS-485 communication. Each part contains one driver and one receiver. The driver slew rates of the MAX485 are not limited, allowing them to transmit up to 2.5Mbps.

This transceiver draws between 120μA and 500μA of supply current when unloaded or fully loaded with disabled drivers. All parts operate from a single 5V supply. Drivers are short-circuit current limited and are protected against excessive power dissipation by thermal shutdown circuitry that places the driver outputs into a high-impedance state. The receiver input has a fail-safe feature that guarantees a logic-high output if the input is open circuit.

PIN DIAGRAM OF MAX 485:



Pin Description of MAX 485

PIN	FUNCTION
RO	Receiver output
$\overline{RE}$	Receiver output enable
DE	Driver output enable
DI	Driver input
GND	Ground
A	Non-inverting Receiver Input and Non-inverting Driver O/p
B	Inverting Receiver Input and Inverting Driver Output
Vcc	Positive Supply: $4.75V \leq VCC \leq 5.25V$

SOFTWARE

SOFTWARE

7.1 PIC CODING

```
#include <pic.h>
#include <f87x.h>
#include <stdio.h>
unsigned char input, value;
unsigned char tabl[4];
unsigned int tr0, timer_value;
bit a;
void Hardware_Intialisation(void);

main()
{
        Hardware_Intialisation();
        while(1);
}

interrupt isr( )
{
 GIE = 0;
        if( RCIF )
        {
                input = getbyte();
                switch( input )
                {
                        case '0':
                        {
                                sprintf( tabl, "%04u", timer_value );
                                isr_putbyte( ':' );
                                isr_putbyte( '0' );
                                isr_putbyte( tabl[0] );
                                isr_putbyte( tabl[1] );
                                isr_putbyte( tabl[2] );
                                isr_putbyte( tabl[3] );
                                break;
                        }
```

```
case '1':
{
        value = adc_read_8bit(0);
        sprintf( tabl, "%04u", value );
        isr_putbyte( ':' );
        isr_putbyte( '1' );
        isr_putbyte( tabl[0] );
        isr_putbyte( tabl[1] );
        isr_putbyte( tabl[2] );
        isr_putbyte( tabl[3] );
        break;
}
case '2':
{
        value = adc_read_8bit(1);
        sprintf( tabl, "%04u", value );
        isr_putbyte( ':' );
        isr_putbyte( '2' );
        isr_putbyte( tabl[0] );
        isr_putbyte( tabl[1] );
        isr_putbyte( tabl[2] );
        isr_putbyte( tabl[3] );
        break;
}
case '3':
{
        value = adc_read_8bit(2);
        sprintf( tabl, "%04u", value );
        isr_putbyte( ':' );
        isr_putbyte( '3' );
        isr_putbyte( tabl[0] );
        isr_putbyte( tabl[1] );
        isr_putbyte( tabl[2] );
        isr_putbyte( tabl[3] );
        break;
}
case '4':
{
        value = adc_read_8bit(3);
        sprintf( tabl, "%04u", value );
```

```
        isr_putbyte( ':' );
        isr_putbyte( '4' );
        isr_putbyte( tabl[0] );
        isr_putbyte( tabl[1] );
        isr_putbyte( tabl[2] );
        isr_putbyte( tabl[3] );
        break;
}
case '5':
{
        value = adc_read_8bit(4);
        sprintf( tabl, "%04u", value );
        isr_putbyte( ':' );
        isr_putbyte( '5' );
        isr_putbyte( tabl[0] );
        isr_putbyte( tabl[1] );
        isr_putbyte( tabl[2] );
        isr_putbyte( tabl[3] );
        break;
}
case '6':
{
        sprintf( tabl, "%04u", PORTD );
        isr_putbyte( ':' );
        isr_putbyte( '6' );
        isr_putbyte( tabl[0] );
        isr_putbyte( tabl[1] );
        isr_putbyte( tabl[2] );
        isr_putbyte( tabl[3] );
        break;
}

case 'A':
{
        RB0 = 1;
        RB1 = 0;
        RB2 = 0;
        RB3 = 0;
        break;
}
```

```
                case 'B':
                {
                        RB0 = 0;
                        RB1 = 1;
                        RB2 = 0;
                        RB3 = 0;
                        break;
                }
                case 'C':
                {
                        RB0 = 0;
                        RB1 = 0;
                        RB2 = 1;
                        RB3 = 0;
                        break;
                }
                case 'D':
                {
                        RB0 = 0;
                        RB1 = 0;
                        RB2 = 0;
                        RB3 = 1;
                        break;
                }
                case 'E':
                {
                        RB0 = 0;
                        RB1 = 0;
                        RB2 = 0;
                        RB3 = 0;
                        break;
                }
        }
        RCIF = 0;
}
if( T0IF )
{
        TMR0 = 60;
        RC5 = !RC5;
        a = RD0 ^ RD1;
```

```
		if( a )
		{
			tr0++;
		}
		else
		{
			timer_value = tr0;
			tr0 = 0;
		}
		T0IF = 0;
	}
 GIE = 1;
}

void Hardware_Intialisation(void)
{
 /* PORT DECLERATION */
	TRISC = 0x80;
	TRISB = 0x00;
	TRISA = 0XFF;
	TRISD = 0XF0;

 /* ADC INTIALISATION */
	ADCON1 = 0x00;
	USART_INIT9600_20MHZ();
	RBPU = 0;

 /* Timer 0 Setup ~ 10ms */
	T0IE = 1;
	T0IF = 0;
	T0CS = 0;
	PSA = 0;
	PS0 = 1;
	PS1 = 1;
	PS2 = 1;

 /* INTERRUPT SETTINGS */
	GIE = 1;
	PEIE = 1;
}
```

