IMPLEMENTATION OF FULLY AUTOMATED GREENHOUSE USING LABVIEW

A PROJECT REPORT

Submitted by

P.DIVYA	**71206107010**
S.RANJANI RENGANATHAN	**71206107038**
S.SUGANYA	**71206107050**
S.SUMATHI	**71206107051**

in partial fulfilment for the award of the degree

of

Bachelor of Engineering

in

Electronics and Instrumentation Engineering

KUMARAGURU COLLEGE OF TECHNOLOGY

ANNA UNIVERSITY: CHENNAI - 600 025

April 2010

ANNA UNIVERSITY : CHENNAI 600 025

BONAFIDE CERTIFICATE

Certified that this project report " **IMPLEMENTATION OF FULLY AUTOMATED GREENHOUSE USING LABVIEW**" is the bonafide work of **P.DIVYA, S.RANJANI RENGANATHAN, S.SUGANYA, S.SUMATHI** who carried out the project under my supervision.

SIGNATURE	**SIGNATURE** 12.04.2010.
Prof.R.Annamalai , M.E	Mr. V.Athappan, M.Tech
HEAD OF THE DEPARTMENT	**SUPERVISOR**
	Lecturer
Department of Electronics	Department of Electronics
& Instrumentation Engineering,	& Instrumentation Engineering,
Kumaraguru College	Kumaraguru College
of Technology.	of Technology.

The candidates with university register numbers 71206107010, 71206107038, 71206107050, 71206107051 were examined by us in the project viva voce examination held on 15/04/10

15/04/10
INTERNAL EXAMINER

15/4/2010
EXTERNAL EXAMINER

ACKNOWLEDGEMENT

ACKNOWLEDGEMENT

We take this opportunity to thank the following persons for their support, guidance and encouragement that made us to successfully complete our project "**IMPLEMENTATION OF FULLY AUTOMATED GREENHOUSE USING LABVIEW**".

Firstly, we thank our beloved principal Dr.S.Ramachandran who has been the backbone of all our deeds.

We are greatly indebted to our Head of the Department – Prof R.Annamalai, M.E. for his continuous motivation towards the successful accomplishment of our project.

Next, we express our deepest gratitude and special thanks to Prof.S.Govindaraju, for his tremendous support and co-operation rendered throughout our work.

We also take pride in offering our sincere thanks to our project guide Mr.V.Athappan, Lecturer of EIE, for his valuable guidance and constant encouragement right from the beginning of our project work.

We are also thankful to all our non teaching staffs for their kind help and assistance.

ABSTRACT

ABSTRACT

This project is designed to control the growth factors inside a greenhouse. A greenhouse is a structure made up of glass, which traps energy to support plant growth. It can be seen as a multivariable process which is quite non -linear in nature and which is influenced by several biological processes. To ensure an optimal environment for efficient plant growth, there arises a necessity to control the factors which affects the greenhouse.

This project aims at "**Automating the Greenhouse**" and the project focuses on automatic control of the greenhouse variables which includes

- Temperature
- Air humidity
- Soil moisture
- Light intensity

This is implemented using a central computer, installed with **LABVIEW**. Here, LABVIEW acts as a supervisory controller. The PC is loaded with DAQ software, which acquires the data from various field points, processes it and sends the control output to the actuator. In addition, the user can also be notified with an e-mail as a warning signal, when the greenhouse deviates from the optimal condition. Since the control action is performed by a PC, it ensures flexibility in parameter settings and high speed data acquisition. Moreover, the user requires less or no technical background. Thus, this design ensures an accessible means for better and convenient control, thereby increasing the overall efficiency.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

CHAPTER 1

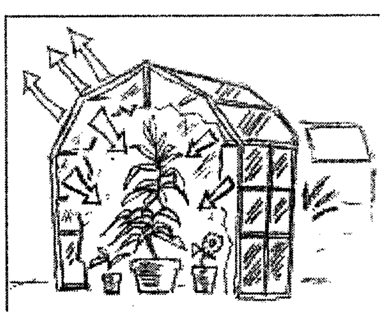
1. INTRODUCTION

Environmental parameters have a tremendous effect on plant growth. The various climatic parameters such as temperature, air humidity, soil moisture, light intensity and CO2 level are non linear and extremely interdependent. So, these parameters must be controlled so as to ensure optimum environment required for plant growth. Our project mainly deals with monitoring and controlling the climactic parameters inside a greenhouse.

1.1. GREENHOUSE:

A **greenhouse** (also called a **glasshouse**) is a building where plants are grown. The glass used for a greenhouse works as a barrier to air flow and its effect is to trap energy within the greenhouse, which heats both the plants and the ground inside it.

Most greenhouses look like a small glass house. Greenhouses are used to grow plants, especially in the winter. Greenhouses work by trapping heat from the sun. The glass panels of the greenhouse let in light but keep heat from escaping. This causes the greenhouse to heat up, much like the inside of a car parked in sunlight, and keeps the plants warm enough to live in the winter.



Greenhouse structures are commonly used to grow off-season horticultural crops when the conditions are not favourable for their normal growing. Greenhouses protect crops from too much heat or cold, shield plants from dust storms and blizzards, and help to keep out pests. Light and temperature control allows greenhouses to turn inarable land into arable land, thereby improving food production in marginal environments.

Greenhouse ensures continuous supply of fruits, vegetables and flowers throughout the year. The various parameters that have an influence on plant growth inside greenhouse are temperature, light intensity, moisture , humidity, Co2 level. To provide a congenial environment for plant growth, it is mandatory to maintain these parameters to an optimum level.

1.2. Why Automation:

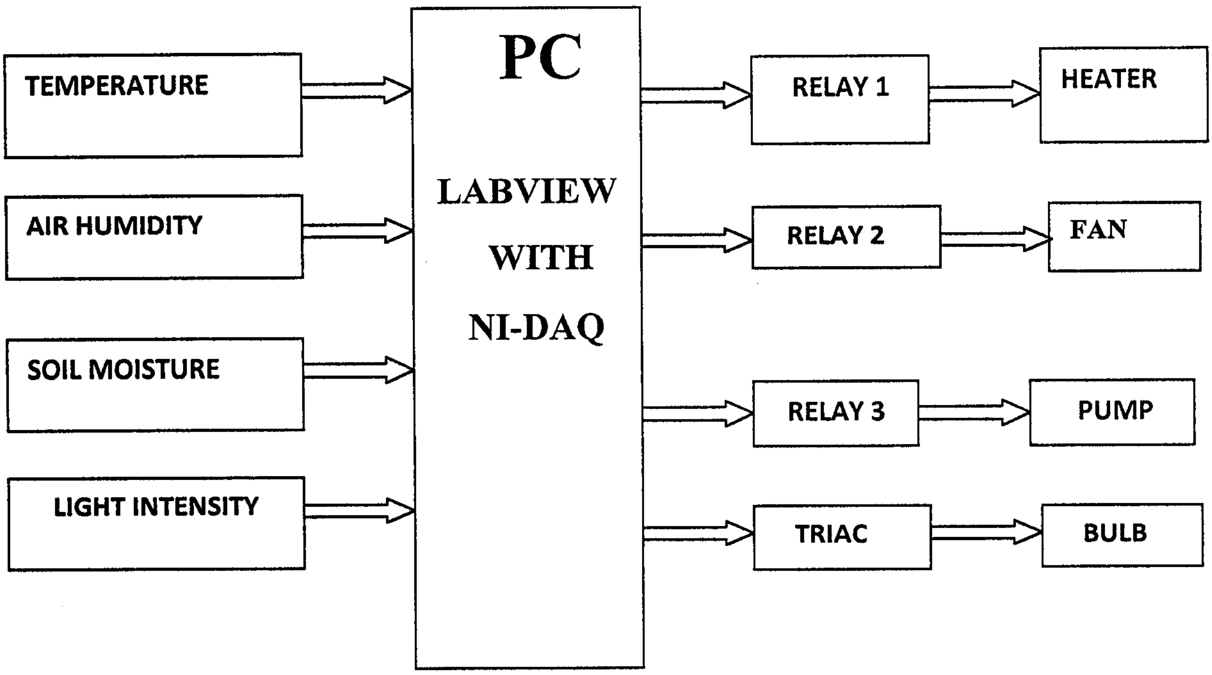
The first and foremost benefit of automation is accuracy and reduction of labour forces. In greenhouses, efficient plant growth depends upon certain requirements .For instance, irrigation is required to support plant growth. Pests and extreme levels of heat and humidity must be controlled so as to prevent plants from blight. Also, significant inputs of heat and light are required, particularly in winter.

So, the requirements and conditions for effective plant growth varies accordingly to the change in seasons. So, this necessitates a proper control of the parameters. However, monitoring and maintaining the parameters manually becomes a tedious task. Manual methods lack consistency and accuracy. Moreover, it is time consuming and always requires user to monitor the status of the process. So, automatic means of controlling is adopted. Thus, in our project, the parameters are monitored and controlled using Lab VIEW software installed in system

PROJECT OVERVIEW

CHAPTER 2

2.1. BLOCK DIAGRAM



There is a central/ host computer, installed with **LABVIEW** software, in the control room. The required sensors are placed at various field points to measure the climatic parameters. The data from the sensors is acquired through the DAQ card installed along with the LABVIEW software. The processing of the data is done at the PC level and the final control elements are actuated by the control signal from the PC.

2.2. PLATFORM

The system is implemented using LABVIEW by National Instruments. Certain features like VI portability, easy upgradeability , Image Processing, availability of advanced processing kits, etc have made this software more preferable. The software has a typical front panel-block coding is done at the block-diagram level while the front panel forms the visual interface to the farmer for monitoring and control. This front panel forms the visual link between the farmer and the system.

VIRTUAL INSTRUMENTATION

CHAPTER 3

3. VIRTUAL INSTRUMENTATION AND LAB VIEW

Virtual instrumentation is the use of customizable software and modular measurement hardware to create user-defined measurement systems, called virtual instruments.

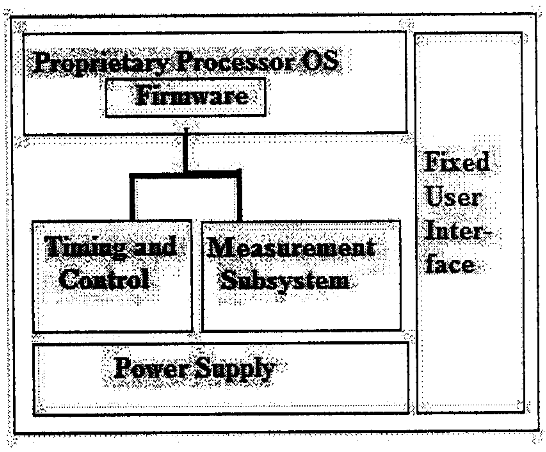
Traditional hardware instrumentation systems are made up of pre-defined hardware components, such as digital multimeters and oscilloscopes that are completely specific to their stimulus, analysis, or measurement function. Because of their hard-coded function, these systems are more limited in their versatility than virtual instrumentation systems. The primary difference between hardware instrumentation and virtual instrumentation is that software is used to replace a large amount of hardware. The software enables complex and expensive hardware to be replaced by already purchased computer hardware; e. g. analog-to-digital converter can act as a hardware complement of a virtual oscilloscope, a potentiostat enables frequency response acquisition and analysis in electrochemical impedance spectroscopy .

