# DEVELOPMENT OF LOW COST DATA LOGGER

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**DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING**

**JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY**

**WAKNAGHAT**

# CERTIFICATE

This is to certify that the work entitled, "Development Of Low Cost Data Logger" submitted by Shivani Gupta, Monika Mittal and Sonam Peden in partial fulfilment for the award of degree of Bachelors of Technology in Electronics and Communication Engineering of Jaypee University of Information Technology has been carried out under my supervision. This work has not been submitted partially or wholly to any other University or Institute for the award of this or any other degree or diploma.

Ms. Vanita Rana
PROJECT GUIDE

Dr. Sunil Bhooshan
HEAD OF THE DEPARTMENT

# ACKNOWLEDGMENT

No project or task can be successfully completed without the help of those people who act as "guiding light" helping to smoothen out the rough edges, providing the inspiration when you have reached a spot you can't seem to get out of.

We are extremely grateful to ***Ms. Vanita Rana***, our respected teacher for her guidance and her motivation. Her thinking and straightforward attitude have inspired us to complete this project under stiff time limits. We are also thankful to ***Mr. Vivek Kumar Sehgal*** for giving direction to our project.

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Also, we would like to express our thanks to our friends, who have supported, encouraged and criticized our efforts which have been instrumental in giving the project its final shape.

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| ADC | Analog Digital Converter |
| AC,A/C | Alternating Current |
| ALE | Address Latch Enable |
| CMOS | Complimentary Metal Oxide-Semiconductor |
| CO | Crystal Oscillator |
| DC | Direct Current |
| GND | Ground |
| LCD | Liquid Crystal Display |
| LED | Light Emitting Diode |
| LSB | Least Significant Bit |
| MCU | Microcontroller |
| MSB | Most Significant Bit |
| PC | Personal Computer |
| PSEN | Program Store Enable |
| RS | Register Select |
| R/W | Read/ Write |
| TTL | Transistor-Transistor Logic |
| µF | Micro Farad |

# ABSTRACT

This Project is used to control an electronic device according to the temperature and it also indicates the temperature. The system will get the temperature from the IC and it will control the working of the device according the values stored by the user. The System is fully controlled by the microcontroller AT89S52. It is a popular 8 bit microcontroller. The circuit consists of three switches, in which two buttons are used to increment and decrement the temperature value and the third to set the value. All the above functions are monitored and controlled by the 8 bit microcontroller AT89S52.

# CHAPTER – 1

# INTRODUCTION

## 1.1 PROBLEM FORMULATION

Data logging can be done by constant human observation, for example recording the temperature changes over the course of an hour in a centrally heated room using a timer, thermometer, pen and paper. But, the same event performed by a data logger, which does the job of all the tools mentioned above, and thus saves great time and expense.

A data logger is an electronic device that records information over a period of time for later reference and can be used in virtually all industries, for example:

- The growing, preparation, storage and transportation of food.
- Internal environmental monitoring of houses, offices, warehouses or museums.
- External environmental monitoring of oceans, rivers, aquaculture, climate and general research into the natural world.
- In agriculture and horticulture.
- The transportation of easily damaged food, plants, instruments, computers, etc
- In laboratories and healthcare for: sterilization processes; the transportation of vaccines and blood products; fridge, freezer and culture rooms.
- Measure temperatures (humidity, etc) of perishables during shipments.
- Process monitoring for maintenance and troubleshooting applications.
- Vehicle Testing.
- Monitoring of relay status in railway signalling.
- Weather station recording (such as wind speed / direction, temperature, relative humidity, solar radiation).
- Road traffic counting.
- Measure vibration and handling (drop height) environment of distribution packaging.

### *FEATURES OF OUR PRODUCT*

- The prices of data loggers available in market are comparatively high. Low cost data loggers in market are low performance products.
- Features of our product i.e. "Data Logger" are flexible as in future we can extend our product with 8 temperature sensors with every data line of AD0808/AD0809.
- We are storing the variations in atmospheric temperature in our PC which can be used for further usage.
- The maintenance issues are less as the hardware is not very complicated and very user friendly.
- The temperature sensor used by us, LM35, is comparatively easy to interface with other components.
- Design flexibility is taken into account as we are proving a keypad with which maximum cut-off value can be set for future usage for particular applications.

## 1.2 DESIGN CONCEPT

Design for this project is explained with the help of block diagram shown below:

**Block Diagram**

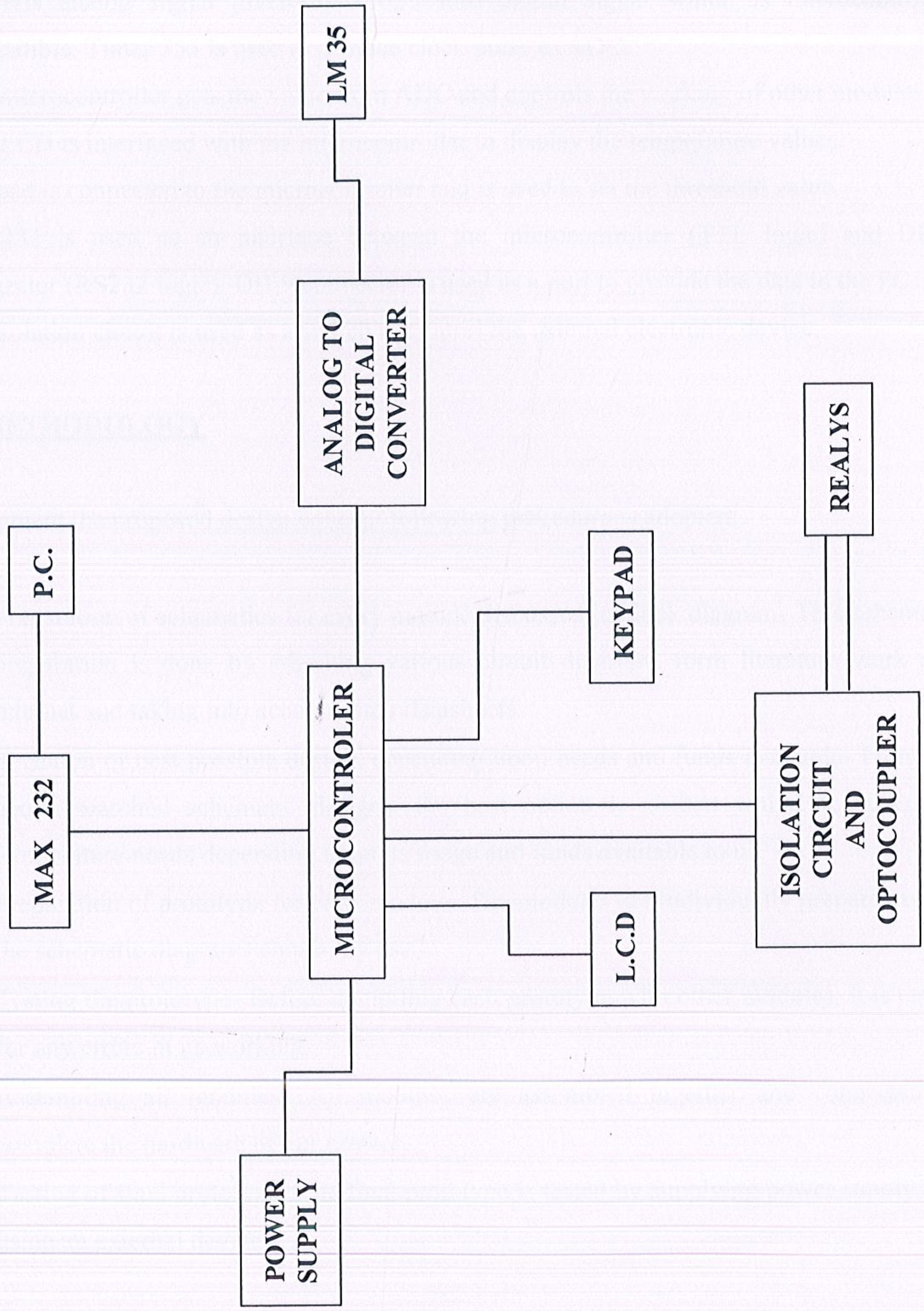



Fig. 1

***DESCRIPTION :***

The output of the power supply is supplied to every module individually. Except for isolation circuit (relay and opto-coupler) which is given 12V, every module is provided with 5V power. The atmospheric temperature is sensed by temperature sensor LM35.ADC converts analog signal given by LM35 into digital signal which is microcontroller compatible. Timer 555 is used to provide clock pulse to ADC.

The microcontroller gets the value from ADC and controls the working of other modules.

The LCD is interfaced with the microcontroller to display the temperature values.

Keypad is connected to the microcontroller and is used to set the threshold value.

Max232 is used as an interface between the microcontroller (TTL logic) and DB-9 connector (RS232 logic). DB-9 connector is used as a port to provide the data to the PC.

An isolation circuit is used as a switch to control the external electronic device.

## 1.3 METHODOLOGY

To implement the proposed design concept following procedure is adopted:

- Preparation of schematics for every module discussed in block diagram- This schematic preparation is done by searching various circuit diagrams form literature work and internet and taking into account their datasheets.
- Selection of best possible design, depending upon needs and funds available- From the above searched schematic designs, the best option is chosen which accounts are temperature needs depending upon its usage and funds available to us.
- Preparation of prototype for each module- The modules are individually prepared using the schematic diagrams chosen by us.
- Testing the prototype- Before compiling each prototype with other modules, it is tested for any errors in its working.
- Assembling all modules- All modules are assembled together and connected to complete the hardware of our project.
- Testing of final prototype- The final prototype is tested by supplying power supply and using an external device.

# CHAPTER – 2

## HARDWARE DESCRIPTION AND IMPLEMENTATION

Basic modules used for designing Development of low cost data logger are :

1. Power supply Module
2. LCD Module
3. Analog to Digital Converter Module
4. Keypad Module
5. Serial Communication Module
6. Relay and Opto-Coupler Module

### 2.1 <u>POWER SOURCE SUPPLY</u>

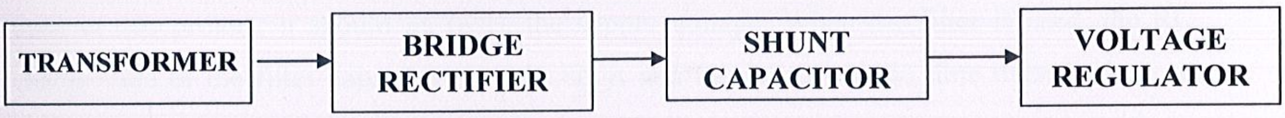



Fig. 2

The power supply circuit comprises of four basic parts:

The transformer steps down the 220 V a/c. into 12 V A/C. The transformer work on the principle of magnetic induction, where two coils: primary and secondary are wound around an iron core. The two coils are physically insulated from each other in such a way that passing an A/C. current through the primary coil creates a changing voltage in the primary coil and a changing magnetic field in the core. This in turn induces a varying A/C voltage in the secondary coil.

The A/C voltage is then fed to the bridge rectifier. The rectifier circuit is used in most electronic power supplies is the single-phase bridge rectifier with capacitor filtering, usually followed by a linear voltage regulator. A rectifier circuit is necessary to convert a signal having zero average value into a non-zero average value. A rectifier transforms alternating current into direct current by limiting or regulating the direction of flow of current. The output resulting from a rectifier is a pulsating D.C. voltage. This voltage is not appropriate for the components that are going to work through it.