7.2 VB CODING

```
Dim Input_String, Device As String
Dim Value_0, Value_1, Value_2, Value_3, Value_4, Value_5, Value_6,
Value_7, Value_8 As Integer

Private Sub Check1_Click()
        If Check1.Value = Checked Then
                Frame6.Enabled = True
        Else
                Frame6.Enabled = False
                MSComm1.Output = "E"
        End If
End Sub

Private Sub Comm1_Click()
        If Comm1.Value = True Then
                MSComm1.CommPort = 1
        End If
End Sub

Private Sub Comm2_Click()
        If Comm2.Value = True Then
                MSComm1.CommPort = 2
        End If
End Sub

Private Sub Communication_Enable_Click()
        If Communication_Enable.Value = Checked Then
                MSComm1.PortOpen = True
                Frame4.Enabled = False
                Check1.Enabled = True
                Check1.Value = Unchecked
                Option2.Value = True
        Else
                MSComm1.PortOpen = False
                Check1.Enabled = False
                Frame4.Enabled = True
        End If
End Sub
```

```
Private Sub Form_Load()
        Comm1.Value = True
        For Value_1 = 1 To 60
                MSChart1.Row = Value_1
                MSChart1.Column = 1
                MSChart1.Data = 0
                MSChart1.Column = 2
                MSChart1.Data = 0
                MSChart1.Column = 3
                MSChart1.Data = 0
        Next Value_1
        Value_1 = 0
End Sub

Private Sub Form_Unload(Cancel As Integer)
        If MSComm1.PortOpen = True Then
                MSComm1.PortOpen = False
        End If
End Sub


Private Sub MSComm1_OnComm()
        If MSComm1.InBufferCount >= 6 Then
                Input_String = MSComm1.Input
        If Mid$(Input_String, 1, 1) = ":" Then
                Text78.Text = Input_String
                Device = Mid$(Input_String, 2, 1)
        If Device = "0" Then
                Value_0 = Val(Mid$(Input_String, 3, 4))
        ElseIf Device = "1" Then
                Value_1 = Val(Mid$(Input_String, 3, 4))
        ElseIf Device = "2" Then
                Value_2 = Val(Mid$(Input_String, 3, 4))
        ElseIf Device = "3" Then
                Value_3 = Val(Mid$(Input_String, 3, 4))
        ElseIf Device = "4" Then
                Value_4 = Val(Mid$(Input_String, 3, 4))
        ElseIf Device = "5" Then
```

```
        Value_5 = Val(Mid$(Input_String, 3, 4))
ElseIf Device = "6" Then
        Value_6 = Val(Mid$(Input_String, 3, 4))
ElseIf Device = "7" Then
        Value_7 = Val(Mid$(Input_String, 3, 4))
ElseIf Device = "8" Then
        Value_8 = Val(Mid$(Input_String, 3, 4))
End If
PF_Label.Caption = Str$((Value_0) / 1000)
MSChart1.Column = 1
MSChart1.Data = Value_1
Voltage_Label.Caption = Str$(Round((Value_1 / 256) * 60, 2))
MSChart1.Column = 2
MSChart1.Data = Value_2
Current_Label.Caption = Str$(Round((Value_2 / 256) * 5, 2))
MSChart1.Column = 3
MSChart1.Data = Value_3
Temperature_Label.Caption = Str$(Round((Value_3 / 256) * 150, 2))
Frequency_Label.Caption = Str$(Round((Value_4 / 1024) * 50, 2))
cont_value = Str$(Round((Value_5 / 1024), 2))
If cont_value >= 0.15 Then
        Contamination_Label.Caption = "LOW"
End If
If cont_value < 0.15 And cont_value > 0.05 Then
        Contamination_Label.Caption = "MEDIUM"
End If
If cont_value <= 0.05 Then
        Contamination_Label.Caption = "HIGH"
End If
If (Val(Value_6) And &H7) = 1 Then Level_Label.Caption = "2"
If (Val(Value_6) And &H7) = 3 Then Level_Label.Caption = "1"
If (Val(Value_6) And &H7) = 7 Then Level_Label.Caption = "0"
If Level_Label.Caption = "-1" Then Level_Label.Caption = "3"
If (Val(Value_6) And &HF0) = 0 Then
        Rogers_Ratio_Label.Caption = "If Ratio CH4/H2 </= 0.1 P.D
Otherwise Normal"
ElseIf (Val(Value_6) And &HF0) = &H80 Then
        Rogers_Ratio_Label.Caption = "Slight Over Heating < 150
Deg. 'C"
ElseIf (Val(Value_6) And &HF0) = &HC0 Then
```

```
        Rogers_Ratio_Label.Caption = "Slight Over Heating 150 - 200
Deg. 'C"
ElseIf (Val(Value_6) And &HF0) = &H40 Then
        Rogers_Ratio_Label.Caption = "Over Heating 200 - 300 Deg.
'C"
ElseIf (Val(Value_6) And &HF0) = &H60 Then
        Rogers_Ratio_Label.Caption = "General Conductor Over
Heating"
ElseIf (Val(Value_6) And &HF0) = &HA0 Then
        Rogers_Ratio_Label.Caption = "Circulating Currents &/ Over
Heated Joints"
ElseIf (Val(Value_6) And &HF0) = &H10 Then
        Rogers_Ratio_Label.Caption = "Flash Over with Power follow
Through"
ElseIf (Val(Value_6) And &HF0) = &H50 Then
        Rogers_Ratio_Label.Caption = "Tap Changer Selector
Breaking Current"
ElseIf (Val(Value_6) And &HF0) = &H30 Then
        Rogers_Ratio_Label.Caption = "Arc with Power Follow
through or Persistant Sparking"
Else
        Rogers_Ratio_Label.Caption = "Undefined"
End If
If Save_Button.Value = Checked Then
        Open CommonDialog1.FileName For Append As #1
        Print #1, "Voltage = " + Voltage_Label.Caption
        Print #1, "Current = " + Current_Label.Caption
        Print #1, "Temperature = " + Temperature_Label.Caption
        Print #1, "Frequency = " + Frequency_Label.Caption
        Print #1, "Contamination = " + Contamination_Label.Caption
        Print #1, "Rogers Ratio = " + Rogers_Ratio_Label.Caption
        Print #1, "Level = " + Level_Label.Caption
        Print #1, "PF = " + PF_Label.Caption
        Print #1, "DATE=" + Date
        Print #1, "TIME=" + Time
        Print #1, "----------------------------"
        Close #1
End If
Else
MSComm1.InputLen = 100
```

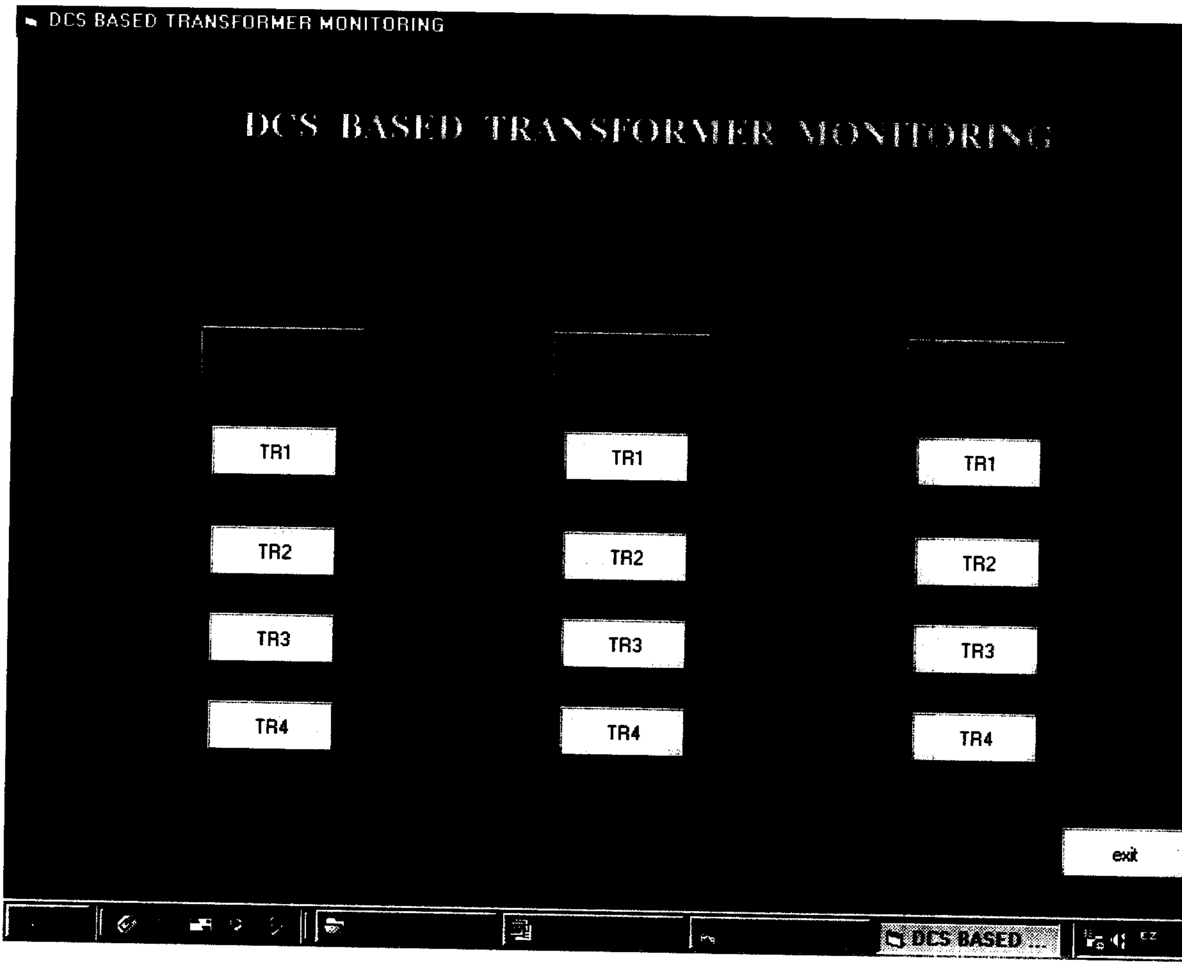
```
        Label1.Caption = MSComm1.Input
        MSComm1.InputLen = 8
        End If
        End If
End Sub

Private Sub Option1_Click()
        If Option1.Value = True Then
                MSComm1.Output = "A"
        End If
End Sub

Private Sub Option2_Click()
        If Option2.Value = True Then
                MSComm1.Output = "B"
        End If
End Sub

Private Sub Option3_Click()
        If Option3.Value = True Then
                MSComm1.Output = "C"
        End If
End Sub

Private Sub Option4_Click()
        If Option4.Value = True Then
                MSComm1.Output = "D"
        End If
End Sub

Private Sub Save_Button_Click()
        If Save_Button.Value = Checked Then
                CommonDialog1.ShowSave
        If CommonDialog1.FileName = "" Then
                MsgBox "No File Selected", vbOKOnly, "Warning"
                Save_Button.Value = Unchecked
        Else
                Open CommonDialog1.FileName For Output As #1
                Close #1
        End If
```

```
        End If
End Sub
Private Sub Timer1_Timer()
        If Communication_Enable.Value = Checked Then
        Select Case Device
        Case 0
                MSComm1.Output = "0"
                Device = 1
        Case 1
                MSComm1.Output = "1"
                Device = 2
        Case 2
                MSComm1.Output = "2"
                Device = 3
        Case 3
                MSComm1.Output = "3"
                Device = 4
        Case 4
                MSComm1.Output = "4"
                Device = 5
        Case 5
                MSComm1.Output = "5"
                Device = 6
        Case 6
                MSComm1.Output = "6"
                Device = 7
        Case 7
                MSComm1.Output = "7"
                If MSChart1.Row = 60 Then
                        MSChart1.Row = 1
                Else
                        MSChart1.Row = MSChart1.Row + 1
                End If
        Device = 0
        End Select
        End If
End Sub
```