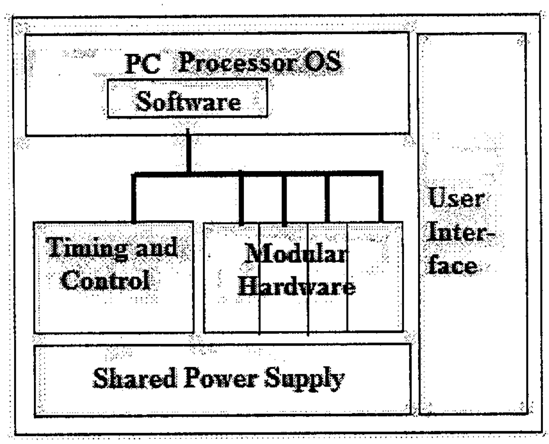
With virtual instrumentation, software based on user requirements defines general-purpose measurement and control hardware functionality. Virtual instrumentation combines mainstream commercial technologies, such as the PC, with flexible software and a wide variety of measurement and control hardware, so as to create user-defined systems which tend to meet user's exact application needs. With virtual instrumentation, one can reduce development time, design higher quality products, and lower the design costs.

As innovation mandates software use of to accelerate new concept and product development, it also requires instrumentation to rapidly adapt to modular I/O, and commercial platforms, it delivers instrumentation capabilities uniquely qualified to keep pace with today's concept and product development.

3.1. Virtual instrumentation vs Traditional instrumentation

Virtual instruments are defined by the user while traditional instruments have fixed vendor-defined functionality.





Virtual instruments **Traditional instruments**

3.2. COMPONENTS OF VI

The heart of any VI is flexible software. Every virtual instrument is built on this flexible and powerful software. The result is a user defined instrument specific to the application needs. With such software, interfacing with real world signals and data analysis can be done with ease.

NI LABVIEW, the productive software component of the virtual instrumentation architecture, is the graphical development platform for test, design and control applications.

3.3. LABVIEW

LabVIEW (short for **Laboratory Virtual Instrumentation Engineering Workbench)** is an integral part of virtual instrumentation because it provides an easy-to-use application development environment designed specifically for engineers. LabVIEW is a powerful graphical development environment for signal acquisition, measurement analysis, and data presentation, giving the flexibility of a programming language without the complexity of traditional development tools. LabVIEW offers powerful features that make it easy to connect to a wide variety of hardware and other software. This ease of use and these features deliver the required flexibility for a virtual instrumentation software development environment. The result is a user-defined interface and user-defined application.

One of the most powerful features that LabVIEW offers is its graphical programming paradigm. With LabVIEW, users can design custom virtual instruments by creating a graphical user interface on the computer screen through which they:

- Operate the instrumentation program
- Control selected hardware
- Analyse acquired data
- Display results

LabVIEW is defined as a **general-purpose programming system**. A LabVIEW program is also referred as **virtual instruments**. Virtual instruments mean that the operations and appearance can imitate actual instruments.

Virtual instruments are structured as follows:

- The control or user interface of virtual instruments is known as the **front panel**. The front panel simulates the panel of a physical instrument.
- Instructions that are given to the virtual instrument are in the form of a **block diagram**.
- Virtual instruments can be used as a "top-level program", or as a subprogram of another program.

Front Panel

The "user interface" of VI looks like that of an instrument. This "user interface" is known as the **front panel**.

Block Diagram

With the **block diagram**, a block diagram can be constructed that wires together objects that send or receive data, perform specific functions, and control the flow of execution.

Icon and Connector

An **icon** is either the pictorial or the textual representation of the purpose of the Virtual Instrument, or its terminals. A **connector** is a set of terminals that correspond to the sub Virtual Instrument controls and indicators.

The front panel generally shows knobs, buttons, charts, and other controls and indicators. Controls are used to give the computer information to process. Indicators display information that the program generates.

indicators look realistic; however, they are pictures on the screen. The diagram is a separate screen which contains the coding. The diagram looks similar to a piece of blank sketch paper. A tool box is available which is used to select or point an object, to wire the blocks, to write texts. Hence, Lab VIEW ensures flexibility and user friendly environment.

DATA ACQUISITION

CHAPTER 4

4. DATA ACQUISITION

The purpose of data acquisition is to measure an electrical or physical phenomenon such as voltage, current, temperature, pressure, or sound. PC-based data acquisition uses a combination of modular hardware, application software, and a computer to take measurements. While each data acquisition system is defined by its application requirements, every system shares a common goal of acquiring, analysing, and presenting information. Data acquisition systems incorporate signals, sensors, actuators, signal conditioning, data acquisition devices, and application software.

Data acquisition (abbreviated as DAQ) is a process of sampling of real world physical conditions and conversion of the resulting samples into digital numeric values that can be manipulated by a computer. Data acquisition systems typically involves the conversion of analog waveforms into digital values for processing.The components of data acquisition system include:

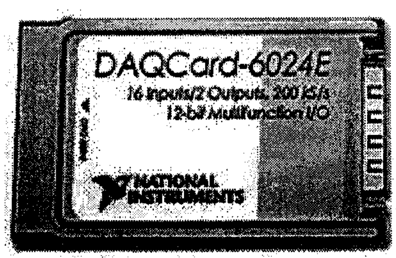
- Sensors that convert physical parameters to electrical signals.
- Signal conditioning circuitry to convert sensor signals into a form that can be converted to digital values.
- Analog to Digital converters which convert conditioned sensor signals into digital values.
- DAQ hardware
- Driver and application software.

DAQ hardware is what usually interfaces between the signal and a PC. It could be in the form of modules that can be connected to the computer ports (parallel, serial, USB) or cards connected to slots (PCI, PCI-E) in the mother board. DAQ cards often contains multiple components (multiplexer, ADC, DAC, TTL, high speed timers).

The real time interfacing with LABVIEW software requires NI DAQ card. The DAQ card used here is **6024E**.But the DAQ card does not support direct signal connectivity. So, it requires a connector and a cable for the purpose of interfacing.

DAQ hardware acts as the interface between the computer and the outside world. It primarily functions as a device that digitizes incoming analog signals so that the computer can interpret them. Other data acquisition functionality includes:

1. Analog Input/Output
2· Digital Input/Output
3· Counter/Timers
4· Multifunction - a combination of analog, digital, and counter operations on a single device



National Instruments offers several hardware platforms for data acquisition. The most readily available platform is the desktop computer. National Instruments offers PCI DAQ boards that plug into any desktop computer. In addition, NI makes DAQ modules for PXI/CompactPCI, a more rugged modular computer platform specifically for measurement and automation applications.

4.1.DRIVER SOFTWARE

Software transforms the PC and the DAQ hardware into a complete data acquisition, analysis, and presentation tool. Without software to control or drive the hardware, the DAQ device will not work properly. Driver software is the layer of software for easily communicating with the hardware. It forms the middle layer between the application software and the hardware. Driver software also prevents a programmer from having to do register-level programming or complicated commands in order to access the hardware functions. National Instruments offers two different options:

- NI-DAQmx driver and additional measurement services software
- NI-DAQmx Base driver software

DAQ Assistant, included with NI-DAQmx, is a graphical, interactive guide for configuring, testing, and acquiring measurement data. With a single click, a code can be generated based on a particular configuration, making it easier and faster to develop complex operations. Because DAQ Assistant is completely menu-driven, only fewer programming errors arise.

NI 6024E Pin diagram

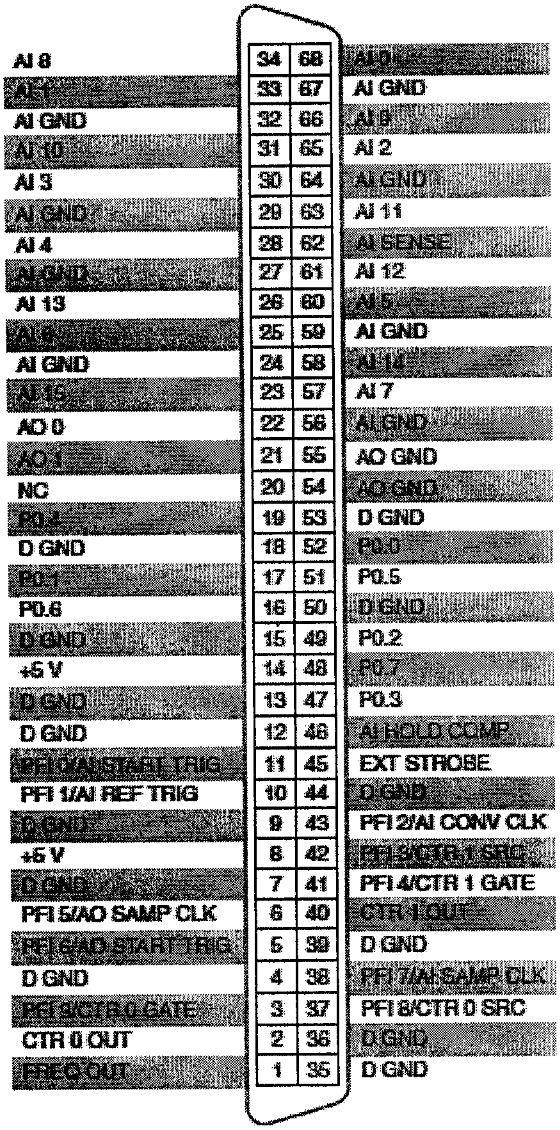


Figure 4.1

4.2. BNC 2120

The BNC-2120 is a desktop or DIN rail-mountable accessory that can be connected directly to E Series devices. The BNC-2120 has the following features:

- Eight BNC connectors for analog input (AI) connection with an optional thermocouple connector, an optional temperature reference, and optional resistor measurement screw terminals
- Two BNC connectors for analog output (AO) connection
- Screw terminals for digital input/output (DIO) connection with state Indicators.
- Screw terminals for TIO connection
- Two user-defined BNC connectors
- A function generator with a frequency-adjustable, TTL-compatible Square wave, and a frequency- and amplitude-adjustable sine wave or triangle wave
- A quadrature encoder

The BNC-2120 has a 68-pin input/output (I/O) connector that connects directly to the DAQ device.

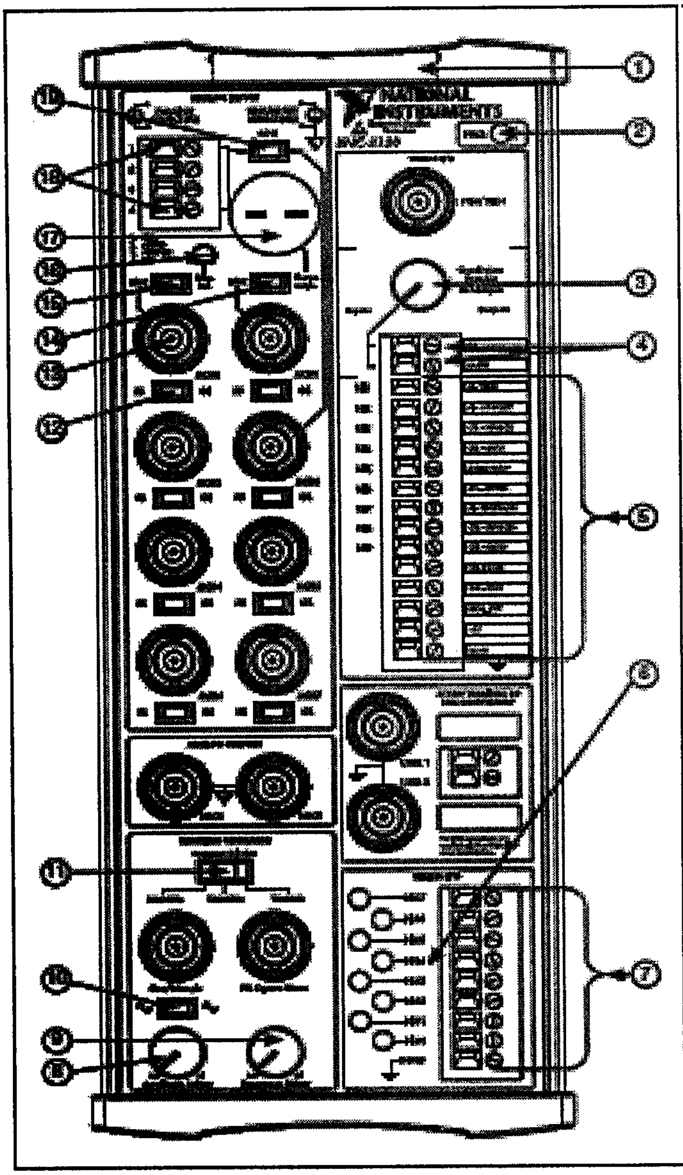
Analog Inputs

BNC-2120 can be used to measure floating and ground-referenced AI signals. BNC-2120 can also be used to measure temperature and resistance.