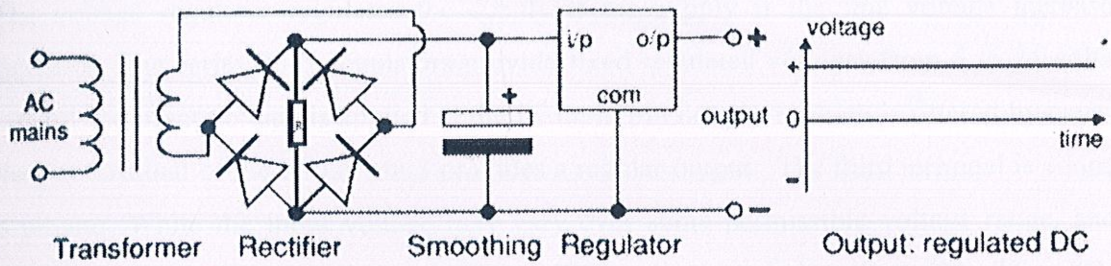



Fig. 3

The ripple of the D.C. voltage is smoothened using a filter capacitor of 1000 μF 25V. The filter capacitor stores electrical charge. If it is large enough the capacitor will store charge as the voltage rises and give up the charge as the voltage falls. This has the effect of smoothing out the waveform and provides steadier voltage output. A filter capacitor is connected at the rectifier output and the D.C. voltage is obtained across the capacitor. When this capacitor is used in this project, it should be twice the supply voltage. When the filter is used, the RC charge time of the filter capacitor must be short and the RC discharge time must be long to eliminate ripple action. In other words the capacitor must charge up fast, preferably with no discharge.

When the rectifier output voltage is increasing, the capacitor charges to the peak voltage $V_m$. Just past the positive peak, the rectifier output voltage starts to fall but at this point the capacitor has $+V_m$ voltage across it. Since the source voltage becomes slightly less than $V_m$, the capacitor will try to send current back through the diode of rectifier. This reverse biases the diode. The diode disconnects or separates the source the source form load. The capacitor starts to discharge through load. This prevents the load voltage from falling to zero. The capacitor continues to discharge until source voltage becomes more than capacitor voltage. The diode again starts conducting and the capacitor is again charged to peak value $V_m$. When capacitor is charging the rectifier supplies the charging through capacitor branch as well as load current, the capacitor sends currents through the load. The rate at which capacitor discharge depends upon time constant RC. The longer the time constant, the steadier is the output voltage. An increase in load current i.e. decrease in resistance makes time constant of discharge path smaller. The ripple increase and D.C output voltage V D.C. decreases. Maximum capacity cannot exceed a certain limit because the larger the capacitance the greater is the current required to charge the capacitor.

The voltage regulator regulates the supply if the supply if the line voltage increases or decreases. The series 78xx regulators provide fixed regulated voltages from 5 to 24 volts. An unregulated input voltage is applied at the IC Input pin i.e. pin 1 which is filtered by capacitor. The out terminal of the IC i.e. pin 3 provides a regular output. The third terminal is connected to ground. While the input voltage may vary over some permissible voltage range, and the output voltage remains constant within specified voltage variation limit. The 78xx IC's are positive voltage regulators whereas 79xx IC's are negative voltage regulators.

These voltage regulators are integrated circuits designed as fixed voltage regulators for a wide variety of applications. These regulators employ current limiting, thermal shutdown and safe area compensation. With adequate heat sinking they can deliver output currents in excess of 1 A. These regulators have internal thermal overload protection. It uses output transistor safe area compensation and the output voltage offered is in 2% and 4% tolerance.

## 2.2 LCD MODULE

### 2.2.1 *INTERFACING OF MICRO CONTROLLER WITH LCD DISPLAY*

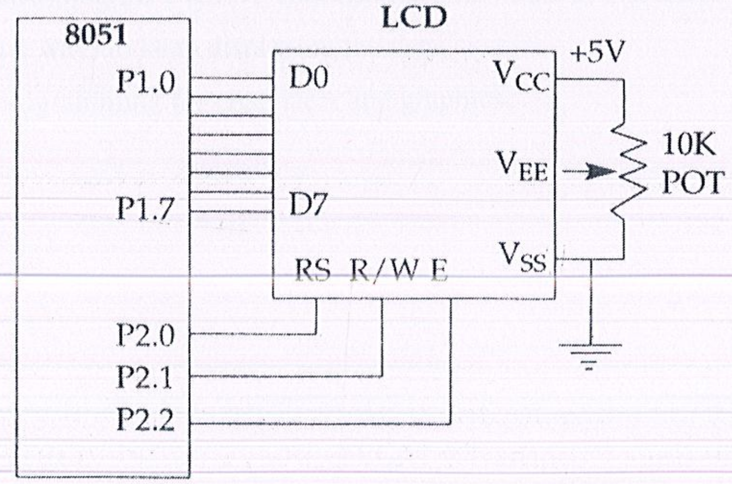



Fig. 4

In most applications, the "R/W" line is grounded. This simplifies the application because when data is read back, the microcontroller I/O pins have to be alternated between input and output modes. In this case, "R/W" is connected to ground and just wait the maximum amount of time for each instruction (4.1 msecs for clearing the display or moving the cursor/display to the "home position", 160 microsecs for all other commands) and also the application software is simpler. It also frees up a microcontroller pin for other uses. Before sending commands or data to the LCD module, the module must be initialized. Once the initialized is complete, the LCD can be written to with data or instructions as required. Each character to display is written like the control bytes, except that the "RS" line is set. During initialization, by setting the "S/C" bit during the "Move Cursor/Shift Display" command, after each character is sent to the LCD, the cursor built into the LCD will increment to the next position (either right or left). Normally, the "S/C" bit is set ( equal to "1").

### *2.2.2 LCD OPERATION*

In recent years the LCD is finding widespread use replacing LEDs (seven-segment LEDs or other multisegment LEDs). This is due to the following reasons:

1. The declining prices of LCDs.
2. The ability to display numbers, characters, and graphics. This is in contrast to LEDs, which are limited to numbers and a few characters.
3. Incorporation of a refreshing controller into the LCD, thereby relieving the CPU of the task of refreshing the LCD. In contrast, the LED must be refreshed by the CPU (or in some other way) to keep displaying the data.
4. Ease of programming for characters and graphics.

### 2.2.3 *PIN DESCRIPTION*

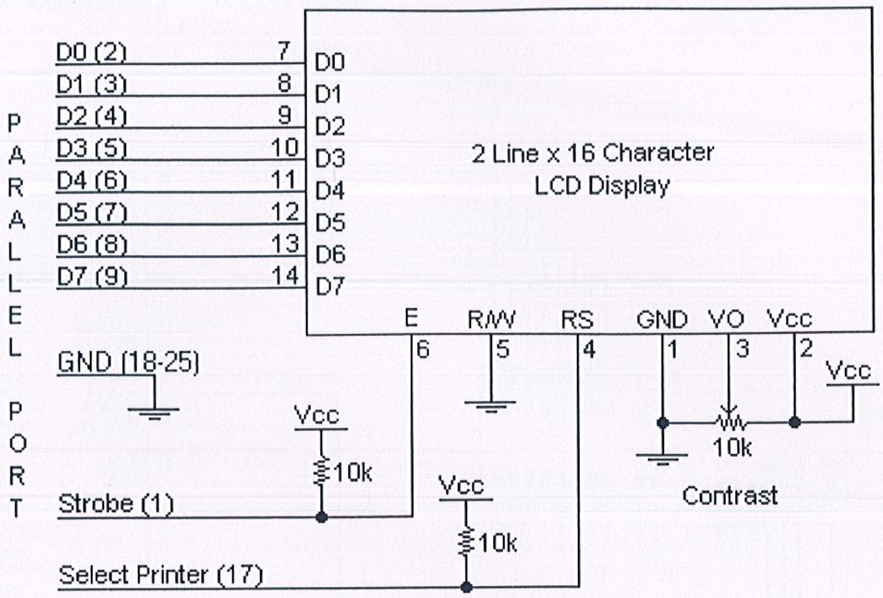



Fig. 5

Pin Descriptions for LCD

| Pin | Symbol | I/O | Description |
|---|---|---|---|
| 1 | $V_{ss}$ | | Ground |
| 2 | $V_{cc}$ | | +5V power supply |
| 3 | $V_{EE}$ | | Power supply to control contrast |
| 4 | RS | I | RS = 0 to select command register,<br>RS = 1 to select data register |
| 5 | R/W | I | R/W = 0 for write, R/W = 1 for read |
| 6 | E | I/O | Enable |
| 7 | OBO | I/O | The 8-bit data bus |
| 8 | OBI | I/O | The 8-bit data bus |
| 9 | OB2 | I/O | The 8-bit data bus |
| 10 | OB3 | I/O | The 8-bit data bus |
| 11 | OB4 | I/O | The 8-bit data bus |
| 12 | OB5 | I/O | The 8-bit data bus |
| 13 | OB6 | I/O | The 8-bit data bus |
| 14 | OB7 | I/O | The 8-bit data bus |

## 2.3 ADC MODULE

### 2.3.1 INTERFACING WITH MCU

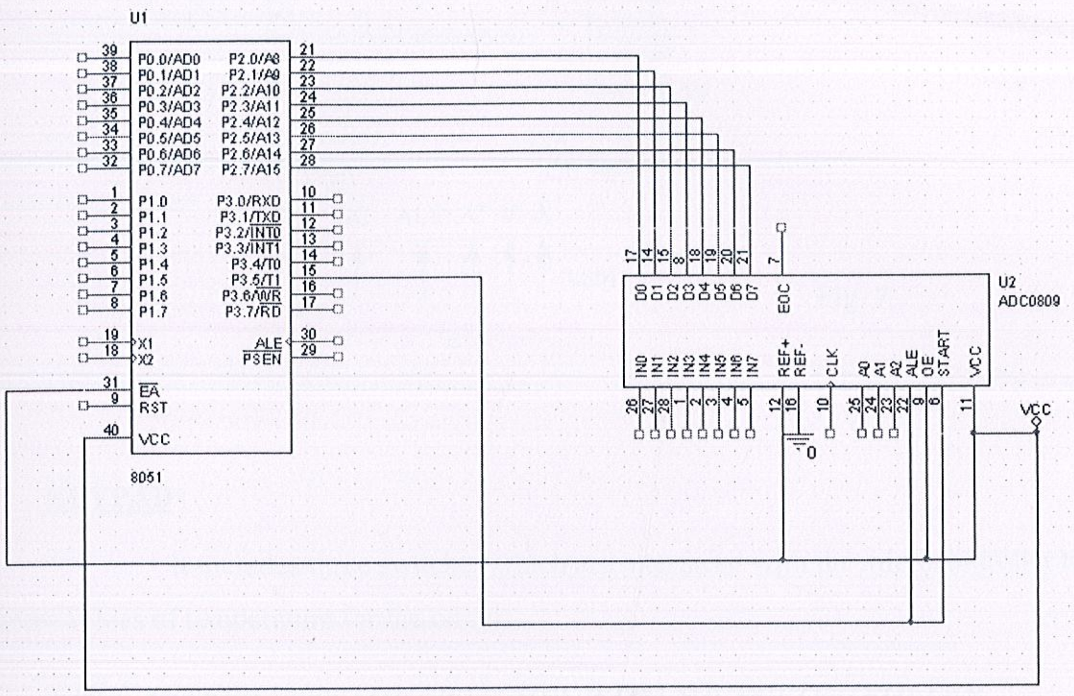


Fig. 6

### 2.3.2 FEATURES :

- Easy interface to all microprocessors
- Operates ratio metrically or with 5 V DC or analog span adjusted voltage reference.
- No zero or full scale adjust required.
- 8-channel multiplexer with address logic.
- 0V to 5V input range with single 5V power supply.
- Outputs meet TTL voltage level specification.
- 28-pin moulded chip carrier package.