RESULTS

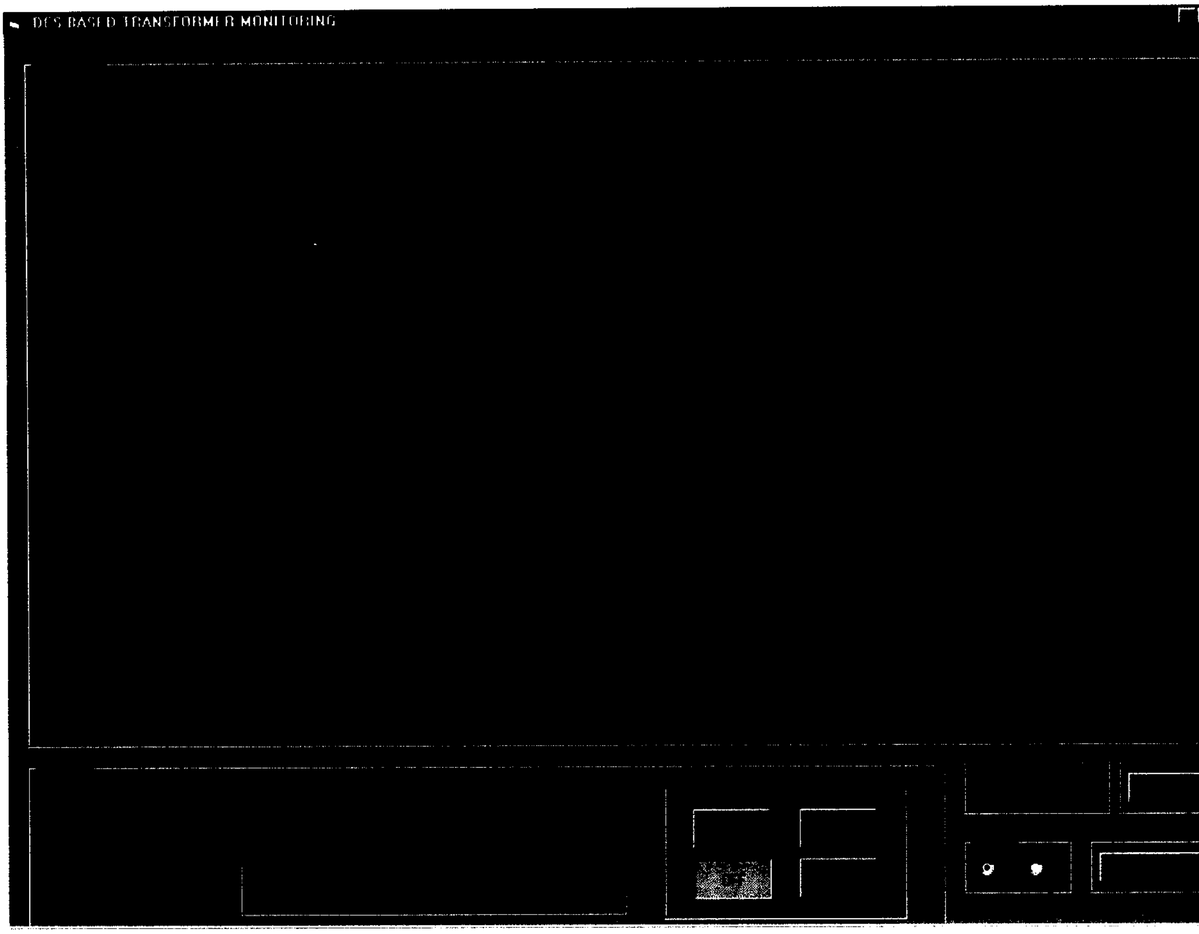
RESULTS

8.1 VB DISPLAY



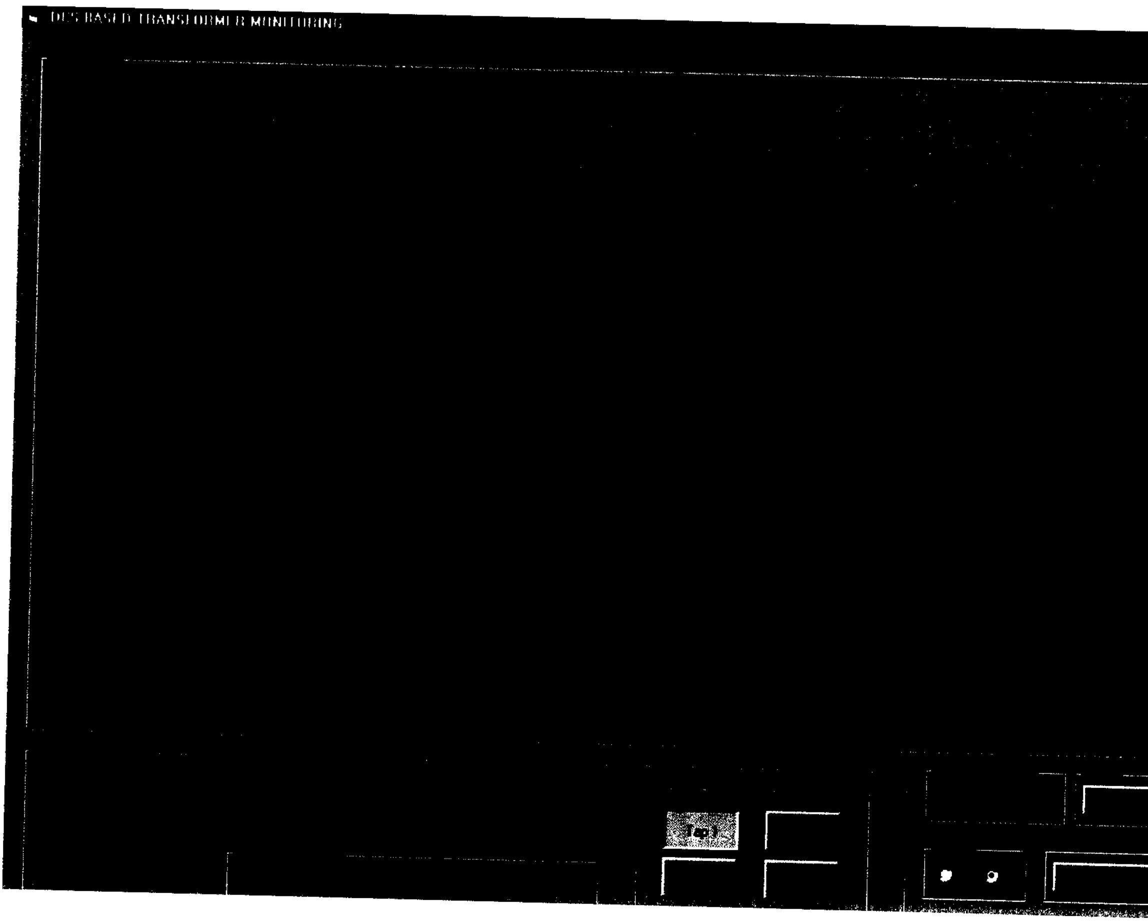
FRONT PANEL: VB DISPLAY 1

Initial screen that displays number of transformers available at different areas that is to be monitored and controlled.