To measure floating signal sources, switches are moved from ACH0 through ACH7 (located below the BNC connectors) to the floating source switch position labelled FS. In the floating source switch position, the negative terminal of the amplifier connects to ground through a 4.99 kΩ resistor.

To measure ground-referenced signals, switches are pushed to either the ground-referenced source position, labeled GS, is used to avoid ground loops.

FRONT PANEL OF BNC 2120



1. 68-Position I/O Connector
2. Power LED Indicator
3. Quadrature Encoder Knob
4. Quadrature Encoder Output Screw Terminals
5. TIO Screw Terminals
6. DIO LED State Indicators
7. DIO Screw Terminals
8. Function Generator Amplitude Adjust Knob
9. Function Generator Frequency Adjust Knob
10. Sine/Triangle Waveform Selection Switch
11. Frequency Range Selection Switch
12. Floating Source (FS)/ Ground-Referenced Source (GS) Switch
13. BNC Connector
14. BNC/Thermocouple Selection Switch
15. BNC/Temperature Reference Selection Switch
16. Temperature Reference
17. Thermocouple Input Connector
18. Resistor Measurement Screw Terminals
19. Resistor/BNC Selection Switch

Figure 4.2

Thermocouple and IC Temperature Reference

To measure temperature, ACH0 and ACH1 have switches for selecting the BNC connectors, used for connecting floating and ground-referenced AI signals (or the temperature reference and the thermocouple connector). These switches are located just above the BNC connectors for ACH0 and ACH1. The integrated circuit (IC) temperature reference provides cold-junction compensation (CJC) through software. The IC sensor voltage is linearly proportional to the sensor temperature where the sensor is accurate to ±1.5 °C. The thermocouple connector is for connecting any type of thermocouple having a two-prong miniature or sub-miniature male connector.

Resistance Measurement

To measure resistance, ACH3 has a switch for selecting the BNC Connector, used for connecting floating and ground-referenced AI signals,

Or the screw terminals, used for connecting resistors. This switch is located above the thermocouple connector. Resistors can be measured with values ranging from 100 Ω to 1 MΩ. Resistor must be connected into the screw terminals labelled RES+ and RES–.

The VI changes the AI mode of the E Series differential channel 3 to referenced single-ended (RSE). The E Series device measures channel 3 for a VCC measurement and channel 11 for voltage drop across an internal 10 kΩ resistor. Using these measurements, the VI calculates the resistor value as

$$\frac{\mathbf{Vch3 - Vch11}}{\mathbf{(Vch11/10k\Omega)}}$$

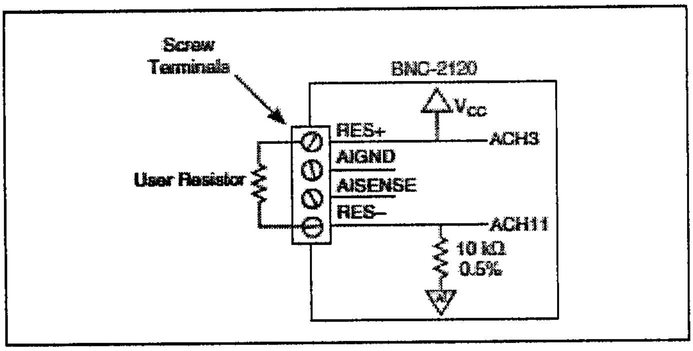


Figure 4.3

Analog Outputs

The BNC-2120 connects to the AO channels of the E Series device with the DAC0OUT and DAC1OUT BNC connectors. AOGND is the reference for these BNC connectors.

Digital I/O

The DIO channels of the E Series device connect to the screw terminals in the DIO section of the BNC-2120. The LEDs next to each screw terminal indicate the state of each digital channel. If the LED is lit, the channel is either pulled high or driven high. If the LED is off, the channel is either low or is driven low. DGND is available at the screw terminals to supply the reference for the DIO signals.

Function Generator

The BNC-2120 has a function generator that produces sine or triangle waveforms and TTL-compatible square waveforms. The Sine/Triangle BNC connector is used to select a sine wave or triangle wave output for the Sine/Triangle BNC connector. A TTL-compatible square wave is always present at the BNC connector labelled TTL Square Wave. To adjust the frequency of the function generator, frequency range is selected using the Frequency Selection switch. 100-10kHz, 1 k-100 kHz, or 13k-within the preselected range for the sine or triangle wave, and the TTL square wave outputs. The Amplitude Adjust knob adjusts the amplitude of the sine or triangle wave output up to 4.4 Vp-p.

Timing I/O

The timing I/O (TIO) signals of the E Series device are connected at the screw terminals in the Timing I/O section of the BNC-2120. The TIO output signal names are categorized and color-coded for specific types of applications.

Quadrature Encoder

The BNC-2120 contains a mechanical quadrature encoder circuit that produces 96 pulses per encoder revolution. Two outputs, CLK and UP/DN, are available at the screw terminals located below the quadrature encoder knob. CLK outputs a pulse train generated by rotating the encoder shaft. It provides four pulses per one mechanical click of the encoder. UP/DN outputs a high or a low signal indicating rotation direction. If the direction is counter clockwise, UP/DN is low. If the direction is clockwise, UP/DN is high.

To use the quadrature encoder with E Series counter 0, CLK is connected to PFI8 and connect UP/DN to DIO6, which is the up/down pin of counter 0. To use it with counter 1, CLK is connected to PFI3 and connect UP/DN to DIO7, which is the up/down pin of counter 1.

4.2.1. SPECIFICATIONS

Analog Input

Number of channels (default)	-	Eight differential
Field connections (default)	-	Eight BNC connectors

Optional inputs

INPUT	DESCRIPTION
ACH0	Temperature sensor
ACH1	Thermocouple
ACH3,ACH11	Resistor measurement

Table 4.1

Resistor measurement range - 100 Ω to 1 MΩ

Resistor measurement error - ≤5%

Analog Output

Field connection - Two BNC connectors

Digital Input/output

Screw terminals - Nine positions

LED state indicator - Eight, one per DIO line

Protection (DC max V)

Powered off - ±5.5 V

Powered on - +10/–5 V

Timing Input/Output

Screw terminals - 14 positions

BNC connector - One, for PFI0/TRIG1

Protection (DC max V)

Powered off - ±1.7 V

Powered on - +6.7/–1.7 V

Quadrature Encoder

Screw terminals - Two

Output signals

CLK - 96 pulses/revolution

UP/DN - High for clockwise rotation, low for counter clockwise rotation

Function Generator

Square wave

Frequency range - 100 Hz to 1 MHz

Frequency adjust - Through Frequency Adjust knob

Rise time - 250 ns

Fall time - 50 ns

Sine/Triangle wave

Frequency range - 100 Hz to 1 MHz

Frequency adjust - Through Frequency Adjust knob

Amplitude range - 60 mVp-p to 4.4 Vp-p

Amplitude adjust - Through Amplitude Adjust knob

Output impedance - 600 Ω

4.3. MEASUREMENT AND AUTOMATION EXPLORER

Measurement & Automation Explorer (MAX) is a tool to manage various NI components. MAX can manage:

1. Interchangeable Virtual Instruments (IVIs)
2. Instrument interface controllers (e.g., GPIB)
3. Instrument connections (VISA, Ethernet, VXI)

Input and output channels in the connector are configured using **"Measurement and Automation Explorer (MAX)".**It is window based application software.

4.3.1. FEATURES OF MAX:

- Configures the NI hardware and software
- Adds new channels and interfaces
- Executes system diagnostics
- Enables scaling of the parameters

POWER SUPPLIES

CHAPTER 5

5. POWER SUPPLIES

Starting with an ac voltage, a steady dc voltage is obtained by rectifying the ac voltage, then filtering to a dc level, and finally, regulating to obtain a desired fixed dc voltage. The regulation is usually obtained from an IC voltage regulator unit, which takes a dc voltage and provides a somewhat lower dc voltage, which remains the same even if the input dc voltage varies, or the output load connected to the dc voltage changes.

A block diagram containing the parts of a typical power supply and the voltage at various points in the unit is shown in fig. The ac voltage, typically 120 V rms, is connected to a transformer, which steps that ac voltage down to the level for the desired dc output. A diode rectifier then provides a full-wave rectified voltage that is initially filtered by a simple capacitor filter to produce a dc voltage. This resulting dc voltage usually has some ripple or ac voltage variation. A regulator circuit can use this dc input to provide a dc voltage that not only has much less ripple voltage but also remains the same dc value even if the input dc voltage varies somewhat, or the load connected to the output dc voltage changes. This voltage regulation is usually obtained using one of a number of popular voltage regulator IC units.

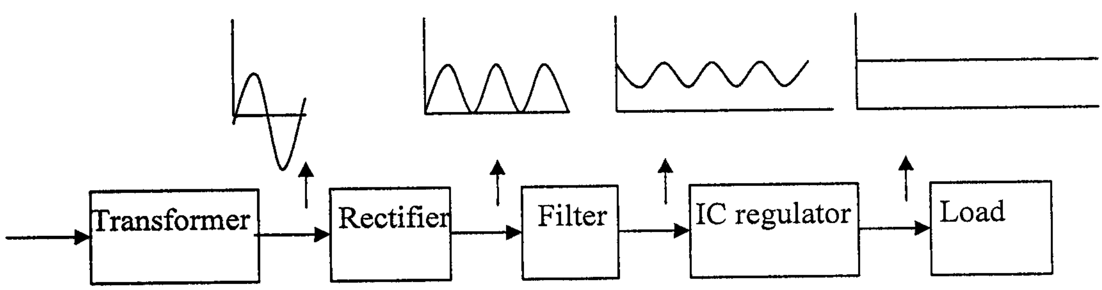


Figure 5.1

5.1. IC VOLTAGE REGULATORS:

Voltage regulators comprise a class of widely used ICs. Regulator IC units contain the circuitry for reference source, comparator amplifier, control device, and overload protection all in a single IC. Although the internal construction of the IC is somewhat different from that described for discrete voltage regulator circuits, the external operation is much the same. IC units provide regulation of either a fixed positive voltage, a fixed negative voltage, or an adjustable set voltage.