### *2.3.3 PIN DIAGRAM*

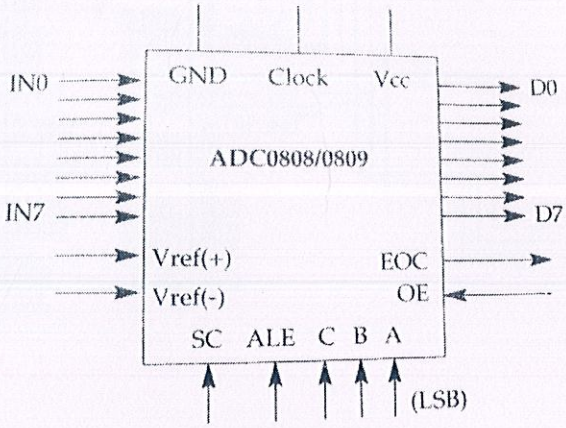



Fig. 7

## 2.4 KEYPAD

It includes three switches which are interfaced with the microcontroller to set different values of temperature for the circuit.

### *2.4.1 INTERFACING OF SWITCHES WITH MICROCONTROLLER*

There are three micro switches in the circuit connected to the microcontroller pin no. p0.5 to p0.7. One end of each switch is grounded and other is connected to the microcontroller port with a 10K pull-up, as in Figure4.12. When switch is pressed that particular port is grounded. The microcontroller always monitors these switches in real time (i.e. in continuous mode)

The configuration of the micro switches is as follows:

Switch1 ($S_1$): Increment

Switch2 ($S_2$): Decrement

Switch3 ($S_3$): Set

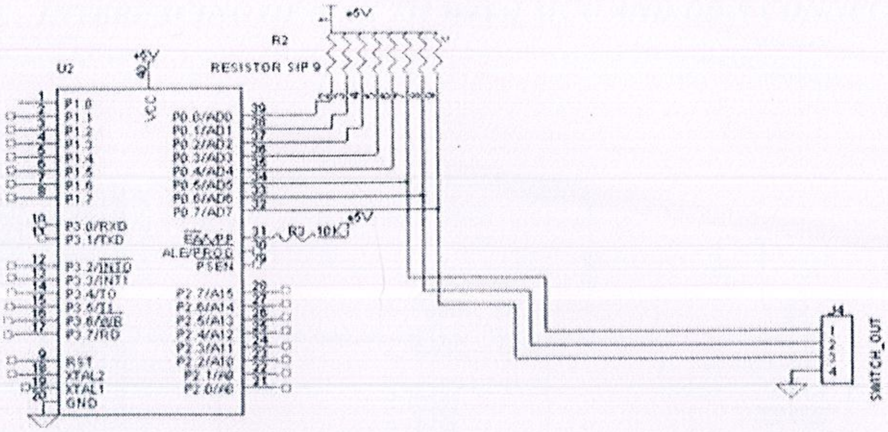


Fig. 8

## 2.5 SERIAL COMMUNICATION (MAX 232)

This chip is used when interfacing micro controller with PC to check the Baud rate and changes the voltage level because micro controller is TTL compatible whereas PC is CMOS compatible. The MAX 232 IC contains the necessary drivers{two} and receivers {two}, to adapt the RS- 232 signal voltage levels to TTL logic. It became popular, because it just needs one voltage{+5V} and generates the necessary RS-232 voltage levels{approx -10V AND +10V} internally. This greatly simplified the design of circuitry. And this made the IC so popular.MAX232 is just a driver/receiver. It does not generate the necessary RS-232 sequence of marks and spaces with the right timing, it does not decode RS-232 signal, it does not provide a serial /parallel conversion. All it does is to convert signal voltage levels.

### *2.5.1 INTERFACING OF MAX 232 WITH MCU AND DB-9 CONNECTOR*

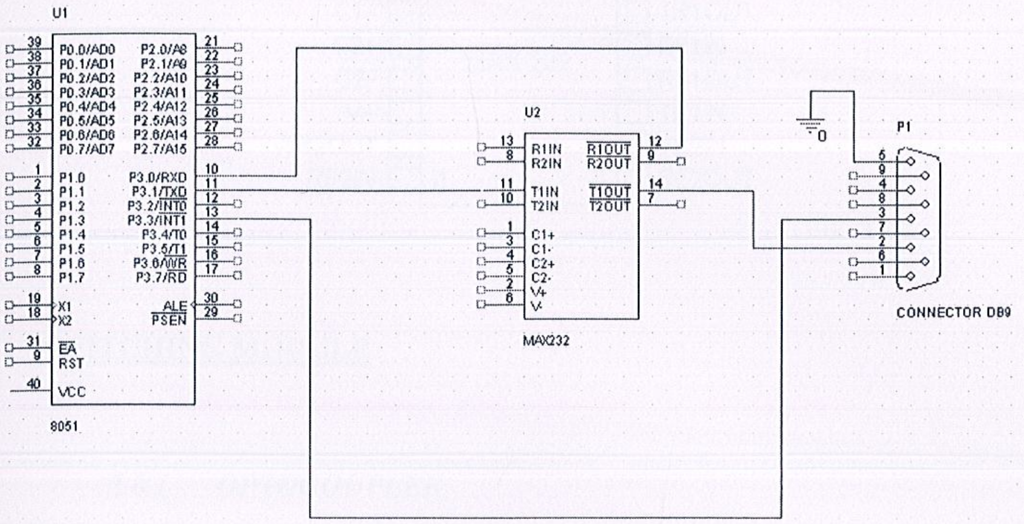



Fig. 9

The MAX232 has two sets of line drivers for transferring and receiving data. The line drivers used for TxD are called Tl and T2, while the line drivers for RxD are designated as Rl and R2. In many applications only one of each is used. For example, Tl and Rl are used together for TxD and RxD of the 8051, and the second is left unused. In MAX232 that the T1 line driver has a designation of Tl in and Tl out on pin numbers 11 and 14, respectively. The T1in pin is the TTL side and is connected to TxD of the micro controller, while T1out is the 232 side that is connected to the RxD pin of the RS232 DB connector. The R1 line driver has a designation of R1in and R1out on pin numbers 13 and 12, respectively. The R1in (pin 13) is the RS232 side that is connected to the TxD pin the RS232 DB connector, and R1out (pin 12) is the TTL side that is connected to the RxD pin of the microcontroller.

MAX232 requires four capacitors ranging from 1 to 22 μF. The most widely used value for these capacitors is 22 μF.

### *2.5.2 FEATURES*

- Superior to bipolar
- Low-power receive mode in shutdown
- Meet all EIA/TIA-232E and v.28 specifications.
- 3-state driver and receiver output.

### *2.5.3 PIN DIAGRAM*

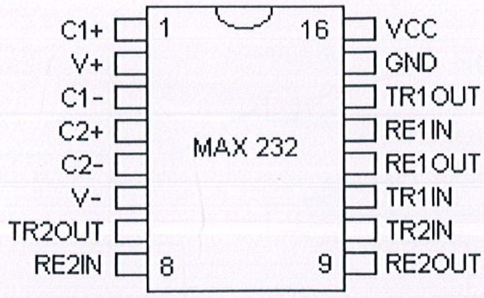



Fig. 10

## 2.6 SWITCHING MODULE

### *2.6.1 OPTOCOUPLER*

When an electrical signal is applied to the input of the opto-isolator, its LED lights, its light sensor then activates, and a corresponding electrical signal is generated at the output. Unlike a transformer, the opto-isolator allows for DC coupling and generally provides significant protection from serious overvoltage conditions in one circuit affecting the other.

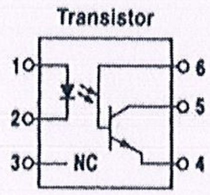



Fig. 11

### *2.6.2 RELAYS*

One point of the relay is given to phase and that point is connected to NC point. VCC is connected to the coil the relay. When $V_{CC}$ is given the coil gets magnetized and slowly phase is connected to NO point which is further connected to the device to be operated by the relay. Neutral must be given to the device.

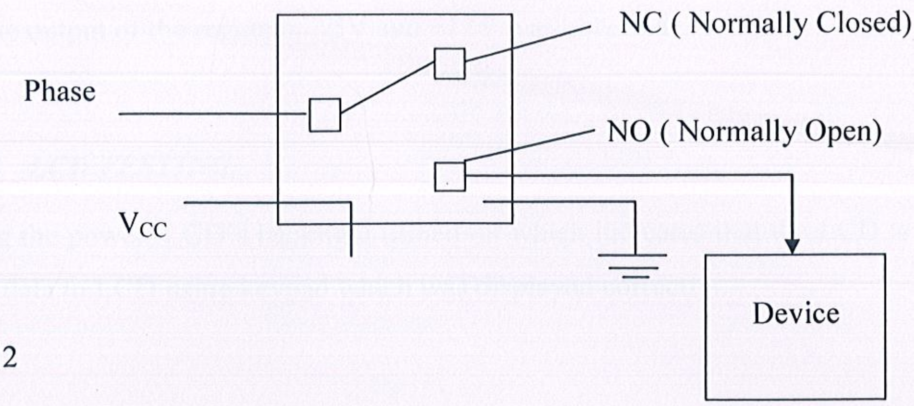



Fig. 12

The industrial applications that require Optoisolation circuits are so prevalent that several companies make plug-in and stand-alone Optoisolation circuits called solid-state relays (SSRs). The SSR provides the Optocoupler circuit in an encapsulated module that has larger terminals available so that it can be used in industrial circuits and requires 3-32 volts dc to turn it on. The LED section of the Optocoupler acts like the coil of a traditional relay. This part of the SSR requires dc voltage because the LED must be forward biased to produce light. The phototransistor section of the Optocoupler inside the SSR is equivalent to the contacts in a relay.

## 2.7 HARDWARE TESTING

Every module's VCC and Ground were checked using multi-meter. The VCC should be approximately equal to the voltage applied to that particular module.

After the microcontroller was programmed, the whole hardware was compiled and tested. The test was done using a device and the effects of the temperature variation on the working of the device was noted i.e. the device stopped working after the cut-off temperature which was set during the programming of the microcontroller.

### *2.7.1 POWER SUPPLY TESTING*

After making the power supply module, it needed to be checked for the correct working of the project. At the output of the regulator +5V and +12V was obtained.

### *2.7.2 LCD TESTING*

On supplying the power, LCD's backlight turned on which indicates that the LCD is working. We send the data to LCD using keypad which was displayed correctly.