FRONT PANEL:VB DISPLAY 2

Parameters of a transformer under OFF condition.



FRONT PANEL:VB DISPLAY 3

Parameters of a transformer under different tap changing conditions.

8.2 RECORDED DATA

DATE=22/03/05
TIME=12:09:33
Voltage = 11.72
Current = .12
Temperature = 22.85
Frequency = 49.56
Contamination = MEDIUM
Rogers Ratio = If Ratio CH4/H2 </= 0.1 P.D Otherwise Normal
Level = 0
PF = 1

DATE=22/03/05
TIME=12:09:33
Voltage = 11.72
Current = .12
Temperature = 22.85
Frequency = 49.56
Contamination = MEDIUM
Rogers Ratio = If Ratio CH4/H2 </= 0.1 P.D Otherwise Normal
Level = 0
PF = 1

DATE=22/03/05
TIME=12:09:33
Voltage = 11.72
Current = .12
Temperature = 22.85
Frequency = 49.56
Contamination = MEDIUM
Rogers Ratio = If Ratio CH4/H2 </= 0.1 P.D Otherwise Normal
Level = 0
PF = 1

DATE=22/03/05
TIME=12:09:34
Voltage = 11.72
Current = .12
Temperature = 22.85

Frequency = 49.56
Contamination = HIGH
Rogers Ratio = If Ratio CH4/H2 </= 0.1 P.D Otherwise Normal
Level = 1
PF = 1

DATE=22/03/05
TIME=12:09:34
Voltage = 11.72
Current = .12
Temperature = 22.85
Frequency = 49.56
Contamination = HIGH
Rogers Ratio = If Ratio CH4/H2 </= 0.1 P.D Otherwise Normal
Level = 1
PF = 1

DATE=22/03/05
TIME=12:09:34
Voltage = 11.72
Current = .12
Temperature = 22.85
Frequency = 49.56
Contamination = HIGH
Rogers Ratio = If Ratio CH4/H2 </= 0.1 P.D Otherwise Normal
Level = 1
PF = 1

DATE=22/03/05
TIME=12:09:35
Voltage = 11.72
Current = .12
Temperature = 22.85
Frequency = 49.56
Contamination = HIGH
Rogers Ratio = Slight Over Heating < 150 Deg . 'C
Level = 1
PF = 1

DATE=22/03/05

TIME=12:09:35
Voltage = 11.72
Current = .12
Temperature = 22.85
Frequency = 49.56
Contamination = HIGH
Rogers Ratio = Slight Over Heating < 150 Deg . 'C
Level = 2
PF = 1

DATE=22/03/05
TIME=12:09:35
Voltage = 11.72
Current = .12
Temperature = 22.85
Frequency = 49.56
Contamination = LOW
Rogers Ratio = Slight Over Heating < 150 Deg . 'C
Level = 2
PF = 1

DATE=22/03/05
TIME=12:09:36
Voltage = 37.27
Current = .12
Temperature = 22.85
Frequency = 49.56
Contamination = LOW
Rogers Ratio = Slight Over Heating 150 – 200 Deg . 'C
Level = 3
PF = 1

8.3 PHOTOGRAPH

CONCLUSION

CONCLUSION

The project facilitates to improve the life management there by reducing the operating costs and enhance the availability and reliability of the transformers. Control over various transformers and their parameters are employed. The evaluation of data acquired by on-line monitoring system shows the capability to detect oncoming failures within active part, on-load tap changer and cooling unit. Remote human intervention control is today's need and the project utilizes the best of it.

Some of the future works that can be implemented are:

- Determination of acidic values using pH sensors.
- Analyzing moisture content of the oil.
- Finding possible ways to implement chromatography at reduced cost.
- Pre-fault analysis using intelligent tools.
- Determination of the life of the transformer's insulation using diagnosis method.

APPENDIX - 1

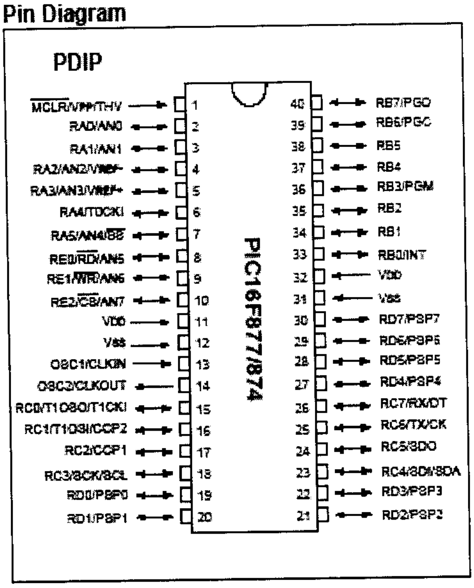
PIC16F87X

28/40-pin 8-Bit CMOS EEPROM/Flash Microcontrollers

Microcontroller Core Features:

- 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 the PIC16C73/74/76/77**
- Interrupt capability (up to 14 internal/external interrupt sources)
- Eight level deep hardware stack
- Direct, indirect, and relative addressing modes
- Power-on Reset (POR)
- Power-up Timer (PWRT) and Oscillator Start-up Timer (OST)
- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Programmable code-protection
- Power saving SLEEP mode
- Selectable oscillator options
- Low-power, high-speed CMOS EPROM/EEPROM technology
- Fully static design
- In-Circuit Serial Programming™ via two pins
- ★ Only single 5V source needed for programming
- ★ In-Circuit Debugging via two pins
- Processor read/write access to program memory
- Wide operating voltage range: 2.5V to 5.5V
- High Sink/Source Current: 25 mA
- Commercial and Industrial temperature ranges
- Low-power consumption:
  - < 2 mA typical @ 5V, 4 MHz
  - 20 µA typical @ 3V, 32 kHz
  - < 1 µA typical standby current