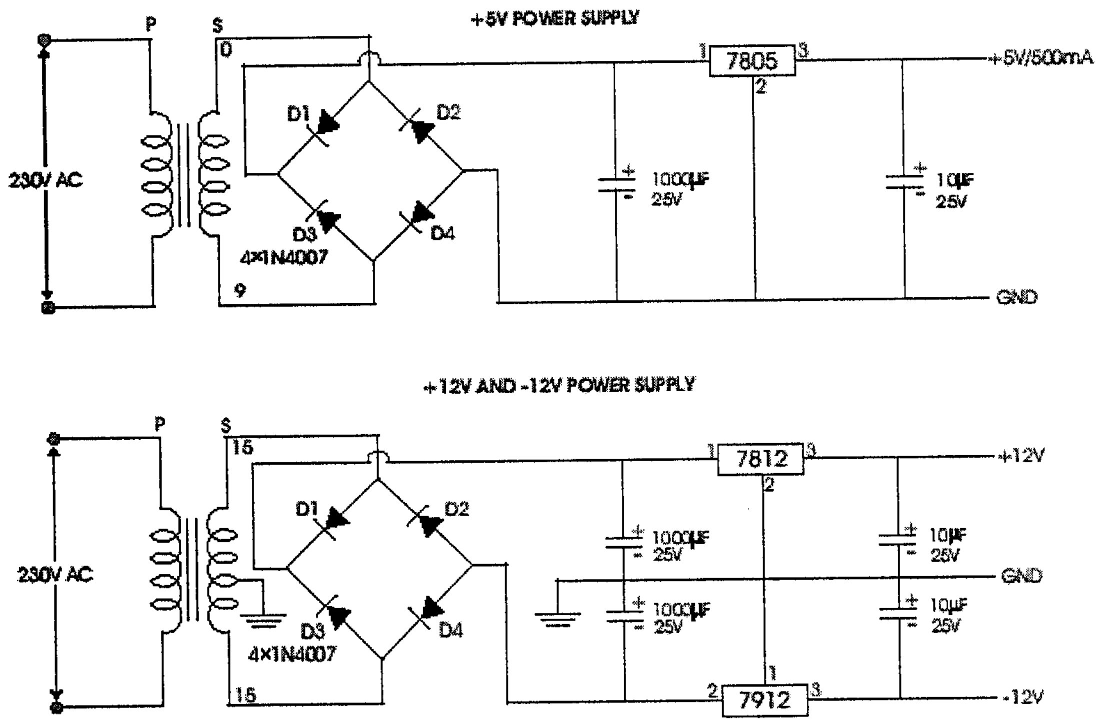


Figure 5.2

A power supply can be built using a transformer connected to the ac supply line to step the ac voltage to desired amplitude, then rectifying that ac voltage, filtering with a capacitor and RC filter, if desired, and finally regulating the dc voltage using an IC regulator. The regulators can be selected for operation with load currents from hundreds of milli amperes to tens of amperes, corresponding to power ratings from milliwatts to tens

SUBSYSTEMS

CHAPTER 6

6. SUBSYSTEMS

This project is classified into 4 subsystems:

- Temperature Subsystem
- Humidity subsystem
- Light intensity subsystem
- Irrigation subsystem

6.1. TEMPERATURE SUBSYSTEM

A **thermistor** is a type of resistor used to measure temperature changes, relying on the change in its resistance with changing temperature. Thermistor is a combination of the words thermal and resistor.

If we assume that the relationship between resistance and temperature is linear (i.e. we make a first-order approximation), then we can say that:

$$\Delta R = k\Delta T$$

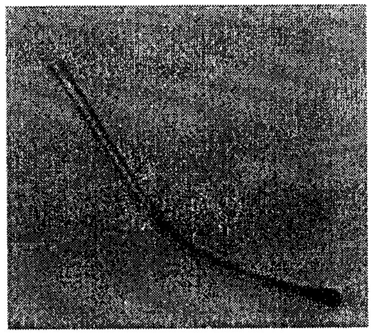
Where

ΔR = change in resistance

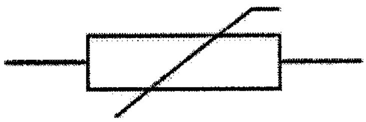
ΔT = change in temperature

k = first-order temperature coefficient of resistance

Thermistors can be classified into two types depending on the sign of k. If k is positive, the resistance increases with increasing temperature, and the device is called a positive temperature coefficient (**PTC**) thermistor, **Posistor**. If k is negative, the resistance decreases with increasing temperature, and the device is called a negative temperature coefficient (**NTC**) thermistor. Resistors that are not thermistors are designed to have the smallest possible k, so that their resistance remains almost constant over a wide temperature range.



Symbol of thermistor:

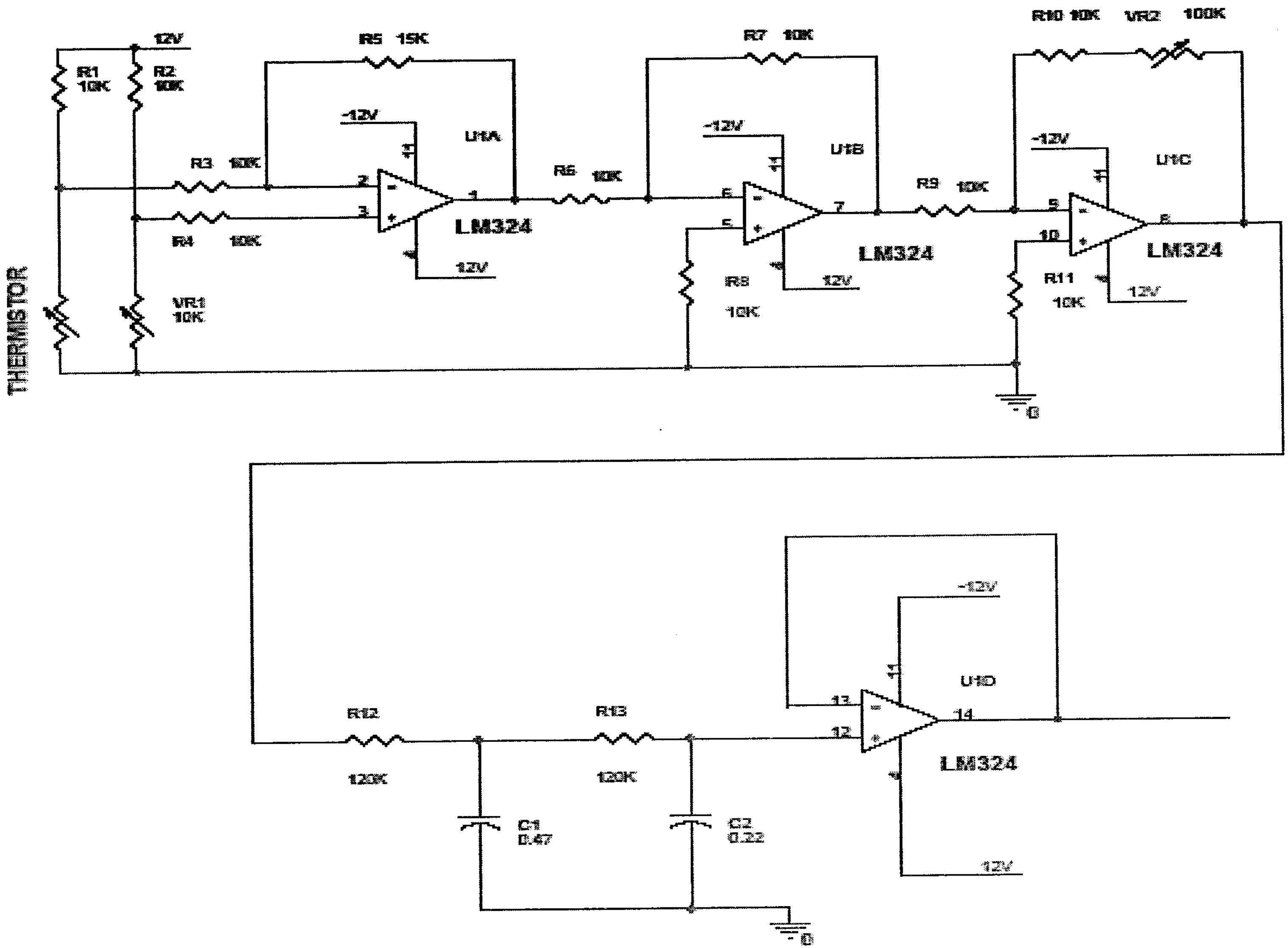


6.1.1. Circuit Description:

In this circuit the thermistor is used to measure the temperature. Thermistor is nothing but temperature sensitive resistor. There are two type of thermistor available such as positive temperature co-efficient and negative temperature co- efficient. Here we are using negative temperature co-efficient in which the resistance value is decreased when the temperature is increased.

Here the thermistor is connected with resister bridge network. The bridge terminals are connected to inverting and non-inverting input terminals of comparator. The comparator is constructed by LM 324 operational amplifier.

The LM 324 consist of four independent, high gains, internally frequency compensated operational amplifier which were designed specifically to operate from a single power supply over a wide voltage range.


THERMISTOR
12V
R1
10K
R2
10K
R3 10K
R4 10K
VR1
10K
R5 15K
-12V
U1A
LM324
12V
R6 10K
R7 10K
U1B
R8
10K
R9 10K
R10 10K
VR2
100K
U1C
R11
10K
0
R12
120K
R13
120K
C1
0.47
C2
0.22
U1D

The first stage is a comparator in which the variable voltage due to thermistor is given to inverting input terminal and reference voltage is given to non-inverting input terminal.

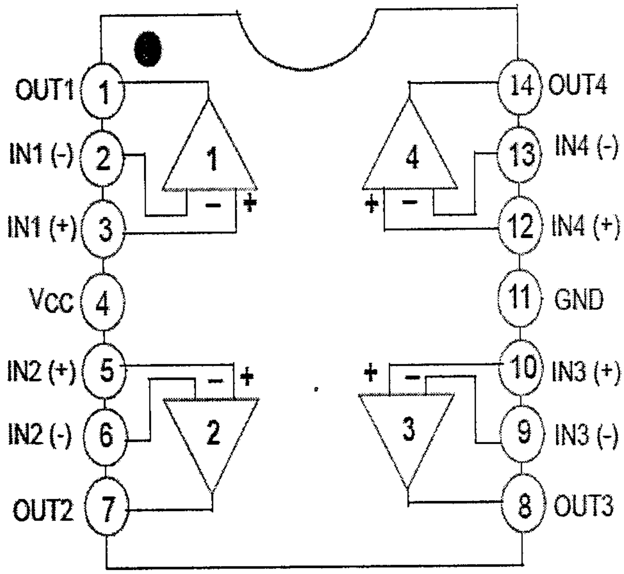
Initially the reference voltage is set to room temperature level so the output of the comparator is zero. When the temperature is increased above the room temperature level, the thermistor resistance is decreased so variable voltage is given to comparator. Now the comparator delivered the error voltage at the output. Then the error voltage is given to next stage of preamplifier. Here the input error voltage is amplified then the amplified voltage is given to next stage of gain amplifier. In this amplifier the variable resistor is connected as feedback resistor. The feedback resistor is adjusted to get desired gain. Then the AC components in the output are filtered with the help of capacitors. Then output voltage is given to final stage of DC voltage follower through this the output voltage is given to ADC or other circuit.