### *2.7.3 ADC TESTING*

ADC IC AD0808/AD0809 was checked using LED's. D0 to D7 pins of the IC were connected with LEDs on bread-board. On supplying the power, different output was shown for different analog input. Initially, we tested +5V for which output was all pins (D0-D7) were high and for 0V output was low. After performing initial test LM-35 sensor's output was tested and ADC showed different output for different temperature inputs.

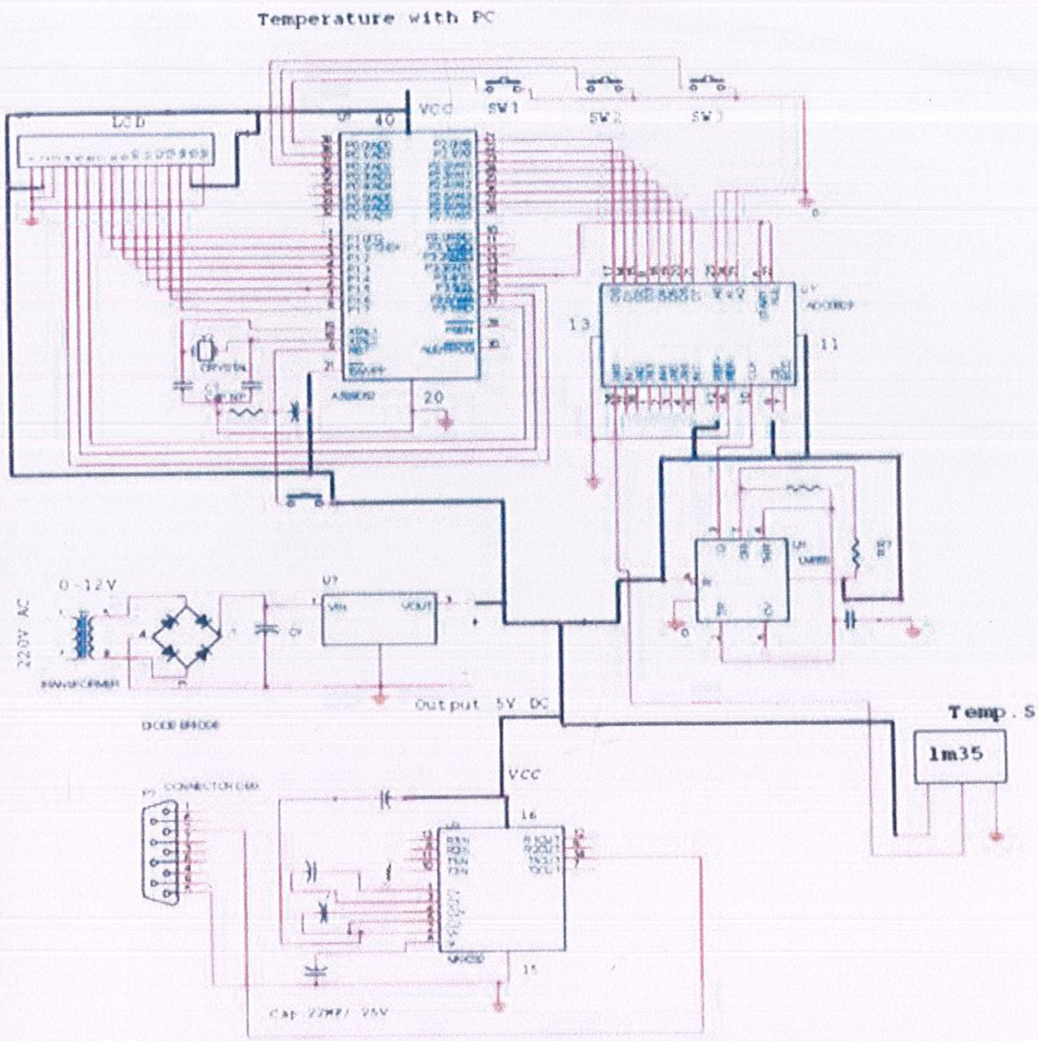
### *2.7.4 MICROCONTROLLER*

Microcontroller is tested by burning the IC. If the IC is burned with the program successfully then the IC is working otherwise the IC is defective.

### *2.7.6 ISOLATION CIRCUIT TESTING*

Isolation circuit is checked by the external device connected to it. On supplying the power, if the external device connected to it is working then it is working otherwise it is not.

## 2.8 CIRCUIT DIAGRAM OF THE PROJECT



## 2.9 SNAP SHOT OF THE PROJECT

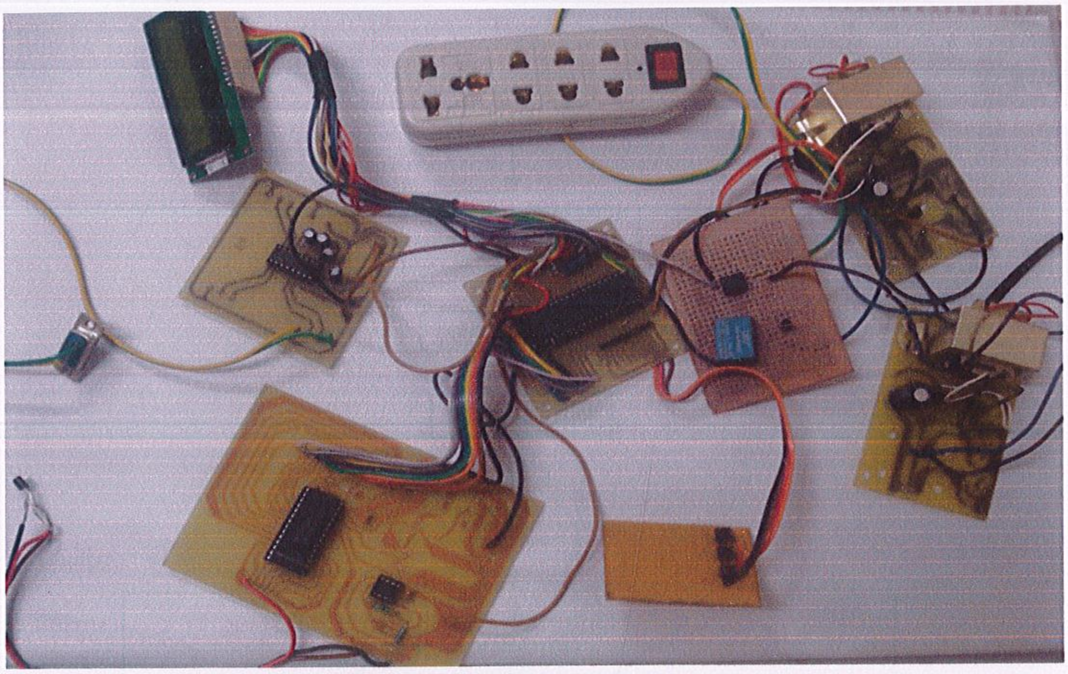
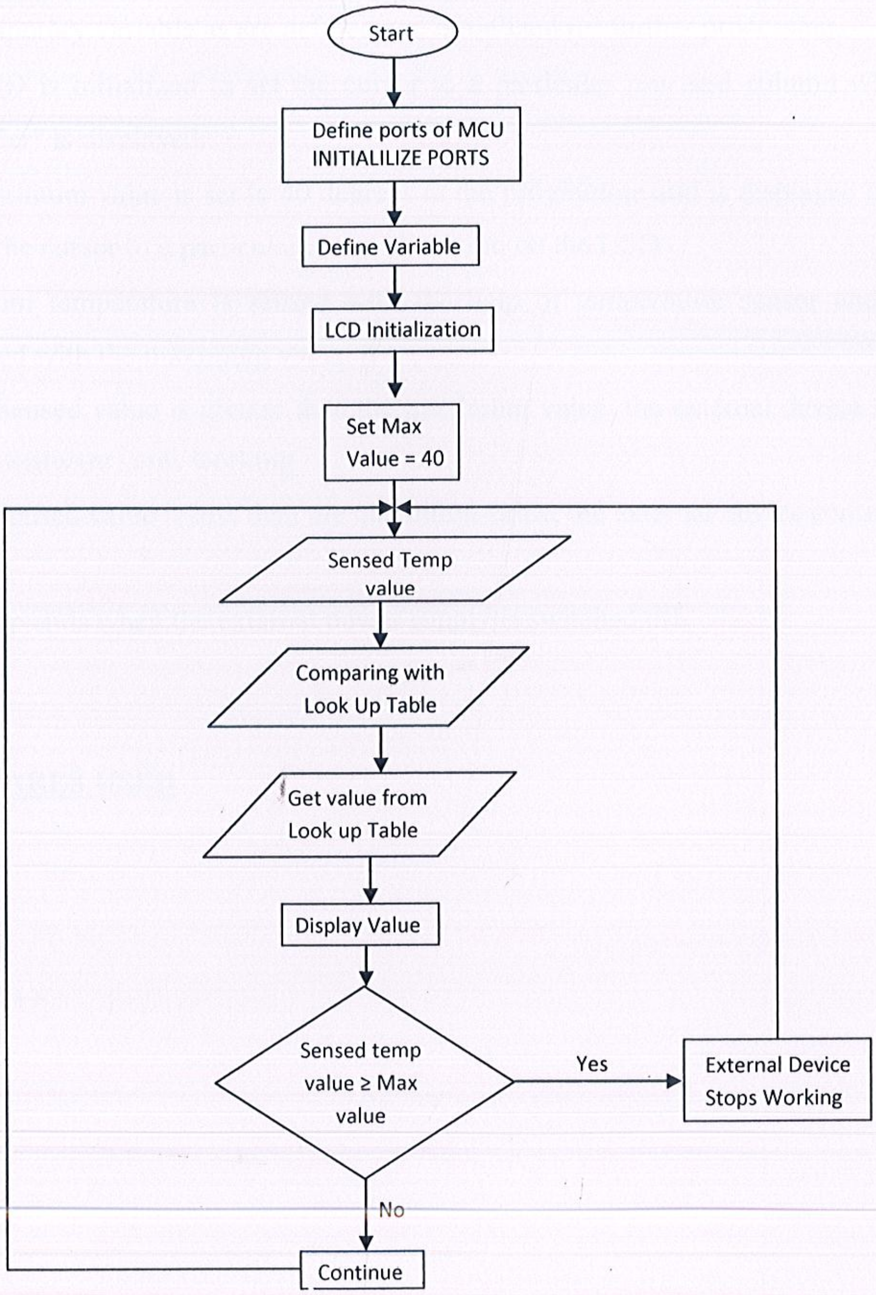


Fig. 13

# CHAPTER 3

## SOFTWARE DESIGN

### 3.1 FLOW CHART



***DESCRIPTION :***

- The first step is to initialize the microcontroller ports, assigning the ports of the microcontroller to its pins according to the interfacing done in the hardware.
- The temporary variable as are defined and initialized for further processing.
- The LCD is initialized to set the cursor to a particular row and column where "Thermal Controller" is displayed.
- The maximum value is set to 40 degrees in the programme and is displayed on the LCD by setting the cursor to a particular row and column on the LCD
- The room temperature is sensed with the help of temperature sensor and this value is compared with the maximum value, if
    1) Sensed value is greater than the maximum value, the external device attached to the hardware stops working
    2) Sensed value is less than the maximum value, the external device continues working

This loop ends when the external power supply is switched off.