Pin Diagram

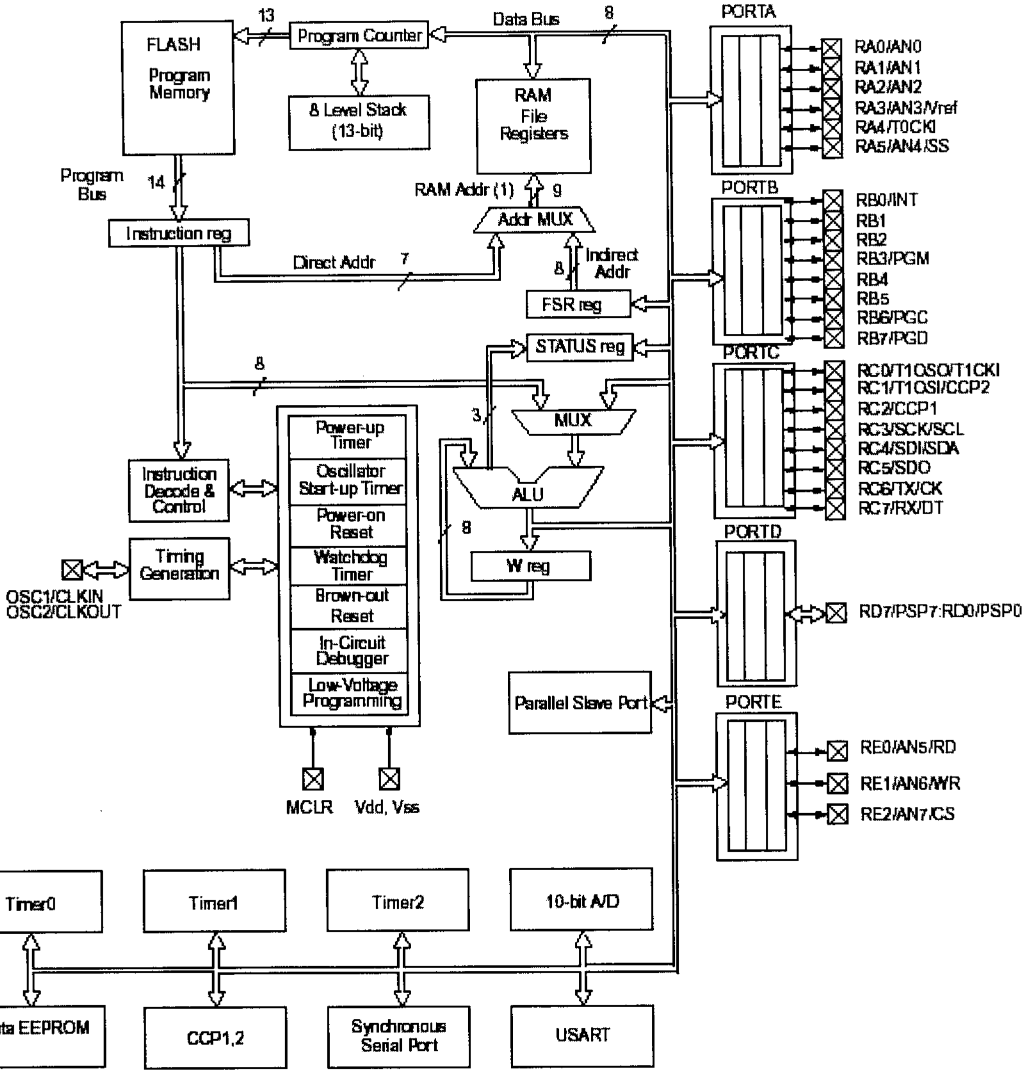


Peripheral Features:

- Timer0: 8-bit timer/counter with 8-bit prescaler
- Timer1: 16-bit timer/counter with prescaler, can be incremented during sleep via external crystal/clock
- Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Two Capture, Compare, PWM modules
- Capture is 16-bit, max. resolution is 12.5 ns, Compare is 16-bit, max. resolution is 200 ns, PWM max. resolution is 10-bit
- ★ 10-bit multi-channel Analog-to-Digital converter
- ★ Synchronous Serial Port (SSP) with SPI™ (Master Mode) and I²C™ (Master/Slave)
- ★ Universal Synchronous Asynchronous Receiver Transmitter (USART/SCI) with 9-bit address detection
- Parallel Slave Port (PSP) 8-bits wide, with external RD, WR and CS controls (40/44-pin only)
- Brown-out detection circuitry for Brown-out Reset (BOR)

PIC16F877 BLOCK DIAGRAM

Device	Program Flash	Data Memory	Data EEPROM
PIC16F874	4K	192 Bytes	128 Bytes
PIC16F877	8K	368 Bytes	256 Bytes



Note 1: Higher order bits are from the STATUS register.

PIC16F877/876 REGISTER FILE MAP

Bank 0	File Address	Bank 1	File Address	Bank 2	File Address	Bank 3	File Address
Indirect addr.(*)	00h	Indirect addr.(*)	80h	Indirect addr.(*)	100h	Indirect addr.(*)	180h
TMR0	01h	OPTION_REG	81h	TMR0	101h	OPTION_REG	181h
PCL	02h	PCL	82h	PCL	102h	PCL	182h
STATUS	03h	STATUS	83h	STATUS	103h	STATUS	183h
FSR	04h	FSR	84h	FSR	104h	FSR	184h
PORTA	05h	TRISA	85h		105h		185h
PORTB	06h	TRISB	86h	PORTB	106h	TRISB	186h
PORTC	07h	TRISC	87h		107h		187h
PORTD (1)	08h	TRISD (1)	88h		108h		188h
PORTE (1)	09h	TRISE (1)	89h		109h		189h
PCLATH	0Ah	PCLATH	8Ah	PCLATH	10Ah	PCLATH	18Ah
INTCON	0Bh	INTCON	8Bh	INTCON	10Bh	INTCON	18Bh
PIR1	0Ch	PIE1	8Ch	EEDATA	10Ch	EECON1	18Ch
PIR2	0Dh	PIE2	8Dh	EEADR	10Dh	EECON2	18Dh
TMR1L	0Eh	PCON	8Eh	EEDATH	10Eh	Reserved(2)	18Eh
TMR1H	0Fh		8Fh	EEADRH	10Fh	Reserved(2)	18Fh
T1CON	10h		90h	General Purpose Register 16 Bytes	110h	General Purpose Register 16 Bytes	190h
TMR2	11h	SSPCON2	91h		111h		191h
T2CON	12h	PR2	92h		112h		192h
SSPBUF	13h	SSPADD	93h		113h		193h
SSPCON	14h	SSPSTAT	94h		114h		194h
CCPR1L	15h		95h		115h		195h
CCPR1H	16h		96h		116h		196h
CCP1CON	17h		97h		117h		197h
RCSTA	18h	TXSTA	98h		118h		198h
TXREG	19h	SPBRG	99h		119h		199h
RCREG	1Ah		9Ah		11Ah		19Ah
CCPR2L	1Bh		9Bh		11Bh		19Bh
CCPR2H	1Ch		9Ch		11Ch		19Ch
CCP2CON	1Dh		9Dh		11Dh		19Dh
ADRESH	1Eh	ADRESL	9Eh		11Eh		19Eh
ADCON0	1Fh	ADCON1	9Fh		11Fh		19Fh
General Purpose Register 96 Bytes	20h	General Purpose Register 80 Bytes	A0h	General Purpose Register 80 Bytes	120h	General Purpose Register 80 Bytes	1A0h
			EFh		16Fh		1EFh
		accesses 70h-7Fh	F0h	accesses 70h-7Fh	170h	accesses 70h - 7Fh	1F0h
	7Fh		FFh		17Fh		1FFh
Bank 0		Bank 1		Bank 2		Bank 3	

■ Unimplemented data memory locations, read as '0'.

* Not a physical register.

Note 1: These registers are not implemented on 28-pin devices.

2: These registers are reserved, maintain these registers clear.

2.2.2.3 INTCON REGISTER

The INTCON Register is a readable and writable register which contains various enable and flag bits for the TMR0 register overflow, RB Port change and External RB0/INT pin interrupts.

Note: Interrupt flag bits get set when an interrupt condition occurs regardless of the state of its corresponding enable bit or the global enable bit, GIE (INTCON<7>). User software should ensure the appropriate interrupt flag bits are clear prior to enabling an interrupt.