6.1.2. LM 324

Features

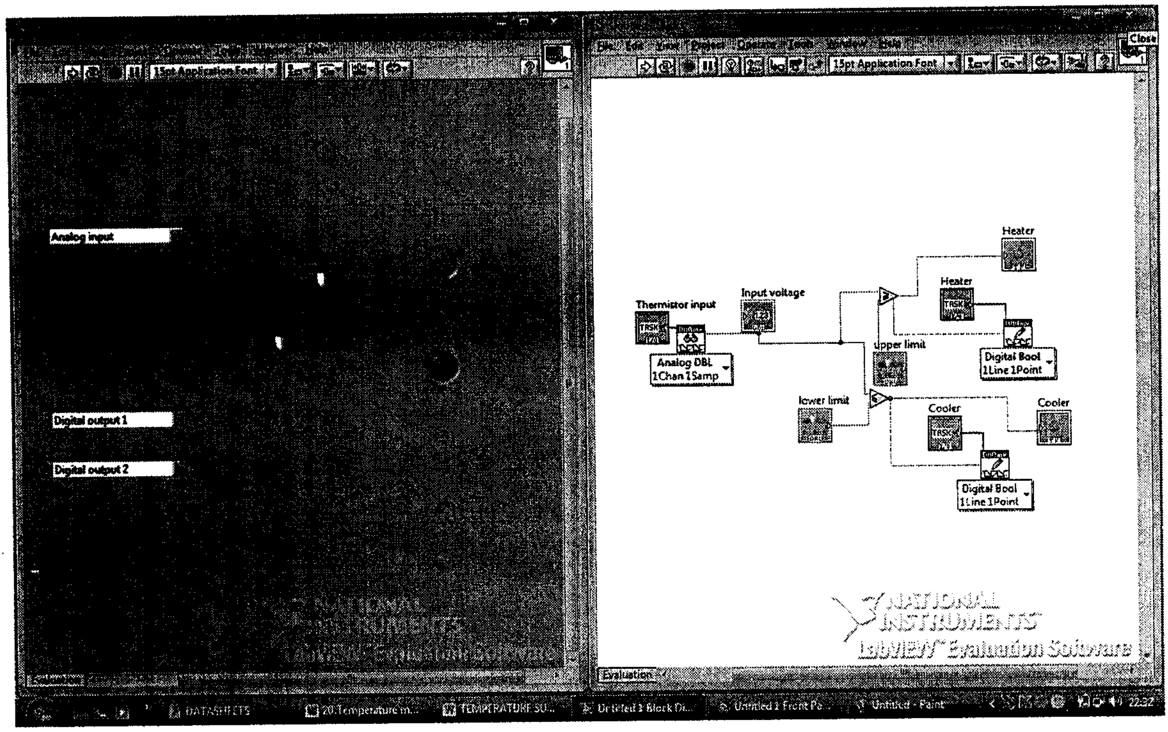
- Internally Frequency Compensated for Unity Gain
- Large DC Voltage Gain: 100dB
- Wide Power Supply Range:
  LM324/LM324A : 3V~32V (or) 1.5 ~15V)
- Input Common Mode Voltage Range Includes Ground
- Large Output Voltage Swing: 0V to VCC -1.5V
- Power Drain Suitable for Battery Operation

Description



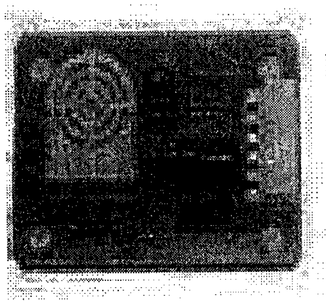
The LM324/LM324A consist of four independent, high gain, internally frequency compensated operational amplifiers which were designed specifically to operate from a single power supply over a wide voltage range. Operation from split power supplies is also possible so long as the difference between the two supplies is 3 volts to 32 volts. Application areas include transducer amplifier, DC gain blocks and all the conventional OP-AMP circuits which now can be easily implemented in single power supply systems.

6.1.3. FRONT PANEL AND BLOCK DIAGRAM OF TEMPERATURE SUBSYSTEM:



6.2. HUMIDITY SUBSYSTEM:

Humidity is the amount of water vapor in an air sample. There are three different ways to measure humidity: absolute humidity, relative humidity, and specific humidity.



Relative humidity is the most frequently encountered measurement of humidity because it is regularly used in weather forecasts. It's an important part of weather reports because it indicates the likelihood of precipitation, dew, or fog. Higher relative humidity also makes it feel hotter outside in the summer because it reduces the effectiveness of sweating to cool the body by preventing the evaporation of perspiration from the skin. This effect is calculated in a heat index table. Warmer air has more thermal energy than cooler air; thus more water molecules can evaporate and stay in the air in a vapour state rather than a liquid state. This may draw out a conclusion that warmer air "holds" more moisture in warmer air, there is more energy for more water molecules to hold themselves in the air (and overcome hydrogen bonds which seek to pull water molecules together). Similarly, humidity level plays an important role in plant growth. Humidity increases the **transpiration** in plants. Optimum humidity level required is 45% RH at 25 deg C room temperature.

HUMIDITY SENSOR SPECIFICATIONS

Type	Relative humidity range	Output voltage range
SYHS220	30 to 90% RH	990mv to 2970mv

Table 6.1

6.2.1. SIGNAL CONDITIONING CIRCUIT:

This circuit is designed to measure the humidity level in the atmosphere air. The humidity sensor is used for the measurement device. The humidity sensor is consists of astable multivibrator in which the capacitance is varied depends on the humidity level.

So the multivibrator produces the varying pulse signal which is converted into corresponding voltage signal.

The voltage signal is given to inverting input terminal of the comparator. The reference voltage is given to non-inverting input terminal. The comparator is designed by the LM 741 operational amplifier.

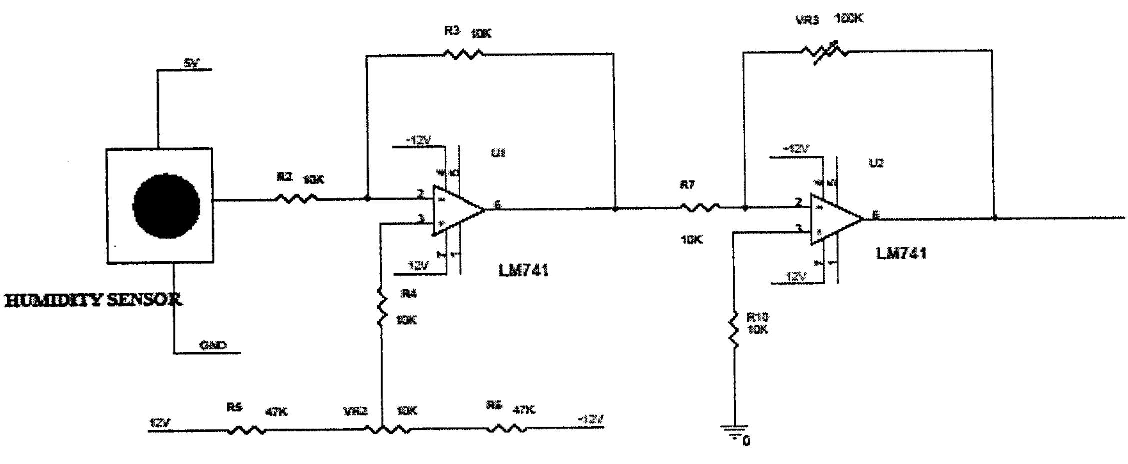


Figure 6.2

The comparator is compared with reference humidity level and delivered the corresponding error voltage at its output which is given to next stage of gain amplifier in which the variable resistor is connected in the

the final voltage is given to microcontroller or other circuit in order to find the humidity level in the atmosphere.

6.2.2. LM741

- Large input voltage range.
- No latch-up.
- High gain.
- Short-circuit protection.
- No frequency compensation required.

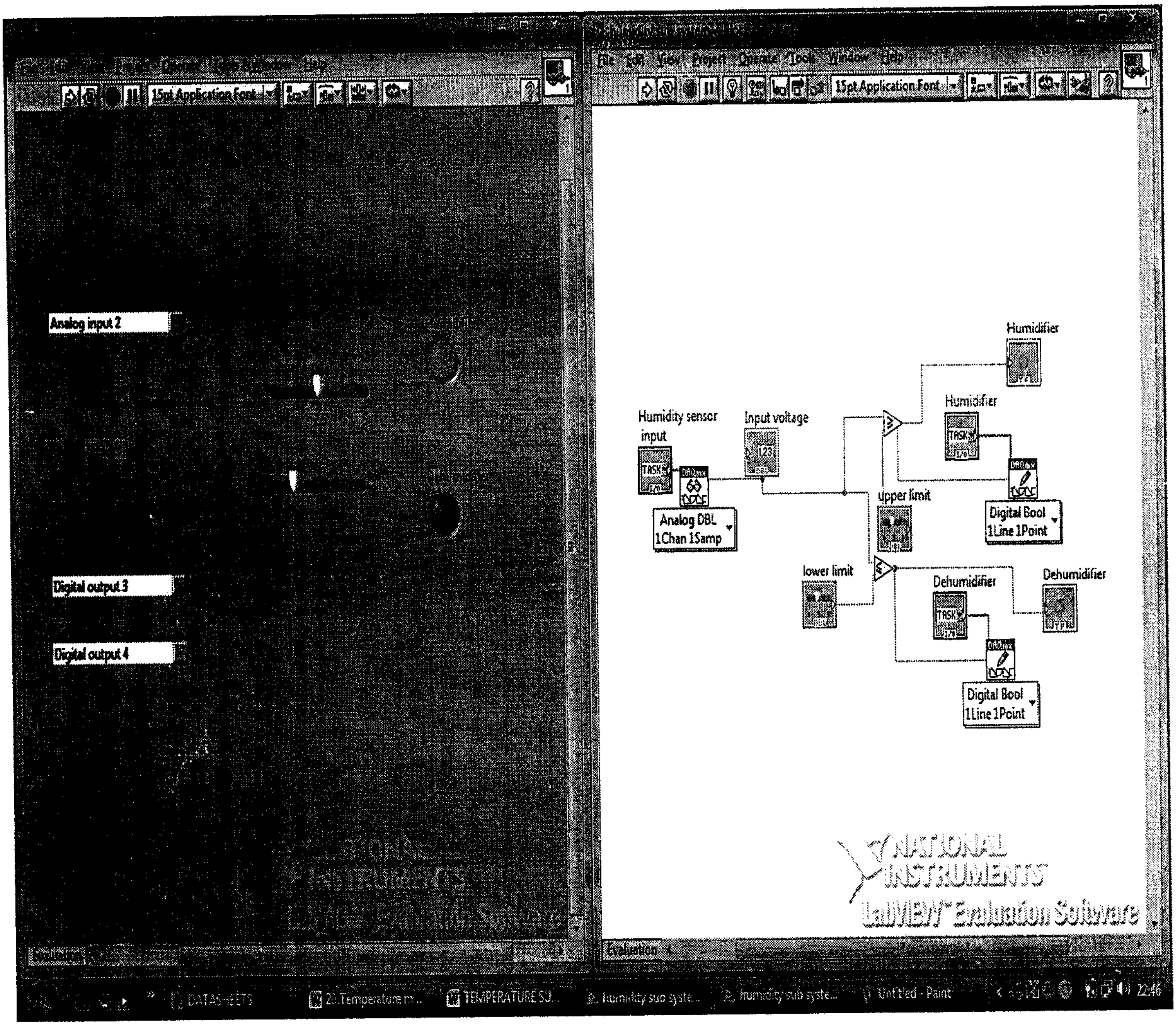
DESCRIPTION

The UA741 is a high performance monolithic operational amplifier constructed on a single silicon chip. It is intended for a wide range of analog applications.