## 3.2 SOFTWARES USED

- Keil
- Proload
- Turbo C++

# CHAPTER 4

## PROBLEMS FACED AND TROUBLESHOOTING

1. **Problem**: The power supply was not working

   Testing: Transistor used as regulator in power supply was defective

   Diagnose: Changing the transistor solved the problem

2. **Problem**: LCD was not displaying data

   Testing: Pins 5,6 and 7 of port 3 and port 1 of microcontroller were tested. Some connections were found loose.

   Diagnose: Checking the connections and re-soldering solved the problem and LCD started working.

3. **Problem**: During soldering , some of the pins got short

   Testing: The device didn't work properly

   Diagnose: Our project guide Ms.Vanita Rana helped us to diagnose and solve the problem.

4. **Problem**: Faced problem in testing ADC

   Testing: LEDs did not glow for any of the voltage applied.

   Diagnose: Connection was checked and problem was faced.

5. **Problem**: Errors in Program Code.

   Testing: Program Code did not execute.

   Diagnose: Referred Software Tutorials.

# CONCLUSION

The working hardware was successfully made with the help of our project guide Ms. Vanita Rana. The hardware was connected to an electronic fan to test the project. The fan stopped working after the cut-off temperature was reached which was sensed by temperature sensor LM35. The atmospheric temperature variations were shown on the LCD and PC monitor and correspondingly its graph was made.

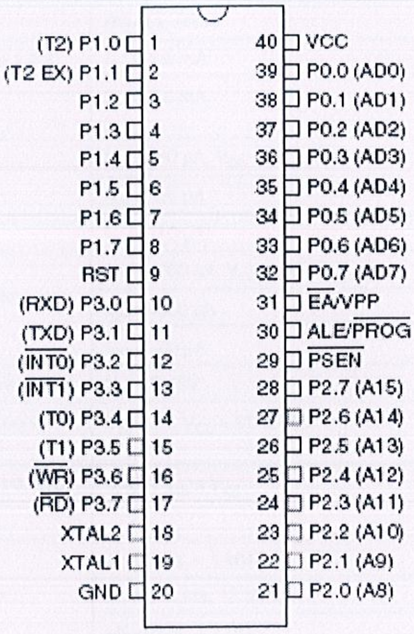
This project can be extended further by changing the temperature range i.e. by increasing the threshold temperature. The other extension can be that a Bluetooth can be connected instead of the external device making it wireless. Other kinds of sensors can also be used in place of LM-35 for different uses. To increase the mobility of the project we can use mobile phones instead of personal computers.

# APPENDIX

# DATA SHEETS

## 1. MICROCONTROLLER AT89C51

### *PIN DIAGRAM*




### *ABSOLUTE MAXIMUM RATINGS*

| | |
|---|---|
| Operating Temperature | -55°C to +125°C |
| Storage Temperature | -65°C to +150°C |
| Voltage on Any Pin with Respect to Ground | -1.0V to +7.0V |
| Maximum Operating Voltage | 6.6V |
| DC Output Current | 15.0 mA |

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

### *DC CHARACTERISTICS*

The values shown in this table are valid for TA = -40°C to 85°C and VCC = 5.0V • } 20%, unless otherwise noted.

| Symbol | Parameter | Condition | Min | Max | Units |
|---|---|---|---|---|---|
| $V_{IL}$ | Input Low-voltage | (Except $\overline{EA}$) | -0.5 | 0.2 $V_{CC}$-0.1 | V |
| $V_{IL1}$ | Input Low-voltage ($\overline{EA}$) | | -0.5 | 0.2 $V_{CC}$-0.3 | V |
| $V_{IH}$ | Input High-voltage | (Except XTAL1, RST) | 0.2 $V_{CC}$+0.9 | $V_{CC}$+0.5 | V |
| $V_{IH1}$ | Input High-voltage | (XTAL1, RST) | 0.7 $V_{CC}$ | $V_{CC}$+0.5 | V |
| $V_{OL}$ | Output Low-voltage[1] (Ports 1,2,3) | $I_{OL}$ = 1.6 mA | | 0.45 | V |
| $V_{OL1}$ | Output Low-voltage[1] (Port 0, ALE, $\overline{PSEN}$) | $I_{OL}$ = 3.2 mA | | 0.45 | V |
| $V_{OH}$ | Output High-voltage (Ports 1,2,3, ALE, $\overline{PSEN}$) | $I_{OH}$ = -60 μA, $V_{CC}$ = 5V ± 10% | 2.4 | | V |
| | | $I_{OH}$ = -25 μA | 0.75 $V_{CC}$ | | V |
| | | $I_{OH}$ = -10 μA | 0.9 $V_{CC}$ | | V |
| $V_{OH1}$ | Output High-voltage (Port 0 in External Bus Mode) | $I_{OH}$ = -800 μA, $V_{CC}$ = 5V ± 10% | 2.4 | | V |
| | | $I_{OH}$ = -300 μA | 0.75 $V_{CC}$ | | V |
| | | $I_{OH}$ = -80 μA | 0.9 $V_{CC}$ | | V |
| $I_{IL}$ | Logical 0 Input Current (Ports 1,2,3) | $V_{IN}$ = 0.45V | | -50 | μA |
| $I_{TL}$ | Logical 1 to 0 Transition Current (Ports 1,2,3) | $V_{IN}$ = 2V, $V_{CC}$ = 5V ± 10% | | -650 | μA |
| $I_{LI}$ | Input Leakage Current (Port 0, $\overline{EA}$) | 0.45 < $V_{IN}$ < $V_{CC}$ | | ±10 | μA |
| RRST | Reset Pulldown Resistor | | 50 | 300 | KΩ |
| $C_{IO}$ | Pin Capacitance | Test Freq. = 1 MHz, $T_A$ = 25°C | | 10 | pF |
| $I_{CC}$ | Power Supply Current | Active Mode, 12 MHz | | 25 | mA |
| | | Idle Mode, 12 MHz | | 6.5 | mA |
| | Power-down Mode[1] | $V_{CC}$ = 6V | | 100 | μA |
| | | $V_{CC}$ = 3V | | 40 | μA |

**Notes:** 1. Under steady state (non-transient) conditions, IOL must be externally limited as follows:

Maximum IOL per port pin: 10 mA

Maximum IOL per 8-bit port:

Port 0: 26 mA Ports 1, 2, 3: 15 mA

Maximum total IOL for all output pins: 71 mA

If IOL exceeds the test condition, VOL may exceed the related specification. Pins are not guaranteed to sink current greater than the listed test conditions.

2. Minimum VCC for Power-down is 2V.

### *AC CHARACTERISTICS*

Under operating conditions, load capacitance for Port 0, ALE/PROG, and PSEN = 100 pF; load capacitance for all other outputs = 80 pF.

## External Program and Data Memory Characteristics

| Symbol | Parameter | 12 MHz Oscillator | | Variable Oscillator | | Units |
|---|---|---|---|---|---|---|
| | | Min | Max | Min | Max | |
| $1/t_{CLCL}$ | Oscillator Frequency | | | 0 | 24 | MHz |
| $t_{LHLL}$ | ALE Pulse Width | 127 | | $2t_{CLCL}$-40 | | ns |
| $t_{AVLL}$ | Address Valid to ALE Low | 43 | | $t_{CLCL}$-13 | | ns |
| $t_{LLAX}$ | Address Hold After ALE Low | 48 | | $t_{CLCL}$-20 | | ns |
| $t_{LLIV}$ | ALE Low to Valid Instruction In | | 233 | | $4t_{CLCL}$-65 | ns |
| $t_{LLPL}$ | ALE Low to $\overline{PSEN}$ Low | 43 | | $t_{CLCL}$-13 | | ns |
| $t_{PLPH}$ | $\overline{PSEN}$ Pulse Width | 205 | | $3t_{CLCL}$-20 | | ns |
| $t_{PLIV}$ | $\overline{PSEN}$ Low to Valid Instruction In | | 145 | | $3t_{CLCL}$-45 | ns |
| $t_{PXIX}$ | Input Instruction Hold after $\overline{PSEN}$ | 0 | | 0 | | ns |
| $t_{PXIZ}$ | Input Instruction Float after $\overline{PSEN}$ | | 59 | | $t_{CLCL}$-10 | ns |
| $t_{PXAV}$ | $\overline{PSEN}$ to Address Valid | 75 | | $t_{CLCL}$-8 | | ns |
| $t_{AVIV}$ | Address to Valid Instruction In | | 312 | | $5t_{CLCL}$-55 | ns |
| $t_{PLAZ}$ | $\overline{PSEN}$ Low to Address Float | | 10 | | 10 | ns |
| $t_{RLRH}$ | $\overline{RD}$ Pulse Width | 400 | | $6t_{CLCL}$-100 | | ns |
| $t_{WLWH}$ | $\overline{WR}$ Pulse Width | 400 | | $6t_{CLCL}$-100 | | ns |
| $t_{RLDV}$ | $\overline{RD}$ Low to Valid Data In | | 252 | | $5t_{CLCL}$-90 | ns |
| $t_{RHDX}$ | Data Hold After $\overline{RD}$ | 0 | | 0 | | ns |
| $t_{RHDZ}$ | Data Float After $\overline{RD}$ | | 97 | | $2t_{CLCL}$-28 | ns |
| $t_{LLDV}$ | ALE Low to Valid Data In | | 517 | | $8t_{CLCL}$-150 | ns |
| $t_{AVDV}$ | Address to Valid Data In | | 585 | | $9t_{CLCL}$-165 | ns |
| $t_{LLWL}$ | ALE Low to $\overline{RD}$ or $\overline{WR}$ Low | 200 | 300 | $3t_{CLCL}$-50 | $3t_{CLCL}$+50 | ns |
| $t_{AVWL}$ | Address to $\overline{RD}$ or $\overline{WR}$ Low | 203 | | $4t_{CLCL}$-75 | | ns |
| $t_{QVWX}$ | Data Valid to $\overline{WR}$ Transition | 23 | | $t_{CLCL}$-20 | | ns |
| $t_{QVWH}$ | Data Valid to $\overline{WR}$ High | 433 | | $7t_{CLCL}$-120 | | ns |
| $t_{WHQX}$ | Data Hold After $\overline{WR}$ | 33 | | $t_{CLCL}$-20 | | ns |
| $t_{RLAZ}$ | $\overline{RD}$ Low to Address Float | | 0 | | 0 | ns |
| $t_{WHLH}$ | $\overline{RD}$ or $\overline{WR}$ High to ALE High | 43 | 123 | $t_{CLCL}$-20 | $t_{CLCL}$+25 | ns |

## 2. <u>ANALOG TO DIGITAL CONVERTER AD0808/AD0809</u>

### *ABSOLUTE MAXIMUM RATINGS*

| | |
|---|---|
| Supply Voltage (VCC) | 6.5V |
| Voltage at Any Pin | −0.3V to (VCC+0.3V) |
| Except Control Inputs | |
| Voltage at Control Inputs | −0.3V to +15V |
| (START, OE, CLOCK, ALE, ADD A, ADD B, ADD C) | |

| | |
|---|---|
| Storage Temperature Range | −65°C to +150°C |
| Package Dissipation at TA=25°C | 875 mW |
| Lead Temp. (Soldering, 10 seconds) | |
| Dual-In-Line Package (plastic) | 260°C |
| Molded Chip Carrier Package | |
| Vapor Phase (60 seconds) | 215°C |
| Infrared (15 seconds) | 220°C |
| ESD Susceptibility (Note 8) | 400V |