FIGURE 2-7: INTCON REGISTER (ADDRESS 0Bh, 8Bh, 10Bh, 18Bh)

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-x
GIE	PEIE	T0IE	INTE	RBIE	T0IF	INTF	RBIF
bit7							bit0

R= Readable bit
W= Writable bit
U= Unimplemented bit, read as '0'
- n= Value at POR reset

bit 7: **GIE**: Global Interrupt Enable bit
1 = Enables all un-masked interrupts
0 = Disables all interrupts

bit 6: **PEIE**: Peripheral Interrupt Enable bit
1 = Enables all un-masked peripheral interrupts
0 = Disables all peripheral interrupts

bit 5: **T0IE**: TMR0 Overflow Interrupt Enable bit
1 = Enables the TMR0 interrupt
0 = Disables the TMR0 interrupt

bit 4: **INTE**: RB0/INT External Interrupt Enable bit
1 = Enables the RB0/INT external interrupt
0 = Disables the RB0/INT external interrupt

bit 3: **RBIE**: RB Port Change Interrupt Enable bit
1 = Enables the RB port change interrupt
0 = Disables the RB port change interrupt

bit 2: **T0IF**: TMR0 Overflow Interrupt Flag bit
1 = TMR0 register has overflowed (must be cleared in software)
0 = TMR0 register did not overflow

bit 1: **INTF**: RB0/INT External Interrupt Flag bit
1 = The RB0/INT external interrupt occurred (must be cleared in software)
0 = The RB0/INT external interrupt did not occur

bit 0: **RBIF**: RB Port Change Interrupt Flag bit
1 = At least one of the RB7:RB4 pins changed state (must be cleared in software)
0 = None of the RB7:RB4 pins have changed state

TIMER0 MODULE

REGISTERS ASSOCIATED WITH TIMER0

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Value on: POR, BOR	Value on all other resets
01h,101h	TMR0	Timer0 module's register								xxxx xxxx	uuuu uuuu
0Bh,8Bh, 10Bh,18Bh	INTCON	GIE	PEIE	T0IE	INTE	RBIE	T0IF	INTF	RBIF	0000 000x	0000 000u
81h,181h	OPTION_REG	RBPU	INTEDG	T0CS	T0SE	PSA	PS2	PS1	PS0	1111 1111	1111 1111
85h	TRISA	—	—	PORTA Data Direction Register						--11 1111	--11 1111

Legend: x = unknown, u = unchanged, - = unimplemented locations read as '0'. Shaded cells are not used by Timer0.

10.0 UNIVERSAL SYNCHRONOUS ASYNCHRONOUS RECEIVER TRANSMITTER (USART)

The Universal Synchronous Asynchronous Receiver Transmitter (USART) module is one of the two serial I/O modules. (USART is also known as a Serial Communications Interface or SCI). The USART can be configured as a full duplex asynchronous system that can communicate with peripheral devices such as CRT terminals and personal computers, or it can be configured as a half duplex synchronous system that can communicate with peripheral devices such as A/D or D/A integrated circuits, Serial EEPROMs etc.

The USART can be configured in the following modes:

- Asynchronous (full duplex)
- Synchronous - Master (half duplex)
- Synchronous - Slave (half duplex)

Bit SPEN (RCSTA<7>), and bits TRISC<7:6>, have to be set in order to configure pins RC6/TX/CK and RC7/RX/DT as the Universal Synchronous Asynchronous Receiver Transmitter.

The USART module also has a multi-processor communication capability using 9-bit address detection.

FIGURE 10-1: TXSTA: TRANSMIT STATUS AND CONTROL REGISTER (ADDRESS 98h)

R/W-0	R/W-0	R/W-0	R/W-0	U-0	R/W-0	R-1	R/W-0
CSRC	TX9	TXEN	SYNC	—	BRGH	TRMT	TX9D
bit7							bit0

R = Readable bit
W = Writable bit
U = Unimplemented bit, read as '0'
- n =Value at POR reset

bit 7: **CSRC**: Clock Source Select bit

Asynchronous mode
Don't care

Synchronous mode
1 = Master mode (Clock generated internally from BRG)
0 = Slave mode (Clock from external source)

bit 6: **TX9**: 9-bit Transmit Enable bit
1 = Selects 9-bit transmission
0 = Selects 8-bit transmission

bit 5: **TXEN**: Transmit Enable bit
1 = Transmit enabled
0 = Transmit disabled
Note: SREN/CREN overrides TXEN in SYNC mode.

bit 4: **SYNC**: USART Mode Select bit
1 = Synchronous mode
0 = Asynchronous mode

bit 3: **Unimplemented:** Read as '0'

bit 2: **BRGH**: High Baud Rate Select bit

Asynchronous mode
1 = High speed
0 = Low speed

Synchronous mode
Unused in this mode

bit 1: **TRMT**: Transmit Shift Register Status bit
1 = TSR empty
0 = TSR full

bit 0: **TX9D**: 9th bit of transmit data. Can be parity bit.

FIGURE 10-2: RCSTA: RECEIVE STATUS AND CONTROL REGISTER (ADDRESS 18h)

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R-0	R-0	R-x
SPEN	RX9	SREN	CREN	ADDEN	FERR	OERR	RX9D

bit7 bit0

R = Readable bit
W = Writable bit
U = Unimplemented bit, read as '0'
- n =Value at POR reset

bit 7: **SPEN**: Serial Port Enable bit
1 = Serial port enabled (Configures RC7/RX/DT and RC6/TX/CK pins as serial port pins)
0 = Serial port disabled

bit 6: **RX9**: 9-bit Receive Enable bit
1 = Selects 9-bit reception
0 = Selects 8-bit reception

bit 5: **SREN**: Single Receive Enable bit

Asynchronous mode
Don't care

Synchronous mode - master
1 = Enables single receive
0 = Disables single receive
This bit is cleared after reception is complete.

Synchronous mode - slave
Unused in this mode

bit 4: **CREN**: Continuous Receive Enable bit

Asynchronous mode
1 = Enables continuous receive
0 = Disables continuous receive

Synchronous mode
1 = Enables continuous receive until enable bit CREN is cleared (CREN overrides SREN)
0 = Disables continuous receive

bit 3: **ADDEN:** Address Detect Enable bit
Asynchronous mode 9-bit (RX9 = 1)
1 = Enables address detection, enable interrupt and load of the receive burffer when RSR<8> is set
0 = Disables address detection, all bytes are received, and ninth bit can be used as parity bit

bit 2: **FERR**: Framing Error bit
1 = Framing error (Can be updated by reading RCREG register and receive next valid byte)
0 = No framing error

bit 1: **OERR**: Overrun Error bit
1 = Overrun error (Can be cleared by clearing bit CREN)
0 = No overrun error

bit 0: **RX9D**: 9th bit of received data (Can be parity bit)

10.1 USART Baud Rate Generator (BRG)

The BRG supports both the Asynchronous and Synchronous modes of the USART. It is a dedicated 8-bit baud rate generator. The SPBRG register controls the period of a free running 8-bit timer. In asynchronous mode bit BRGH (TXSTA<2>) also controls the baud rate. In synchronous mode bit BRGH is ignored. Table 10-1 shows the formula for computation of the baud rate for different USART modes which only apply in master mode (internal clock).

Given the desired baud rate and Fosc, the nearest integer value for the SPBRG register can be calculated using the formula in Table 10-1. From this, the error in baud rate can be determined.

Example 10-1 shows the calculation of the baud rate error for the following conditions:

FOSC = 16 MHz
Desired Baud Rate = 9600
BRGH = 0
SYNC = 0

EXAMPLE 10-1: CALCULATING BAUD RATE ERROR

Desired Baud rate = Fosc / (64 (X + 1))

9600 = 16000000 /(64 (X + 1))

X = ⌊25.042⌋ = 25

Calculated Baud Rate=16000000 / (64 (25 + 1))

= 9615

Error = (Calculated Baud Rate - Desired Baud Rate) / Desired Baud Rate

= (9615 - 9600) / 9600

= 0.16%

It may be advantageous to use the high baud rate (BRGH = 1) even for slower baud clocks. This is because the FOSC/(16(X + 1)) equation can reduce the baud rate error in some cases.

Writing a new value to the SPBRG register, causes the BRG timer to be reset (or cleared), this ensures the BRG does not wait for a timer overflow before outputting the new baud rate.

10.1.1 SAMPLING

The data on the RC7/RX/DT pin is sampled three times by a majority detect circuit to determine if a high or a low level is present at the RX pin.

TABLE 10-1 BAUD RATE FORMULA

SYNC	BRGH = 0 (Low Speed)	BRGH = 1 (High Speed)
0	(Asynchronous) Baud Rate = FOSC/(64(X+1))	Baud Rate= FOSC/(16(X+1))
1	(Synchronous) Baud Rate = FOSC/(4(X+1))	NA

X = value in SPBRG (0 to 255)

TABLE 10-2 REGISTERS ASSOCIATED WITH BAUD RATE GENERATOR

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Value on: POR, BOR	Value on all other resets
98h	TXSTA	CSRC	TX9	TXEN	SYNC	—	BRGH	TRMT	TX9D	0000 -010	0000 -010
18h	RCSTA	SPEN	RX9	SREN	CREN	ADDEN	FERR	OERR	RX9D	0000 000x	0000 000x
99h	SPBRG	Baud Rate Generator Register								0000 0000	0000 0000

Legend: x = unknown, - = unimplemented read as '0'. Shaded cells are not used by the BRG.