- Summing amplifier
- Voltage follower
- Integrator
- Active filter
- Function generator

The high gain and wide range of operating voltages provide superior performances in integrator, summing amplifier and general feedback applications. The internal compensation network (6dB / octave) ensures stability in closed loop circuits.

6.2.3. FRONT PANEL AND BLOCK DIAGRAM OF HUMIDITY SUBSYSTEM:



6.3. LIGHT INTENSITY SUBSYSTEM:

The predominant factor required in the photosynthesis process is **LIGHT**. Thus the amount of light must be regulated to promote efficient growth of plants. Greenhouse lighting systems allow us to extend the growing season by providing plants with an indoor equivalent to sunlight.

LDR is used to measure the intensity of the light based on the change in resistance. TRIAC control is used to modulate the intensity of the light by varying the gate voltage.

LDR

LDR SPECIFICATIONS

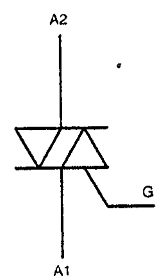
Type	Resistance range	Operating Temperature
PDV-P9203	5K- 20M	-30 to75degC

Table 6.2

6.3.1. TRIAC CONTROL

A TRIAC, or Triode for Alternating Current is an electronic component approximately equivalent to two silicon-controlled rectifiers (SCRs/thyristors) joined in inverse parallel (paralleled but with the polarity reversed) and with their gates connected together. This result in a direction when it is triggered (turned on). It can be triggered by either a positive or a negative voltage being applied to its *gate* electrode. Once triggered, the device continues to conduct until the current through it drops below a certain threshold value, such as at the end of a half-cycle of alternating current (AC) mains power. This makes the TRIAC a very convenient switch for AC circuits, allowing the control of very large power flows with milliampere-scale control currents. In addition, applying a trigger pulse at a controllable point in an AC cycle allows one to control the percentage of current that flows through the TRIAC to the load (so-called phase control).

Symbol of Triac:



Application:

Low power TRIACs are used in many applications such as light dimmers, speed controls for electric fans and other electric motors, and in the modern computerized control circuits of many household small and major appliances. However, when used with inductive loads such as electric fans, care must be taken to assure that the TRIAC will turn off correctly at the end of each half-cycle of the ac power.

Circuit working and description:

This circuit is designed to control the 230V AC load such as heater, motor etc. The 230V AC voltage is step down with help of step down transformer. The step down voltage is rectified by the full wave rectifier.

the transistor Q1. Whenever peak pulse is come the transistor Q1 is conducting and ground voltage is given to Q2 transistor base. Rest of the time 12V is given to base of the Q2 transistor which is connected across the feedback capacitor of U1A saw tooth generator. The saw tooth generator is constructed by LM1458 operational amplifier.

The LM1458 is the general purpose duel operational amplifier with sharing common supply. U1A delivered the saw tooth wave output which is given to non-inverting input terminal of comparator. The comparator is constructed by the U1B. The 12V square wave signal is given to inverting input terminal. The 12V square wave signal is generated by the comparator U5 which is constructed by LM 741 operational amplifier. The U1B comparator compares the input saw tooth wave and square wave signal and outputs the +12V to -12V square pulse. The -12V square pulse is rectified by D3 diode.

The positive 12 square pulse is given to isolation circuit. The isolation is constructed by the MOC3011 Opto coupler. The isolation is used to separate the 230V AC voltage and DC voltages. The opto coupler consists of photo LED and photo transistor. Whenever the 12V signal is given to photo LED the light rays' falls on the photo transistor. Now the photo transistor is conducting and high pulse is given to triac gate. So the triac is conducting and 230V AC voltage is given to load. Depending on the pulse given to triac gate the conduction angel is varied. Then the variable AC voltage is rectified by the full wave rectifier unit. So that DC voltage flowing through load is varied in order to control the load to the desired level.

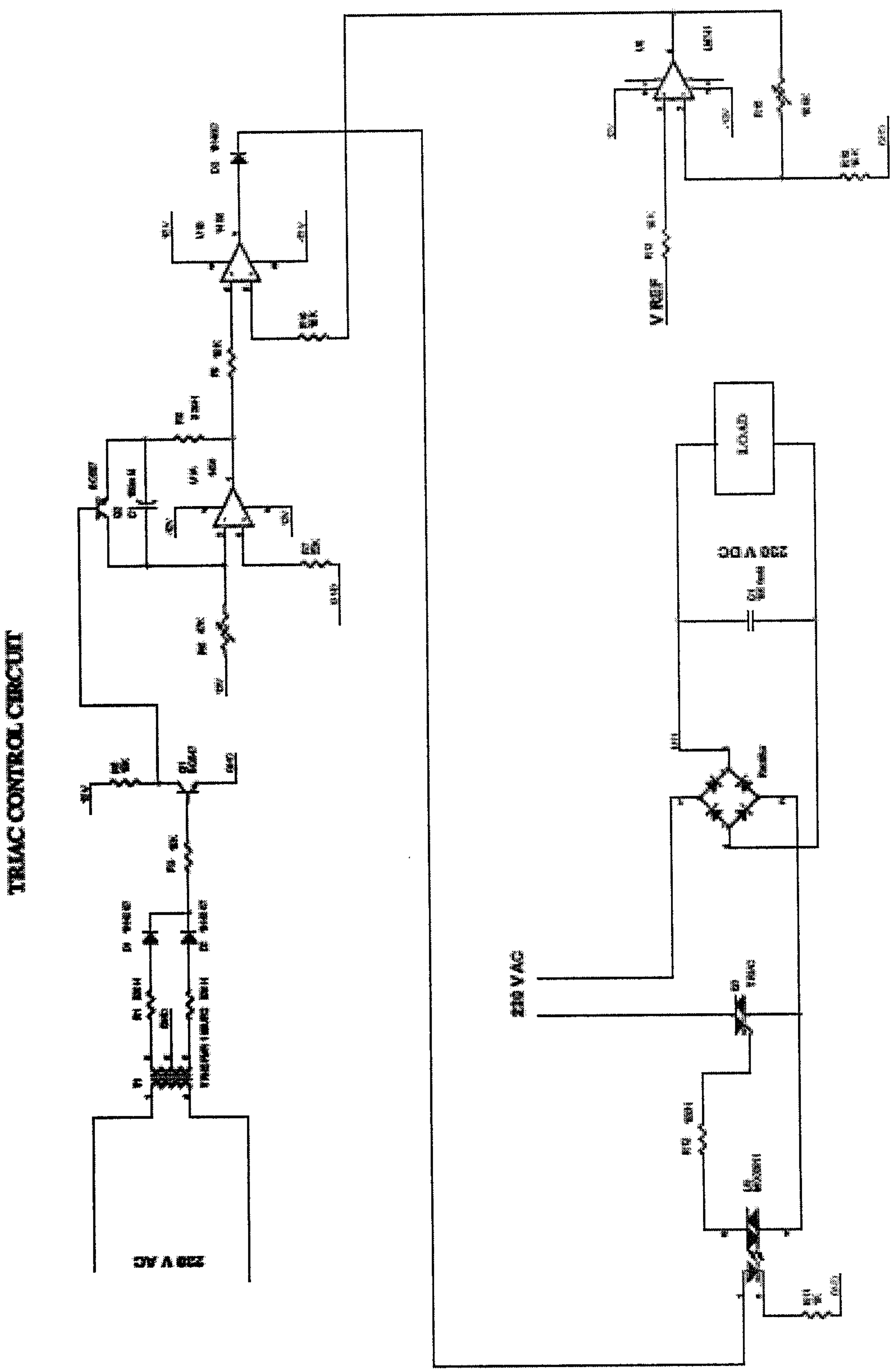


Figure 6.3

6.3.2. REAL TIME INTERFACING

6.3.3. LM 1458

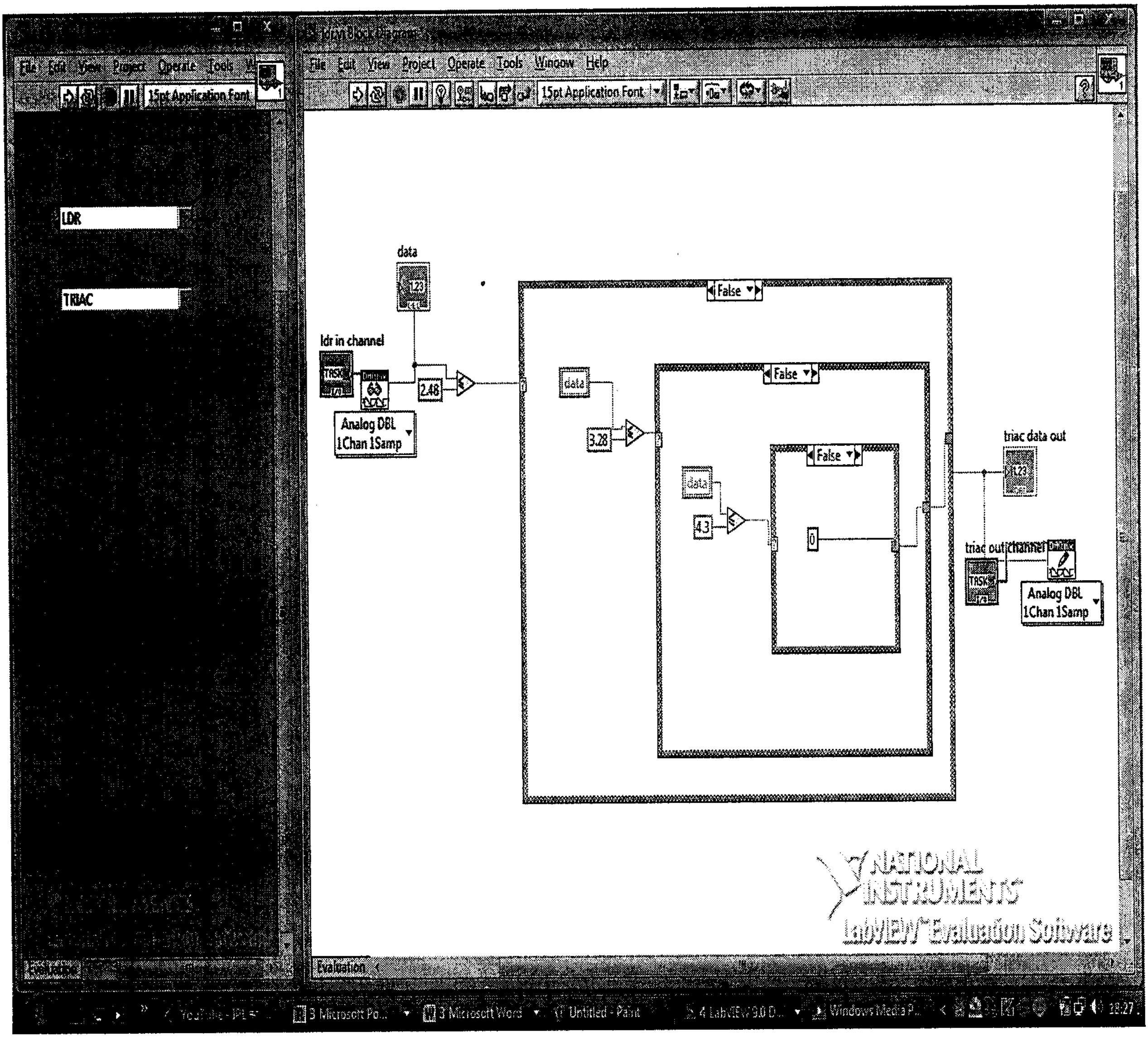
General Description

The LM1458 is a general purpose dual operational amplifier. The two amplifiers share a common bias network and power supply leads. Otherwise, their operation is completely independent. LM1458 has its specifications guaranteed over the temperature range from 0degC to 70degC .