## *OPERATING CONDITIONS*

| | |
|---|---|
| Temperature Range | TMIN≤TA≤TMAX |
| ADC0808CCN,ADC0809CCN | −40°C≤TA≤+85°C |
| Range of VCC | 4.5 VDC to 6.0 VDC |

## *ELECTRICAL CHARACTERISTICS*

**Converter Specifications:** $V_{CC}$=5 VDC=$V_{REF+}$, $V_{REF(-)}$=GND, $T_{MIN} \le T_A \le T_{MAX}$ and $f_{CLK}$=640 kHz unless otherwise stated.

| Symbol | Parameter | Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| | ADC0808 Total Unadjusted Error (Note 5) | 25˚C | | | ±½ | LSB |
| | | $T_{MIN}$ to $T_{MAX}$ | | | ±¾ | LSB |
| | ADC0809 Total Unadjusted Error (Note 5) | 0˚C to 70˚C | | | ±1 | LSB |
| | | $T_{MIN}$ to $T_{MAX}$ | | | ±1¼ | LSB |
| | Input Resistance | From Ref(+) to Ref(−) | 1.0 | 2.5 | | kΩ |
| | Analog Input Voltage Range | (Note 4) V(+) or V(−) | GND−0.10 | | $V_{CC}$+0.10 | $V_{DC}$ |
| $V_{REF(+)}$ | Voltage, Top of Ladder | Measured at Ref(+) | | $V_{CC}$ | $V_{CC}$+0.1 | V |
| $\frac{V_{REF(+)}+V_{REF(-)}}{2}$ | Voltage, Center of Ladder | | $V_{CC}$/2-0.1 | $V_{CC}$/2 | $V_{CC}$/2+0.1 | V |
| $V_{REF(-)}$ | Voltage, Bottom of Ladder | Measured at Ref(−) | −0.1 | 0 | | V |
| $I_{IN}$ | Comparator Input Current | $f_c$=640 kHz, (Note 6) | −2 | ±0.5 | 2 | µA |

## *ELECTRICAL CHARACTERISTICS*

**Digital Levels and DC Specifications:** ADC0808CCN, ADC0808CCV, ADC0809CCN and ADC0809CCV, 4.75≤$V_{CC}$≤5.25V, −40°C≤$T_A$≤+85°C unless otherwise noted.

| Symbol | Parameter | Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| **ANALOG MULTIPLEXER** | | | | | | |
| $I_{OFF(+)}$ | OFF Channel Leakage Current | $V_{CC}$=5V, $V_{IN}$=5V, | | | | |
| | | $T_A$=25°C | | 10 | 200 | nA |
| | | $T_{MIN}$ to $T_{MAX}$ | | | 1.0 | μA |
| $I_{OFF(-)}$ | OFF Channel Leakage Current | $V_{CC}$=5V, $V_{IN}$=0, | | | | |
| | | $T_A$=25°C | −200 | −10 | | nA |
| | | $T_{MIN}$ to $T_{MAX}$ | −1.0 | | | μA |
| **CONTROL INPUTS** | | | | | | |
| $V_{IN(1)}$ | Logical "1" Input Voltage | | $V_{CC}$−1.5 | | | V |
| $V_{IN(0)}$ | Logical "0" Input Voltage | | | | 1.5 | V |
| $I_{IN(1)}$ | Logical "1" Input Current (The Control Inputs) | $V_{IN}$=15V | | | 1.0 | μA |
| $I_{IN(0)}$ | Logical "0" Input Current (The Control Inputs) | $V_{IN}$=0 | −1.0 | | | μA |
| $I_{CC}$ | Supply Current | $f_{CLK}$=640 kHz | | 0.3 | 3.0 | mA |
| **DATA OUTPUTS AND EOC (INTERRUPT)** | | | | | | |
| $V_{OUT(1)}$ | Logical "1" Output Voltage | $V_{CC}$ = 4.75V | | | | |
| | | $I_{OUT}$ = −360μA | | 2.4 | | V(min) |
| | | $I_{OUT}$ = −10μA | | 4.5 | | V(min) |
| $V_{OUT(0)}$ | Logical "0" Output Voltage | $I_O$=1.6 mA | | | 0.45 | V |
| $V_{OUT(0)}$ | Logical "0" Output Voltage EOC | $I_O$=1.2 mA | | | 0.45 | V |
| $I_{OUT}$ | TRI-STATE Output Current | $V_O$=5V | | | 3 | μA |
| | | $V_O$=0 | −3 | | | μA |

## *ELECTRICAL CHARACTERISTICS*

Timing Specifications $V_{CC}=V_{REF(+)}=5V$, $V_{REF(-)}=GND$, tr=tf=20 ns and $T_A=25°C$ unless otherwise noted.

| Symbol | Parameter | Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| $t_{WS}$ | Minimum Start Pulse Width | (*Figure 5*) | | 100 | 200 | ns |
| $t_{WALE}$ | Minimum ALE Pulse Width | (*Figure 5*) | | 100 | 200 | ns |
| $t_s$ | Minimum Address Set-Up Time | (*Figure 5*) | | 25 | 50 | ns |
| $t_H$ | Minimum Address Hold Time | (*Figure 5*) | | 25 | 50 | ns |
| $t_D$ | Analog MUX Delay Time From ALE | $R_S=0\Omega$ (*Figure 5*) | | 1 | 2.5 | μs |
| $t_{H1}$, $t_{H0}$ | OE Control to Q Logic State | $C_L=50$ pF, $R_L=10k$ (*Figure 8*) | | 125 | 250 | ns |
| $t_{1H}$, $t_{0H}$ | OE Control to Hi-Z | $C_L=10$ pF, $R_L=10k$ (*Figure 8*) | | 125 | 250 | ns |
| $t_c$ | Conversion Time | $f_c=640$ kHz, (*Figure 5*) (Note 7) | 90 | 100 | 116 | μs |
| $f_c$ | Clock Frequency | | 10 | 640 | 1280 | kHz |
| $t_{EOC}$ | EOC Delay Time | (*Figure 5*) | 0 | | 8+2 μS | Clock Periods |
| $C_{IN}$ | Input Capacitance | At Control Inputs | | 10 | 15 | pF |
| $C_{OUT}$ | TRI-STATE Output Capacitance | At TRI-STATE Outputs | | 10 | 15 | pF |

**Note 1:** Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. DC and AC electrical specifications do not apply when operating the device beyond its specified operating conditions.

**Note 2:** All voltages are measured with respect to GND, unless othewise specified.

**Note 3:** A zener diode exists, internally, from $V_{CC}$ to GND and has a typical breakdown voltage of 7 $V_{DC}$.

**Note 4:** Two on-chip diodes are tied to each analog input which will forward conduct for analog input voltages one diode drop below ground or one diode drop greater than the $V_{CC}$n supply. The spec allows 100 mV forward bias of either diode. This means that as long as the analog VIN does not exceed the supply voltage by more than 100 mV, the output code will be correct. To achieve an absolute $0V_{DC}$ to $5V_{DC}$ input voltage range will therefore require a minimum supply voltage of 4.900 $V_{DC}$ over temperature variations, initial tolerance and loading.

**Note 5:** Total unadjusted error includes offset, full-scale, linearity, and multiplexer errors. None of these A/Ds requires a zero or full-scale adjust. However, if an all zero code is desired for an analog input other than 0.0V, or if a narrow full-scale span exists (for example: 0.5V to 4.5V full-scale) the reference voltages can be adjusted to achieve this.

**Note 6:** Comparator input current is a bias current into or out of the chopper stabilized comparator. The bias current varies directly with clock frequency and has little temperature dependence.

**Note 7:** The outputs of the data register are updated one clock cycle before the rising edge of EOC.

**Note 8:** Human body model, 100 pF discharged through a 1.5 kΩ resistor.

### 3. LM-35

***ABSOLUTE MAXIMUM RATINGS***

| | |
|---|---|
| Supply Voltage | +35V to −0.2V |
| Output Voltage | +6V to −1.0V |
| Output Current | 10 mA |
| Storage Temp.; | |
| TO-46 Package, | −60°C to +180°C |
| TO-92 Package, | −60°C to +150°C |
| SO-8 Package, | −65°C to +150°C |
| TO-220 Package, | −65°C to +150°C |
| Lead Temp.: | |
| TO-46 Package, | |
| (Soldering, 10 seconds) | 300°C |
| TO-92 and TO-220 Package, | |
| (Soldering, 10 seconds) | 260°C |
| SO Package | |
| Vapor Phase (60 seconds) | 215°C |
| Infrared (15 seconds) | 220°C |
| ESD Susceptibility | 2500V |
| Specified Operating Temperature Range: TMIN to T MAX | |
| LM35, LM35A | −55°C to +150°C |
| LM35C, LM35CA | −40°C to +110°C |
| LM35D | 0°C to +100°C |

*ELECTRICAL CHARACTERISTICS*

| Parameter | Conditions | LM35A | | | LM35CA | | | Units (Max.) |
|---|---|---|---|---|---|---|---|---|
| | | Typical | Tested Limit (Note 4) | Design Limit (Note 5) | Typical | Tested Limit (Note 4) | Design Limit (Note 5) | |
| Accuracy (Note 7) | $T_A$=+25°C | ±0.2 | ±0.5 | | ±0.2 | ±0.5 | | °C |
| | $T_A$=−10°C | ±0.3 | | | ±0.3 | | ±1.0 | °C |
| | $T_A=T_{MAX}$ | ±0.4 | ±1.0 | | ±0.4 | ±1.0 | | °C |
| | $T_A=T_{MIN}$ | ±0.4 | ±1.0 | | ±0.4 | | ±1.5 | °C |
| Nonlinearity (Note 8) | $T_{MIN}\le T_A\le T_{MAX}$ | ±0.18 | | ±0.35 | ±0.15 | | ±0.3 | °C |
| Sensor Gain (Average Slope) | $T_{MIN}\le T_A\le T_{MAX}$ | +10.0 | +9.9, +10.1 | | +10.0 | | +9.9, +10.1 | mV/°C |
| Load Regulation (Note 3) $0\le I_L\le 1$ mA | $T_A$=+25°C | ±0.4 | ±1.0 | | ±0.4 | ±1.0 | | mV/mA |
| | $T_{MIN}\le T_A\le T_{MAX}$ | ±0.5 | | ±3.0 | ±0.5 | | ±3.0 | mV/mA |
| Line Regulation (Note 3) | $T_A$=+25°C | ±0.01 | ±0.05 | | ±0.01 | ±0.05 | | mV/V |
| | $4V\le V_S\le 30V$ | ±0.02 | | ±0.1 | ±0.02 | | ±0.1 | mV/V |
| Quiescent Current (Note 9) | $V_S$=+5V, +25°C | 56 | 67 | | 56 | 67 | | μA |
| | $V_S$=+5V | 105 | | 131 | 91 | | 114 | μA |
| | $V_S$=+30V, +25°C | 56.2 | 68 | | 56.2 | 68 | | μA |
| | $V_S$=+30V | 105.5 | | 133 | 91.5 | | 116 | μA |
| Change of Quiescent Current (Note 3) | $4V\le V_S\le 30V$, +25°C | 0.2 | 1.0 | | 0.2 | 1.0 | | μA |
| | $4V\le V_S\le 30V$ | 0.5 | | 2.0 | 0.5 | | 2.0 | μA |
| Temperature Coefficient of Quiescent Current | | +0.39 | | +0.5 | +0.39 | | +0.5 | μA/°C |
| Minimum Temperature for Rated Accuracy | In circuit of *Figure 1*, $I_L$=0 | +1.5 | | +2.0 | +1.5 | | +2.0 | °C |
| Long Term Stability | $T_J=T_{MAX}$, for 1000 hours | ±0.08 | | | ±0.08 | | | °C |