11.0 ANALOG-TO-DIGITAL CONVERTER (A/D) MODULE

The analog-to-digital (A/D) converter module has five inputs for the 28-pin devices, and eight for the other devices.

The analog input charges a sample and hold capacitor. The output of the sample and hold capacitor is the input into the converter. The converter then generates a digital result of this analog level via successive approximation. This A/D conversion, of the analog input signal, results in a corresponding 10-bit digital number.

The A/D converter has a unique feature of being able to operate while the device is in SLEEP mode. To operate in sleep, the A/D clock must be derived from the A/D's internal RC oscillator.

The A/D module has four registers. These registers are:

- A/D Result High Register (ADRESH)
- A/D Result Low Register (ADRESL)
- A/D Control Register0 (ADCON0)
- A/D Control Register1 (ADCON1)

The ADCON0 register, shown in Figure 11-1, controls the operation of the A/D module. The ADCON1 register, shown in Figure 11-2, configures the functions of the port pins. The port pins can be configured as analog inputs (RA3 can also be the voltage reference) or as digital I/O.

FIGURE 11-1: ADCON0 REGISTER (ADDRESS: 1Fh)

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	U-0	R/W-0
ADCS1	ADCS0	CHS2	CHS1	CHS0	GO/$\overline{\text{DONE}}$	—	ADON
bit7							bit0

R = Readable bit
W = Writable bit
U = Unimplemented bit, read as '0'
- n = Value at POR reset

bit 7-6: **ADCS1:ADCS0:** A/D Conversion Clock Select bits
00 = FOSC/2
01 = FOSC/8
10 = FOSC/32
11 = FRC (clock derived from an RC oscillation)

bit 5-3: **CHS2:CHS0:** Analog Channel Select bits
000 = channel 0, (RA0/AN0)
001 = channel 1, (RA1/AN1)
010 = channel 2, (RA2/AN2)
011 = channel 3, (RA3/AN3)
100 = channel 4, (RA5/AN4)
101 = channel 5, (RE0/AN5)(1)
110 = channel 6, (RE1/AN6)(1)
111 = channel 7, (RE2/AN7)(1)

bit 2: **GO/$\overline{\text{DONE}}$:** A/D Conversion Status bit
If ADON = 1
1 = A/D conversion in progress (setting this bit starts the A/D conversion)
0 = A/D conversion not in progress (This bit is automatically cleared by hardware when the A/D conversion is complete)

bit 1: **Unimplemented:** Read as '0'

bit 0: **ADON:** A/D On bit
1 = A/D converter module is operating
0 = A/D converter module is shutoff and consumes no operating current

Note 1: These channels are not available on the 28-pin devices.

TABLE 13-2 PIC16CXXX INSTRUCTION SET

Mnemonic, Operands		Description	Cycles	14-Bit Opcode				Status Affected	Notes
				MSb			LSb		
BYTE-ORIENTED FILE REGISTER OPERATIONS									
ADDWF	f, d	Add W and f	1	00	0111	dfff	ffff	C,DC,Z	1,2
ANDWF	f, d	AND W with f	1	00	0101	dfff	ffff	Z	1,2
CLRF	f	Clear f	1	00	0001	lfff	ffff	Z	2
CLRW	-	Clear W	1	00	0001	0xxx	xxxx	Z	
COMF	f, d	Complement f	1	00	1001	dfff	ffff	Z	1,2
DECF	f, d	Decrement f	1	00	0011	dfff	ffff	Z	1,2
DECFSZ	f, d	Decrement f, Skip if 0	1(2)	00	1011	dfff	ffff		1,2,3
INCF	f, d	Increment f	1	00	1010	dfff	ffff	Z	1,2
INCFSZ	f, d	Increment f, Skip if 0	1(2)	00	1111	dfff	ffff		1,2,3
IORWF	f, d	Inclusive OR W with f	1	00	0100	dfff	ffff	Z	1,2
MOVF	f, d	Move f	1	00	1000	dfff	ffff	Z	1,2
MOVWF	f	Move W to f	1	00	0000	lfff	ffff		
NOP	-	No Operation	1	00	0000	0xx0	0000		
RLF	f, d	Rotate Left f through Carry	1	00	1101	dfff	ffff	C	1,2
RRF	f, d	Rotate Right f through Carry	1	00	1100	dfff	ffff	C	1,2
SUBWF	f, d	Subtract W from f	1	00	0010	dfff	ffff	C,DC,Z	1,2
SWAPF	f, d	Swap nibbles in f	1	00	1110	dfff	ffff		1,2
XORWF	f, d	Exclusive OR W with f	1	00	0110	dfff	ffff	Z	1,2
BIT-ORIENTED FILE REGISTER OPERATIONS									
BCF	f, b	Bit Clear f	1	01	00bb	bfff	ffff		1,2
BSF	f, b	Bit Set f	1	01	01bb	bfff	ffff		1,2
BTFSC	f, b	Bit Test f, Skip if Clear	1 (2)	01	10bb	bfff	ffff		3
BTFSS	f, b	Bit Test f, Skip if Set	1 (2)	01	11bb	bfff	ffff		3
LITERAL AND CONTROL OPERATIONS									
ADDLW	k	Add literal and W	1	11	111x	kkkk	kkkk	C,DC,Z	
ANDLW	k	AND literal with W	1	11	1001	kkkk	kkkk	Z	
CALL	k	Call subroutine	2	10	0kkk	kkkk	kkkk		
CLRWDT	-	Clear Watchdog Timer	1	00	0000	0110	0100	$\overline{TO}$,$\overline{PD}$	
GOTO	k	Go to address	2	10	1kkk	kkkk	kkkk		
IORLW	k	Inclusive OR literal with W	1	11	1000	kkkk	kkkk	Z	
MOVLW	k	Move literal to W	1	11	00xx	kkkk	kkkk		
RETFIE	-	Return from interrupt	2	00	0000	0000	1001		
RETLW	k	Return with literal in W	2	11	01xx	kkkk	kkkk		
RETURN	-	Return from Subroutine	2	00	0000	0000	1000		
SLEEP	-	Go into standby mode	1	00	0000	0110	0011	$\overline{TO}$,$\overline{PD}$	
SUBLW	k	Subtract W from literal	1	11	110x	kkkk	kkkk	C,DC,Z	
XORLW	k	Exclusive OR literal with W	1	11	1010	kkkk	kkkk	Z	

Note 1: When an I/O register is modified as a function of itself (e.g., `MOVF PORTB, 1`), the value used will be that value present on the pins themselves. For example, if the data latch is '1' for a pin configured as input and is driven low by an external device, the data will be written back with a '0'.

2: If this instruction is executed on the TMR0 register (and, where applicable, d = 1), the prescaler will be cleared if assigned to the Timer0 Module.

3: If Program Counter (PC) is modified or a conditional test is true, the instruction requires two cycles. The second cycle is executed as a NOP.

National Semiconductor

May 2000

LM78XX
Series Voltage Regulators

General Description

The LM78XX series of three terminal regulators is available with several fixed output voltages making them useful in a wide range of applications. One of these is local on card regulation, eliminating the distribution problems associated with single point regulation. The voltages available allow these regulators to be used in logic systems, instrumentation, HiFi, and other solid state electronic equipment. Although designed primarily as fixed voltage regulators these devices can be used with external components to obtain adjustable voltages and currents.

The LM78XX series is available in an aluminum TO-3 package which will allow over 1.0A load current if adequate heat sinking is provided. Current limiting is included to limit the peak output current to a safe value. Safe area protection for the output transistor is provided to limit internal power dissipation. If internal power dissipation becomes too high for the heat sinking provided, the thermal shutdown circuit takes over preventing the IC from overheating.