Features

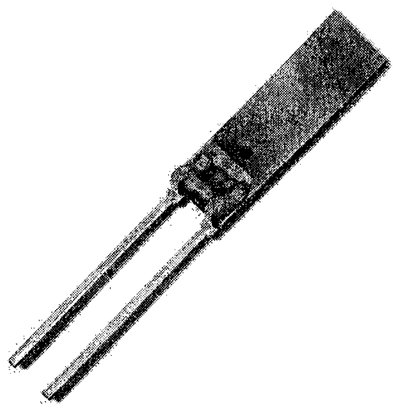
- No frequency compensation required
- Short-circuit protection
- Wide common-mode and differential voltage ranges
- Low-power consumption
- 8-lead can and 8-lead mini DIP
- No latch up when input common mode range is exceeded.

6.3.4. FRONT PANEL AND BLOCK DIAGRAM OF LIGHT INTENSITY SUB SYSTEM



6.4. IRRIGATION SUBSYSTEM:

It refers to the pump control based on soil moisture level. A capacitive soil moisture sensor senses the variation in capacitance due to the change in moisture level. The removal of human error in estimating and adjusting available soil moisture levels enables the farmer to maximize net profits. The sensor used for soil moisture control is **MK33**.



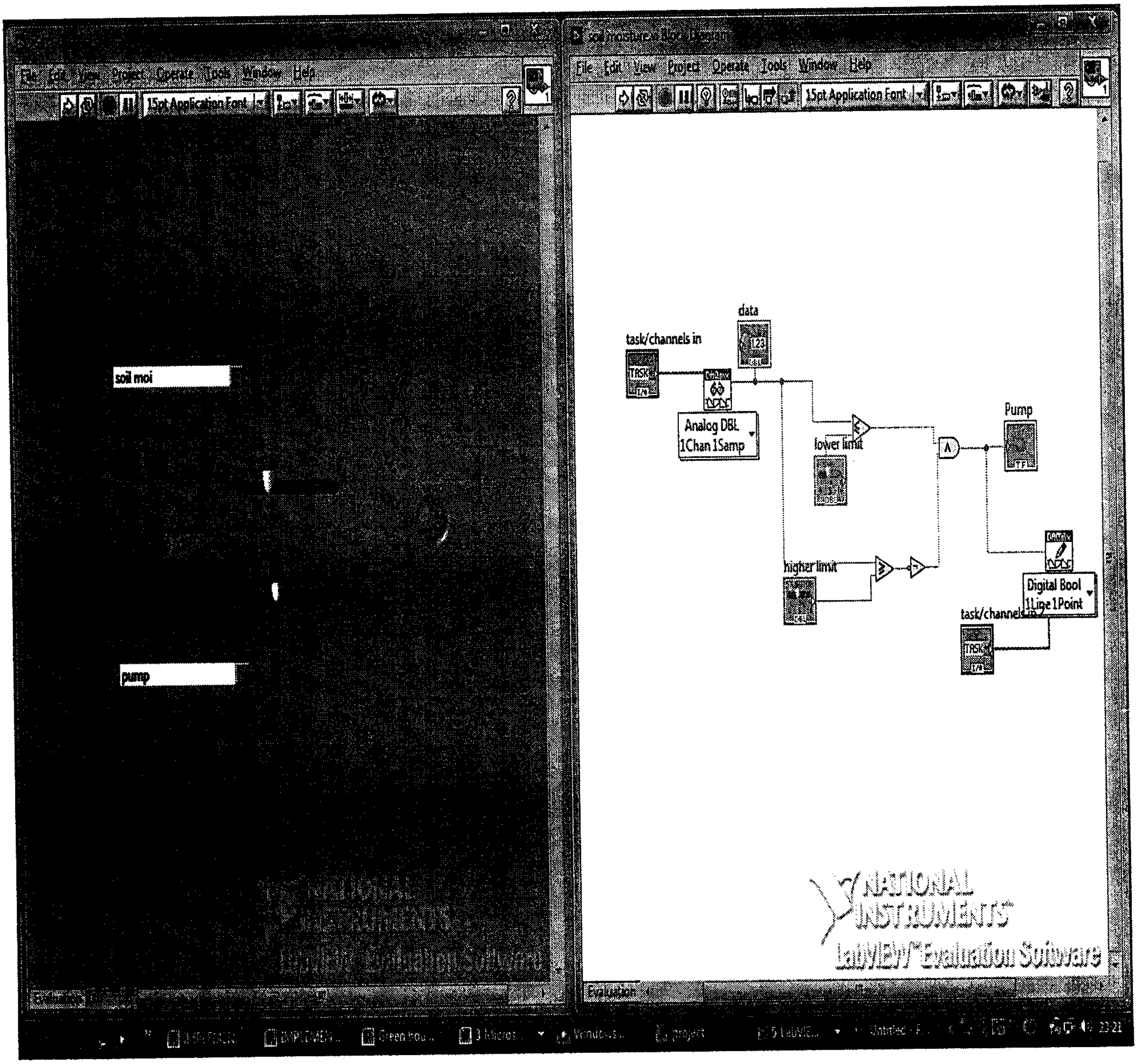
SPECIFICATIONS

Type	Relative Humidity range	Operating Temperature Range
MK33	0 to 100% RH	-40 to 190 deg C

Table 6.3

The signal from sensor is acquired through the analog port. Based on the upper and lower limit values set, the final control element is switched to the corresponding state. The signal to the final control element is sent through the digital write port. The digital signal is given to the relay circuit which switches the state of the final control element. The final

6.4.1. BLOCK DIAGRAM AND FRONT PANEL OF SOIL MOISTURE SUBSYSTEM



6.5. RELAY:

A relay is an electrically operated switch. Current flowing through the coil of the relay creates a magnetic field which attracts a lever and changes the switch contacts. The coil current can be on or off so relays have two switch positions and they are double throw (changeover) switches. Relays allow one circuit to switch a second circuit which can be completely separate from the first. For example a low voltage battery circuit can use a relay to switch a 230V AC mains circuit. There is no electrical connection inside the relay between the two circuits; the link is magnetic and mechanical.

RELAY CIRCUIT - SPST

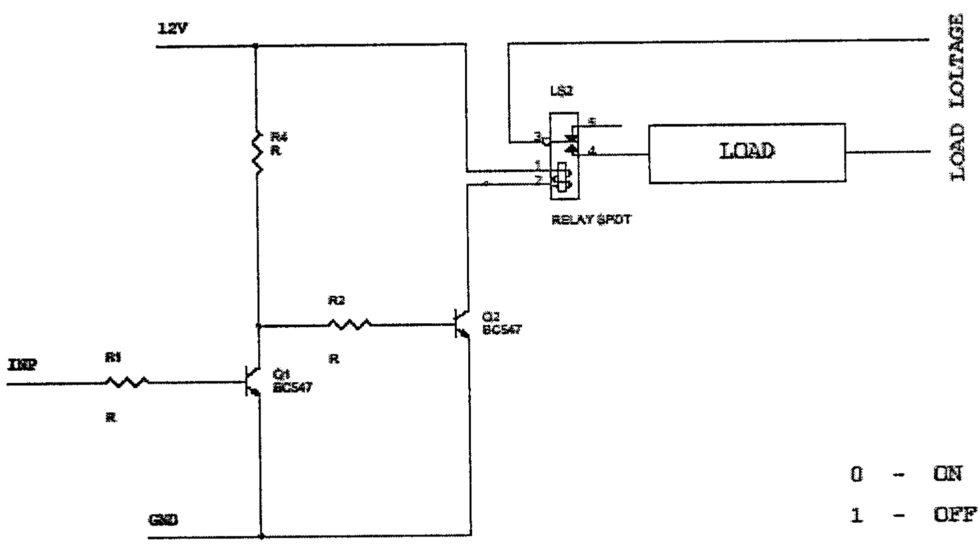
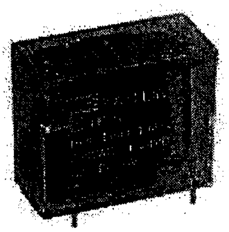
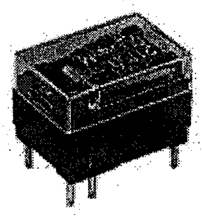


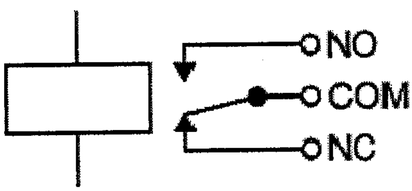
Figure 6.4

The coil of a relay passes a relatively large current, typically 30mA for a 12V relay, but it can be as much as 100mA for relays designed to operate from lower voltages. Most ICs (chips) cannot provide this current and a transistor is usually used to amplify the small IC current to the larger value required for the relay coil. The maximum output current for the popular 555 timer IC is 200mA so these devices can supply relay coils directly without amplification.





Relays are usually SPDT or DPDT but they can have many more sets of switch contacts, for example relays with 4 sets of changeover contacts are readily available. The picture shows a working relay with its coil and switch contacts. A lever on the left is attracted by magnetism when the coil is switched on. This lever moves the switch contacts. There is one set of contacts (SPDT) in the foreground and another behind them, making the relay DPDT.



The relay's switch connections are usually labeled COM, NC and NO:

- **COM** = Common, always connect to this, it is the moving part of the switch.
- **NC** = Normally Closed, COM is connected to this when the relay coil is **off**.
- **NO** = Normally Open, COM is connected to this when the relay coil is **on**.

Circuit description:

This circuit is designed to control the load. The load may be motor or any other load. The load is turned ON and OFF through relay. The relay ON and OFF is controlled by the pair of switching transistors (BC 547). The relay is connected in the Q2 transistor collector terminal. A Relay is nothing but electromagnetic switching device which consists of three pins. They are Common, Normally close (NC) and Normally open (NO).The relay common pin is connected to supply voltage. The normally open (NO) pin connected to load. When high pulse signal is given to base of the Q1 transistors, the transistor is conducting and shorts the collector and emitter terminal and zero signals is given to base of the Q2 transistor. So the relay is turned OFF state.

When low pulse is given to base of transistor Q1 transistor, the transistor is turned OFF. Now 12v is given to base of Q2 transistor so the transistor is conducting and relay is turned ON. Hence the common terminal and NO terminal of relay are shorted. Now load gets the supply voltage through relay.

Voltage signal from PC	**Transistor Q1**	**Transistor Q2**	**Relay**
1	**On**	**Off**	**Off**
0	**Off**	**On**	**On**

Table 6.4

SPECIAL FEATURES

CHAPTER 7

SPECIAL FEATURES

Some of the features that are implemented in this project are:

- **Web publishing**

It allows the user to control the parameters from a remote area.

- **Notification through G-mail**

A report on the various greenhouse parameters is generated, attached and sent to the user.