| Parameter | Conditions | LM35 | | | LM35C, LM35D | | | Units (Max.) |
|---|---|---|---|---|---|---|---|---|
| | | Typical | Tested Limit (Note 4) | Design Limit (Note 5) | Typical | Tested Limit (Note 4) | Design Limit (Note 5) | |
| Accuracy, LM35, LM35C (Note 7) | $T_A$=+25°C | ±0.4 | ±1.0 | | ±0.4 | ±1.0 | | °C |
| | $T_A$=−10°C | ±0.5 | | | ±0.5 | | ±1.5 | °C |
| | $T_A=T_{MAX}$ | ±0.8 | ±1.5 | | ±0.8 | | ±1.5 | °C |
| | $T_A=T_{MIN}$ | ±0.8 | | ±1.5 | ±0.8 | | ±2.0 | °C |
| Accuracy, LM35D (Note 7) | $T_A$=+25°C | | | | ±0.6 | ±1.5 | | °C |
| | $T_A=T_{MAX}$ | | | | ±0.9 | | ±2.0 | °C |
| | $T_A=T_{MIN}$ | | | | ±0.9 | | ±2.0 | °C |
| Nonlinearity (Note 8) | $T_{MIN}≤T_A≤T_{MAX}$ | ±0.3 | | ±0.5 | ±0.2 | | ±0.5 | °C |
| Sensor Gain (Average Slope) | $T_{MIN}≤T_A≤T_{MAX}$ | +10.0 | +9.8, +10.2 | | +10.0 | | +9.8, +10.2 | mV/°C |
| Load Regulation (Note 3) $0≤I_L≤1$ mA | $T_A$=+25°C | ±0.4 | ±2.0 | | ±0.4 | ±2.0 | | mV/mA |
| | $T_{MIN}≤T_A≤T_{MAX}$ | ±0.5 | | ±5.0 | ±0.5 | | ±5.0 | mV/mA |
| Line Regulation (Note 3) | $T_A$=+25°C | ±0.01 | ±0.1 | | ±0.01 | ±0.1 | | mV/V |
| | $4V≤V_S≤30V$ | ±0.02 | | ±0.2 | ±0.02 | | ±0.2 | mV/V |
| Quiescent Current (Note 9) | $V_S$=+5V, +25°C | 56 | 80 | | 56 | 80 | | µA |
| | $V_S$=+5V | 105 | | 158 | 91 | | 138 | µA |
| | $V_S$=+30V, +25°C | 56.2 | 82 | | 56.2 | 82 | | µA |
| | $V_S$=+30V | 105.5 | | 161 | 91.5 | | 141 | µA |
| Change of Quiescent Current (Note 3) | $4V≤V_S≤30V$, +25°C | 0.2 | 2.0 | | 0.2 | 2.0 | | µA |
| | $4V≤V_S≤30V$ | 0.5 | | 3.0 | 0.5 | | 3.0 | µA |
| Temperature Coefficient of Quiescent Current | | +0.39 | | +0.7 | +0.39 | | +0.7 | µA/°C |
| Minimum Temperature for Rated Accuracy | In circuit of *Figure 1*, $I_L$=0 | +1.5 | | +2.0 | +1.5 | | +2.0 | °C |
| Long Term Stability | $T_J=T_{MAX}$, for 1000 hours | ±0.08 | | | ±0.08 | | | °C |

**Note 1:** Unless otherwise noted, these specifications apply: −55°C£TJ£+150°C for the LM35 and LM35A; −40°£TJ£+110°C for the LM35C and LM35CA; and 0°£TJ£+100°C for the LM35D. VS=+5Vdc and ILOAD=50 µA. These specifications also apply from +2°C to TMAX in the circuit of Figure 1.

**Note 2:** Thermal resistance of the TO-46 package is 400°C/W, junction to ambient, and 24°C/W junction to case. Thermal resistance of the TO-92 package is 180°C/W junction to ambient. Thermal resistance of the small outline molded package is 220°C/W junction to ambient. Thermal resistance of the TO-220 package is 90°C/W junction to ambient. For additional thermal resistance information see table in the Applications section.

**Note 3:** Regulation is measured at constant junction temperature, using pulse testing with a low duty cycle. Changes in output due to heating effects can be computed by multiplying the internal dissipation by the thermal resistance.

**Note 4:** Tested Limits are guaranteed and 100% tested in production.

**Note 5:** Design Limits are guaranteed (but not 100% production tested) over the indicated temperature and supply voltage ranges. These limits are not used to calculate outgoing quality levels.

**Note 6:** Specifications in boldface apply over the full rated temperature range.

**Note 7:** Accuracy is defined as the error between the output voltage and 10mv/°C times the device's case temperature, at specified conditions of voltage, current, and temperature (expressed in °C).

**Note 8:** Nonlinearity is defined as the deviation of the output-voltage-versus-temperature curve from the best-fit straight line, over the device's rated temperature range.

**Note 9:** Quiescent current is defined in the circuit of Figure 1.

**Note 10:** Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. DC and AC electrical specifications do not apply when operating the device beyond its rated operating conditions. See Note 1.

**Note 11:** Human body model, 100 pF discharged through a 1.5 kW resistor.

**Note 12:** See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" or the section titled "Surface Mount" found in a current National Semiconductor Linear Data Book for other methods of soldering surface mount devices.

## *TEMPERATURE RISE OF LM35 DUE TO SELF-HEATING (THERMAL RESISTANCE,θJA)*

| | TO-46, no heat sink | TO-46*, small heat fin | TO-92, no heat sink | TO-92**, small heat fin | SO-8 no heat sink | SO-8** small heat fin | TO-220 no heat sink |
|---|---|---|---|---|---|---|---|
| Still air | 400°C/W | 100°C/W | 180°C/W | 140°C/W | 220°C/W | 110°C/W | 90°C/W |
| Moving air | 100°C/W | 40°C/W | 90°C/W | 70°C/W | 105°C/W | 90°C/W | 26°C/W |
| Still oil | 100°C/W | 40°C/W | 90°C/W | 70°C/W | | | |
| Stirred oil | 50°C/W | 30°C/W | 45°C/W | 40°C/W | | | |
| (Clamped to metal, Infinite heat sink) | | (24°C/W) | | | | (55°C/W) | |

*Wakefield type 201, or 1" disc of 0.020" sheet brass, soldered to case, or similar.

**TO-92 and SO-8 packages glued and leads soldered to 1" square of 1/16" printed circuit board with 2 oz. foil or similar.

## 4. MAX-232

***ABSOLUTE MAXIMUM RATINGS***

| | |
|---|---|
| Supply Voltage (VCC) | -0.3V to +6V |
| Input Voltages | |
| TIN | -0.3V to (VCC - 0.3V) |
| RIN | ±30V |
| RIN | ±25V |
| TOUT | ±15V |
| TOUT | ±13.2V |
| Output Voltages | |
| TOUT | ±15V |
| ROUT | -0.3V to (VCC + 0.3V) |
| Driver/Receiver Output Short Circuited to GND | Continuous |

Continuous Power Dissipation (TA = +70°C)

16-Pin Plastic DIP (derate 10.53mW/°C above +70°C)....842mW

18-Pin Plastic DIP (derate 11.11mW/°C above +70°C)....889mW

20-Pin Plastic DIP (derate 8.00mW/°C above +70°C) .....440mW

16-Pin Narrow SO (derate 8.70mW/°C above +70°C) .....696mW

16-Pin Wide SO (derate 9.52mW/°C above +70°C).........762mW

18-Pin Wide SO (derate 9.52mW/°C above +70°C).........762mW

20-Pin Wide SO (derate 10.00mW/°C above +70°C).......800mW

20-Pin SSOP (derate 8.00mW/°C above +70°C) .............640mW

16-Pin CERDIP (derate 10.00mW/°C above +70°C).......800mW

18-Pin CERDIP (derate 10.53mW/°C above +70°C).......842mW

| | |
|---|---|
| Operating Temperature Ranges | |
| MAX2_ _AC_ _, MAX2_ _C_ _ | 0°C to +70°C |
| MAX2_ _AE_ _, MAX2_ _E_ _ | -40°C to +85°C |
| MAX2_ _AM_ _, MAX2_ _M_ _. | -55°C to +125°C |
| Storage Temperature Range | -65°C to +160°C |
| Lead Temperature (soldering, 10s) | +300°C |

## *ELECTRICAL CHARACTERISTICS*

(VCC = +5V ±10%, C1–C4 = 0.1µF, MAX220, C1 = 0.047µF, C2–C4 = 0.33µF, TA = TMIN to TMAX, unless otherwise noted.)

| PARAMETER | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|
| **RS-232 TRANSMITTERS** | | | | | |
| Output Voltage Swing | All transmitter outputs loaded with 3kΩ to GND | ±5 | ±8 | | V |
| Input Logic Threshold Low | | | 1.4 | 0.8 | V |
| Input Logic Threshold High | All devices except MAX220 | 2 | 1.4 | | V |
| | MAX220: $V_{CC}$ = 5.0V | 2.4 | | | |
| Logic Pull-Up/Input Current | All except MAX220, normal operation | | 5 | 40 | µA |
| | $\overline{SHDN}$ = 0V, MAX222/242, shutdown, MAX220 | | ±0.01 | ±1 | |
| Output Leakage Current | $V_{CC}$ = 5.5V, $\overline{SHDN}$ = 0V, $V_{OUT}$ = ±15V, MAX222/242 | | ±0.01 | ±10 | µA |
| | $V_{CC}$ = $\overline{SHDN}$ = 0V, $V_{OUT}$ = ±15V | | ±0.01 | ±10 | |
| Data Rate | | | 200 | 116 | kbps |
| Transmitter Output Resistance | $V_{CC}$ = V+ = V- = 0V, $V_{OUT}$ = ±2V | 300 | 10M | | Ω |
| Output Short-Circuit Current | $V_{OUT}$ = 0V | ±7 | ±22 | | mA |
| **RS-232 RECEIVERS** | | | | | |
| RS-232 Input Voltage Operating Range | | | | ±30 | V |
| RS-232 Input Threshold Low | $V_{CC}$ = 5V, All except MAX243 $R2_{IN}$ | 0.8 | 1.3 | | V |
| | $V_{CC}$ = 5V, MAX243 $R2_{IN}$ (Note 2) | -3 | | | |
| RS-232 Input Threshold High | $V_{CC}$ = 5V, All except MAX243 $R2_{IN}$ | | 1.8 | 2.4 | V |
| | $V_{CC}$ = 5V, MAX243 $R2_{IN}$ (Note 2) | | -0.5 | -0.1 | |
| RS-232 Input Hysteresis | All except MAX243, $V_{CC}$ = 5V, no hysteresis in shdn. | 0.2 | 0.5 | 1 | V |
| | MAX243 | | 1 | | |
| RS-232 Input Resistance | | 3 | 5 | 7 | kΩ |
| TTL/CMOS Output Voltage Low | $I_{OUT}$ = 3.2mA | | 0.2 | 0.4 | V |
| TTL/CMOS Output Voltage High | $I_{OUT}$ = -1.0mA | 3.5 | $V_{CC}$ - 0.2 | | V |
| TTL/CMOS Output Short-Circuit Current | Sourcing $V_{OUT}$ = GND | -2 | -10 | | mA |
| | Shrinking $V_{OUT}$ = $V_{CC}$ | 10 | 30 | | |