Considerable effort was expanded to make the LM78XX series of regulators easy to use and minimize the number of external components. It is not necessary to bypass the output, although this does improve transient response. Input bypassing is needed only if the regulator is located far from the filter capacitor of the power supply.

For output voltage other than 5V, 12V and 15V the LM117 series provides an output voltage range from 1.2V to 57V.

Features

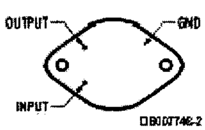
- Output current in excess of 1A
- Internal thermal overload protection
- No external components required
- Output transistor safe area protection
- Internal short circuit current limit
- Available in the aluminum TO-3 package

Voltage Range

LM7805C	5V
LM7812C	12V
LM7815C	15V

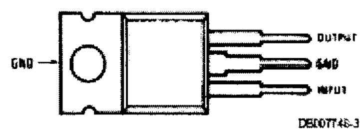
Connection Diagrams

Metal Can Package
TO-3 (K)
Aluminum



Bottom View
Order Number LM7805CK,
LM7812CK or LM7815CK
See NS Package Number KC02A

Plastic Package
TO-220 (T)



Top View
Order Number LM7805CT,
LM7812CT or LM7815CT
See NS Package Number T03B

June 2000

National Semiconductor

LM2907/LM2917 Frequency to Voltage Converter

General Description

The LM2907, LM2917 series are monolithic frequency to voltage converters with a high gain op amp/comparator designed to operate a relay, lamp, or other load when the input frequency reaches or exceeds a selected rate. The tachometer uses a charge pump technique and offers frequency doubling for low ripple, full input protection in two versions (LM2907-8, LM2917-8) and its output swings to ground for a zero frequency input.

The op amp/comparator is fully compatible with the tachometer and has a floating transistor as its output. This feature allows either a ground or supply referred load of up to 50 mA. The collector may be taken above V_{CC} up to a maximum V_{CE} of 28V.

The two basic configurations offered include an 8-pin device with a *ground referenced tachometer* input and an internal connection between the tachometer output and the op amp non-inverting input. This version is well suited for single speed or frequency switching or fully buffered frequency to voltage conversion applications.

The more versatile configurations provide differential tachometer input and uncommitted op amp inputs. With this version the tachometer input may be floated and the op amp becomes suitable for active filter conditioning of the tachometer output.

Both of these configurations are available with an active shunt regulator connected across the power leads. The regulator clamps the supply such that stable frequency to voltage and frequency to current operations are possible with any supply voltage and a suitable resistor.

Advantages

- Output swings to ground for zero frequency input
- Easy to use; $V_{OUT} = f_{IN} \times V_{CC} \times R1 \times C1$
- Only one RC network provides frequency doubling
- Zener regulator on chip allows accurate and stable frequency to voltage or current conversion (LM2917)

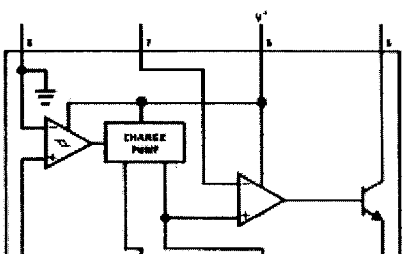
Features

- Ground referenced tachometer input interfaces directly with variable reluctance magnetic pickups
- Op amp/comparator has floating transistor output
- 50 mA sink or source to operate relays, solenoids, meters, or LEDs
- Frequency doubling for low ripple
- Tachometer has built-in hysteresis with either differential input or ground referenced input
- Built-in zener on LM2917
- ±0.3% linearity typical
- Ground referenced tachometer is fully protected from damage due to swings above V_{CC} and below ground

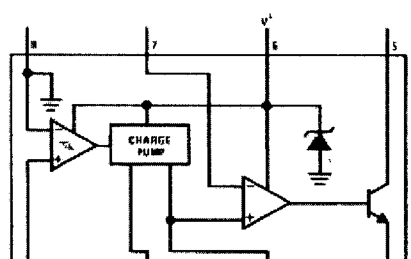
Applications

- Over/under speed sensing
- Frequency to voltage conversion (tachometer)
- Speedometers
- Breaker point dwell meters
- Hand-held tachometer
- Speed governors
- Cruise control
- Automotive door lock control
- Clutch control
- Horn control
- Touch or sound switches

Block and Connection Diagrams Dual-In-Line and Small Outline Packages, Top Views



Order Number LM2907M-8 or LM2907N-8
See NS Package Number M08A or N08E



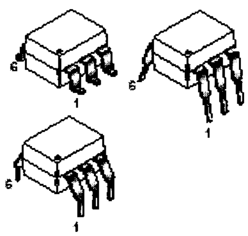
Order Number LM2917M-8 or LM2917N-8
See NS Package Number M08A or N08E

FAIRCHILD SEMICONDUCTOR®

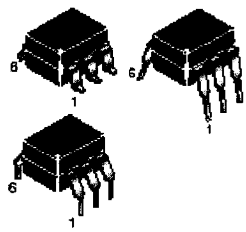
PHOTOTRANSISTOR OPTOCOUPLERS

MCT2	**MCT2E**	**MCT210**	**MCT271**
MCT2200	**MCT2201**	**MCT2202**	

WHITE PACKAGE (-M SUFFIX)



BLACK PACKAGE (NO -M SUFFIX)



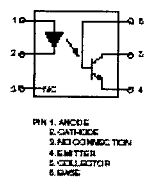
DESCRIPTION

The MCT2XXX series optoisolators consist of a gallium arsenide infrared emitting diode driving a silicon phototransistor in a 6-pin dual in-line package.

FEATURES

- UL recognized (File # E90700)
- VDE recognized (File # 94766)
  - -Add option V for white package (e.g., MCT2V-M)
  - -Add option 300 for black package (e.g., MCT2.300)
- MCT2 and MCT2E are also available in white package by specifying -M suffix, eg. MCT2-M.

SCHEMATIC



APPLICATIONS

- Power supply regulators
- Digital logic inputs
- Microprocessor inputs

SPECIFICATIONS OF RS 232 AND RS 485

SPECIFICATIONS	RS232	RS423	RS422	RS485
Mode of Operation	SINGLE -ENDED	SINGLE -ENDED	DIFFERENTIAL	DIFFERENTIAL
Total Number of Drivers and Receivers on One Line (One driver active at a time for RS485 networks)	1 DRIVER 1 RECVR	1 DRIVER 10 RECVR	1 DRIVER 10 RECVR	32 DRIVER 32 RECVR
Maximum Cable Length	50 FT.	4000 FT.	4000 FT.	4000 FT.
Maximum Data Rate (40ft. - 4000ft. for RS422/RS485)	20kb/s	100kb/s	10Mb/s-100Kb/s	10Mb/s-100Kb/s
Maximum Driver Output Voltage	+/-25V	+/-6V	-0.25V to +6V	-7V to +12V
Driver Output Signal Level (Loaded Min.) — **Loaded**	+/-5V to +/-15V	+/-3.6V	+/-2.0V	+/-1.5V
Driver Output Signal Level (Unloaded Max) — **Unloaded**	+/-25V	+/-6V	+/-6V	+/-6V
Driver Load Impedance (Ohms)	3k to 7k	>=450	100	54
Max. Driver Current in High Z State — **Power On**	N/A	N/A	N/A	+/-100uA
Max. Driver Current in High Z State — **Power Off**	+/-6mA @ +/-2v	+/-100uA	+/-100uA	+/-100uA
Slew Rate (Max.)	30V/uS	Adjustable	N/A	N/A
Receiver Input Voltage Range	+/-15V	+/-12V	-10V to +10V	-7V to +12V
Receiver Input Sensitivity	+/-3V	+/-200mV	+/-200mV	+/-200mV
Receiver Input Resistance (Ohms), (1 Standard Load for RS485)	3k to 7k	4k min.	4k min.	>=12k

REFERENCES

REFERENCES

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