| PARAMETER | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| TTL/CMOS Output Leakage Current | $\overline{SHDN}$ = $V_{CC}$ or $\overline{EN}$ = $V_{CC}$ ($\overline{SHDN}$ = 0V for MAX222), 0V ≤ $V_{OUT}$ ≤ $V_{CC}$ | | | ±0.05 | ±10 | µA |
| $\overline{EN}$ Input Threshold Low | MAX242 | | | 1.4 | 0.8 | V |
| $\overline{EN}$ Input Threshold High | MAX242 | | 2.0 | 1.4 | | V |
| Operating Supply Voltage | | | 4.5 | | 5.5 | V |
| $V_{CC}$ Supply Current ($\overline{SHDN}$ = $V_{CC}$), Figures 5, 6, 11, 19 | No load | MAX220 | | 0.5 | 2 | mA |
| | | MAX222/232A/233A/242/243 | | 4 | 10 | |
| | 3kΩ load both inputs | MAX220 | | 12 | | |
| | | MAX222/232A/233A/242/243 | | 15 | | |
| Shutdown Supply Current | MAX222/242 | $T_A$ = +25°C | | 0.1 | 10 | µA |
| | | $T_A$ = 0°C to +70°C | | 2 | 50 | |
| | | $T_A$ = -40°C to +85°C | | 2 | 50 | |
| | | $T_A$ = -55°C to +125°C | | 35 | 100 | |
| $\overline{SHDN}$ Input Leakage Current | MAX222/242 | | | | ±1 | µA |
| $\overline{SHDN}$ Threshold Low | MAX222/242 | | | 1.4 | 0.8 | V |
| $\overline{SHDN}$ Threshold High | MAX222/242 | | 2.0 | 1.4 | | V |
| Transition Slew Rate | $C_L$ = 50pF to 2500pF, $R_L$ = 3kΩ to 7kΩ, $V_{CC}$ = 5V, $T_A$ = +25°C, measured from +3V to -3V or -3V to +3V | MAX222/232A/233A/242/243 | 6 | 12 | 30 | V/µs |
| | | MAX220 | 1.5 | 3 | 30 | |
| Transmitter Propagation Delay TLL to RS-232 (Normal Operation), Figure 1 | $t_{PHLT}$ | MAX222/232A/233A/242/243 | | 1.3 | 3.5 | µs |
| | | MAX220 | | 4 | 10 | |
| | $t_{PLHT}$ | MAX222/232A/233A/242/243 | | 1.5 | 3.5 | |
| | | MAX220 | | 5 | 10 | |
| Receiver Propagation Delay RS-232 to TLL (Normal Operation), Figure 2 | $t_{PHLR}$ | MAX222/232A/233A/242/243 | | 0.5 | 1 | µs |
| | | MAX220 | | 0.6 | 3 | |
| | $t_{PLHR}$ | MAX222/232A/233A/242/243 | | 0.6 | 1 | |
| | | MAX220 | | 0.8 | 3 | |
| Receiver Propagation Delay RS-232 to TLL (Shutdown), Figure 2 | $t_{PHLS}$ | MAX242 | | 0.5 | 10 | µs |
| | $t_{PLHS}$ | MAX242 | | 2.5 | 10 | |
| Receiver-Output Enable Time, Figure 3 | $t_{ER}$ | MAX242 | | 125 | 500 | ns |
| Receiver-Output Disable Time, Figure 3 | $t_{DR}$ | MAX242 | | 160 | 500 | ns |
| Transmitter-Output Enable Time ($\overline{SHDN}$ Goes High), Figure 4 | $t_{ET}$ | MAX222/242, 0.1µF caps (includes charge-pump start-up) | | 250 | | µs |
| Transmitter-Output Disable Time ($\overline{SHDN}$ Goes Low), Figure 4 | $t_{DT}$ | MAX222/242, 0.1µF caps | | 600 | | ns |
| Transmitter + to - Propagation Delay Difference (Normal Operation) | $t_{PHLT}$ - $t_{PLHT}$ | MAX222/232A/233A/242/243 | | 300 | | ns |
| | | MAX220 | | 2000 | | |
| Receiver + to - Propagation Delay Difference (Normal Operation) | $t_{PHLR}$ - $t_{PLHR}$ | MAX222/232A/233A/242/243 | | 100 | | ns |
| | | MAX220 | | 225 | | |

## 5. LCD

### *ABSOLUTE MAXIMUM RATINGS*

| Item | Symbol | Min. | Max. | Unit |
|---|---|---|---|---|
| Supply Voltage(Logic) | $V_{DD}$ - $V_{SS}$ | -0.3 | 7.0 | V |
| Supply Voltage(LCD) | $V_{DD}$ - $V_O$ | -0.3 | 13.0 | V |
| Input Voltage | $V_I$ | -0.3 | $V_{DD}$ + 0.3 | V |
| Operating Temp. | $T_{opr}$ | -20 | 70 | °C |
| Storage Temp. | $T_{stg}$ | -30 | 80 | °C |

### *ELECTRICAL CHARACTERISTICS ($V_{dd}$=5v±0.25v)*

| Item | Symbol | Test Condition | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| Input High Voltage | $V_{IH}$ | -- | 2.2 | -- | $V_{DD}$ | V |
| Input Low Voltage | $V_{IL}$ | -- | - 0.3 | -- | 0.6 | V |
| Output High Voltage | $V_{OH}$ | $I_{OH}$ = - 0.2mA | 2.4 | -- | $V_{DD}$ | V |
| Output Low Voltage | $V_{OL}$ | $I_{OL}$ = 1.2mA | 0 | -- | 0.4 | V |
| Supply Current | $I_{DD}$ | $V_{DD}$ = 5.0V | -- | 1.5 | 3.0 | mA |
| LCD Driving Voltage | $V_{DD}$ - $V_O$ | Ta=25°C | -- | 4.6 | -- | V |

### *LED BACKLIGHT SPECIFICATIONS ($T_a$=25°C)*

| Item | Symbol | Typ. | Max. | Unit |
|---|---|---|---|---|
| Forward Voltage | $V_f$ | 4.1 | 4.3 | V |
| Forward Current | $I_f$ | 156 | -- | mA |
| Emission Wave Length | $\lambda_p$ | 568 | -- | nm |

## 6. 555 TIMER

### *ABSOLUTE MAXIMUM RATINGS ($T_a$=25°c)*

| Parameter | Symbol | Value | Unit |
|---|---|---|---|
| Supply Voltage | $V_{CC}$ | 16 | V |
| Lead Temperature (Soldering 10sec) | $T_{LEAD}$ | 300 | °C |
| Power Dissipation | $P_D$ | 600 | mW |
| Operating Temperature Range<br>LM555/NE555<br>SA555 | $T_{OPR}$ | <br>0 ~ +70<br>-40 ~ +85 | °C |
| Storage Temperature Range | $T_{STG}$ | -65 ~ +150 | °C |

### *ELECTRICAL CHARACTERISTICS*

*($T_A$=25°C, $V_{CC}$=5~15V, unless otherwise specified)*

| Parameter | Symbol | Conditions | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| Supply Voltage | VCC | - | 4.5 | - | 16 | V |
| Supply Current (Low Stable) (Note1) | ICC | VCC = 5V, RL = ∞ | - | 3 | 6 | mA |
| | | VCC = 15V, RL = ∞ | - | 7.5 | 15 | mA |
| Timing Error (Monostable)<br>Initial Accuracy (Note2)<br>Drift with Temperature (Note4)<br>Drift with Supply Voltage (Note4) | ACCUR<br>Δt/ΔT<br>Δt/ΔVCC | RA = 1kΩ to100kΩ<br>C = 0.1μF | - | 1.0<br>50<br>0.1 | 3.0<br><br>0.5 | %<br>ppm/°C<br>%/V |
| Timing Error (Astable)<br>Intial Accuracy (Note2)<br>Drift with Temperature (Note4)<br>Drift with Supply Voltage (Note4) | ACCUR<br>Δt/ΔT<br>Δt/ΔVCC | RA = 1kΩ to 100kΩ<br>C = 0.1μF | - | 2.25<br>150<br>0.3 | - | %<br>ppm/°C<br>%/V |
| Control Voltage | VC | VCC = 15V | 9.0 | 10.0 | 11.0 | V |
| | | VCC = 5V | 2.6 | 3.33 | 4.0 | V |
| Threshold Voltage | VTH | VCC = 15V | - | 10.0 | - | V |
| | | VCC = 5V | - | 3.33 | - | V |
| Threshold Current (Note3) | ITH | - | - | 0.1 | 0.25 | μA |
| Trigger Voltage | VTR | VCC = 5V | 1.1 | 1.67 | 2.2 | V |
| | | VCC = 15V | 4.5 | 5 | 5.6 | V |
| Trigger Current | ITR | VTR = 0V | | 0.01 | 2.0 | μA |
| Reset Voltage | VRST | - | 0.4 | 0.7 | 1.0 | V |
| Reset Current | IRST | - | | 0.1 | 0.4 | mA |
| Low Output Voltage | VOL | VCC = 15V<br>ISINK = 10mA<br>ISINK = 50mA | - | <br>0.06<br>0.3 | <br>0.25<br>0.75 | <br>V<br>V |
| | | VCC = 5V<br>ISINK = 5mA | - | 0.05 | 0.35 | V |
| High Output Voltage | VOH | VCC = 15V<br>ISOURCE = 200mA<br>ISOURCE = 100mA | <br><br>12.75 | <br>12.5<br>13.3 | - | <br>V<br>V |
| | | VCC = 5V<br>ISOURCE = 100mA | 2.75 | 3.3 | - | V |
| Rise Time of Output (Note4) | tR | - | - | 100 | - | ns |
| Fall Time of Output (Note4) | tF | - | - | 100 | - | ns |
| Discharge Leakage Current | ILKG | - | - | 20 | 100 | nA |

Notes:

1. When the output is high, the supply current is typically 1mA less than at VCC = 5V.
2. Tested at VCC = 5.0V and VCC = 15V.
3. This will determine the maximum value of RA + RB for 15V operation, the max. total R = 20MΩ, and for 5V operation, the max. total R = 6.7MΩ.
4. These parameters, although guaranteed, are not 100% tested in production.

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