7.1. WEB PUBLISHING TOOL

- Used for Creating HTML Documents and Embedding VI Front Panel Images

Using this tool, one can embed images of a VI front panel in an existing HTML document. The following are the steps to create an html document and to embed images on it:

1. The VI whose front panel has to be viewed by clients is opened.
2. Tools» Web Publishing Tool is selected to display the Web Publishing Tool dialog box.
3. A VI name is selected in the VI Name field or Browse is selected from the VI Name pull-down menu and is navigated to a VI.

Note The Web Publishing Tool creates an HTML file in the application instance from which the VI is opened..

4. The front panel appearance is configured in the Web browser.

In the Viewing Mode section, a particular mode is chosen –embed mode, snapshot or monitor mode.

The Next button is clicked to display HTML output options. Now, the Document title, Header, and Footer text boxes are entered. In order to preview the document, **Start Web server** is clicked, followed by saving the file. The path to the directory where the HTML file has to be saved is verified8. The Document URL dialog box displays the URL for the Web page if the document is saved in the Web Server root directory.

If the clients who do not have LabVIEW installed have to view and control a front panel remotely, they must install the LabVIEW Run-Time Engine, and then view the front panel remotely. The HTML file created by the Web Publishing Tool can be opened in any HTML editor and can also be customized.

7.2. NOTIFICATION THROUGH GMAIL

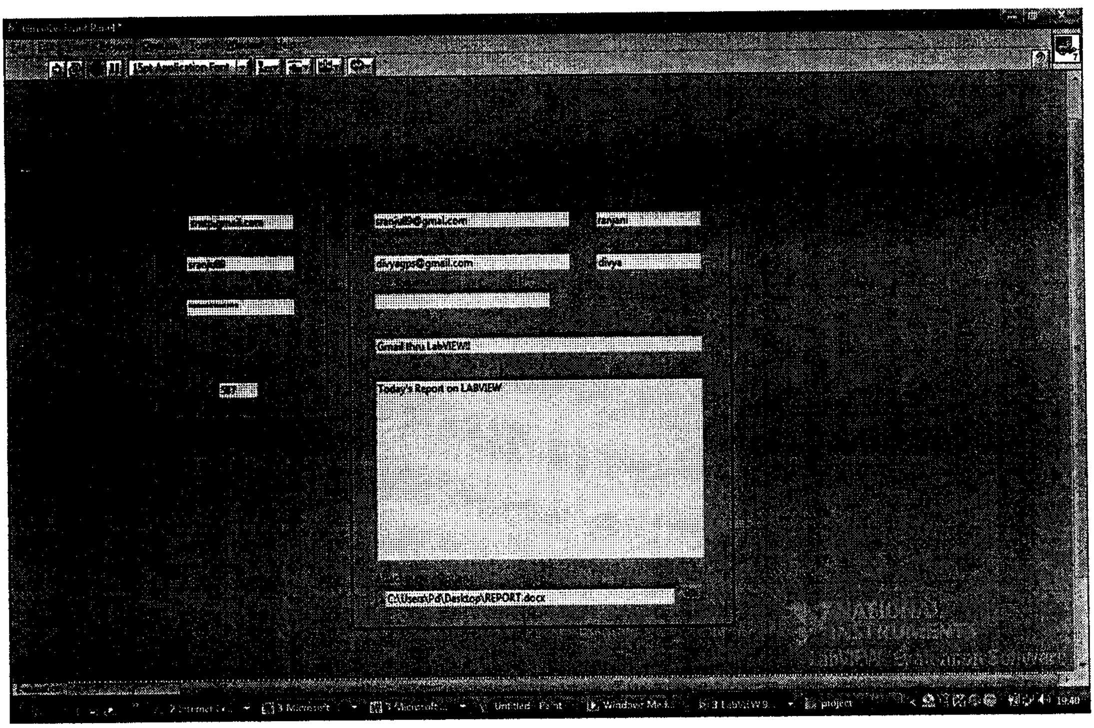
LabVIEW features built-in SMTP functions. In modern times, nearly all email services require authentication. Microsoft's .NET Framework, on the other hand, does support sending SSL and TSL authenticated email (such as that required by GMAIL), which can be accessed using LabVIEW's .NET Constructor Nodes.

7.2.1. SIMPLE MAIL TRANSFER PROTOCOL

SMTP is an internet standard for electronic mail transmission across internet protocol (IP) networks. While electronic mail servers and other mail transfer agents use SMTP to send and receive mail messages, user level client mail applications typically only use SMTP for sending messages to a mail server for relaying. An E-mail client requires the name or the IP address of an SMTP server as a part of its configuration. The server will deliver messages on behalf of the user. End users connected to the internet can use the services of an email provider that is not necessarily the same as their connection provider (ISP). Network topology, or the location of the client within a network or outside a network, is no longer a limiting factor for email delivery. Modern SMTP client's location (IP address), to determine whether it is eligible to relay email. Server administrators choose whether clients use TCP port 25 (SMTP) or port 587 (submission), for relaying outbound mail to a mail server. Some servers are set up to reject all relaying on port 25, but valid users authenticating on port 587 are allowed to relay mail to any valid address.

Secure Sockets Layer (SSL), are cryptographic protocols that provide security for communications over networks such as the Internet. TLS and SSL encrypt the segments of network connections at the Transport Layer end-to-end. This protocol allows client/server applications to communicate across a network in a way designed to prevent eavesdropping and tampering. TLS provides endpoint authentication and communications confidentiality over the Internet using cryptography.

FRONT PANEL OF GMAIL CODING



CONCLUSION

CHAPTER 8

RESULTS AND CONCLUSION

This project work gives an optimized solution by adopting efficient and user friendly techniques to have an optimum control of the parameters like temperature, humidity, soil moisture and light intensity inside the green house environment, thereby ensuring effective climatic control for the nourishment of plants. As LABVIEW is used as controller, it also ensures flexibility and better performance of the greenhouse environment.

FUTURE ENHANCEMENTS

Since the VI design is generic, the same system can be applied to any crop, by just tweaking certain parameter values. The project leaves a significant scope for further research in same and allied fields. The system, if implemented and standardized all over world, will form a unified, efficient and user-friendly way of greenhouse automation.

BIBLIOGRAPHY

BIBLIOGRAPHY

E-REFERENCE

- www.ni.com (National Instruments)
- www.thermometrics.com
- www.libelium.com
- www.sensirion.com

BOOKS

- NI DAQ Measurements manual
- BNC 2120 user guide
- Liptak instrument engineers handbook

JOURNALS

- IEEE Conference on "Development of the Environmental Control Network System in Greenhouse" in Agricultural Information Technology (2004).
- "Optimal Management of Greenhouse Environments" in EFITA 2003 Conference.

APPENDIX

GENERAL PURPOSE SINGLE OPERATIONAL AMPLIFIERS

- LARGE INPUT VOLTAGE RANGE
- NO LATCH-UP
- HIGH GAIN
- SHORT-CIRCUIT PROTECTION
- NO FREQUENCY COMPENSATION REQUIRED
- SAME PIN CONFIGURATION AS THE UA709
- ESD INTERNAL PROTECTION

N
DIP8
(Plastic Package)

D
SO8
(Plastic Micropackage)

DESCRIPTION

The UA741 is a high performance monolithic operational amplifier constructed on a single silicon chip. It is intented for a wide range of analog applications.

- Summing amplifier
- Voltage follower
- Integrator
- Active filter
- Function generator

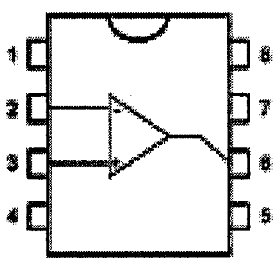
The high gain and wide range of operating voltages provide superior performances in integrator, summing amplifier and general feedback applications. The internal compensation network (6dB / octave) insures stability in closed loop circuits.

ORDER CODES

Part Number	Temperature Range	Package N	Package D
UA741C/E	0°C, +70°C	•	•
UA741I	-40°C, +105°C	•	•
UA741M/A	-55°C, +125°C	•	•

Example : UA741CN

PIN CONNECTIONS (top view)



1 - Offset null 1
2 - Inverting input
3 - Non-inverting input
4 - Vcc⁻
5 - Offset null 2
6 - Output
7 - Vcc⁺
8 - N.C.

ELECTRICAL CHARACTERISTICS

V_{CC} = ±15V, T_{amb} = 25°C (unless otherwise specified)

Symbol	Parameter	Min.	Typ.	Max.	Unit
V_{io}	Input Offset Voltage ($R_s \leq 10k\Omega$) T_{amb} = 25°C $T_{min.} \leq T_{amb} \leq T_{max.}$ UA741E.A T_{amb} = 25°C $T_{min.} \leq T_{amb} \leq T_{max.}$		1 1	5 6 2 4	mV
I_{io}	Input Offset Current T_{amb} = 25°C $T_{min.} \leq T_{amb} \leq T_{max.}$		2	30 70	nA
I_{ib}	Input Bias Current T_{amb} = 25°C $T_{min.} \leq T_{amb} \leq T_{max.}$		10	100 200	nA
A_{vd}	Large Signal Voltage Gain (V_o = ±10V, R_L = 2kΩ) T_{amb} = 25°C $T_{min.} \leq T_{amb} \leq T_{max.}$	50 25	200		V/mV
SVR	Supply Voltage Rejection Ratio ($R_s \leq 10k\Omega$) T_{amb} = 25°C $T_{min.} \leq T_{amb} \leq T_{max.}$	77 77	90		dB
I_{CC}	Supply Current, no load T_{amb} = 25°C $T_{min.} \leq T_{amb} \leq T_{max.}$		1	2.8 3.3	mA
V_{icm}	Input Common Mode Voltage Range T_{amb} = 25°C $T_{min.} \leq T_{amb} \leq T_{max.}$	±12 ±12			V
CMR	Common Mode Rejection Ratio ($R_s \leq 10k\Omega$) T_{amb} = 25°C $T_{min.} \leq T_{amb} \leq T_{max.}$	70 70	90		dB
I_{os}	Output Short-circuit Current	10	35		mA
$\pm V_{OPP}$	Output Voltage Swing T_{amb} = 25°C R_L = 10kΩ R_L = 2kΩ $T_{min.} \leq T_{amb} \leq T_{max}$ R_L = 10kΩ R_L = 2kΩ	12 10 12 10	14 13		V
SR	Slew Rate (V_i = ±10V, R_L = 2kΩ, C_L = 100pF, T_{amb} = 25°C, unity gain)	0.25	0.5		V/μs
t_r	Rise Time (V_i = ±20mV, R_L = 2kΩ, C_L = 100pF, T_{amb} = 25°C, unity gain)		0.3		μs
K_{ov}	Overshoot (V_i = ±20mV, R_L = 2kΩ, C_L = 100pF, T_{amb} = 25°C, unity gain)		5		%
R_i	Input Resistance	0.3	2		MΩ
GBP	Gain Bandwidth Product (V_i = 10mV, R_L = 2kΩ, C_L = 100pF, f = 100kHz)	0.7	1		MHz
THD	Total Harmonic Distortion (f = 1kHz, A_V = 20dB, R_L = 2kΩ, V_o = 2V_{PP}, C_L = 100pF, T_{amb} = 25°C)		0.06		%
e_n	Equivalent Input Noise Voltage (f = 1kHz, R_s = 100Ω)		23		$\frac{nV}{\sqrt{Hz}}$
Øm	Phase Margin		70		Degrees

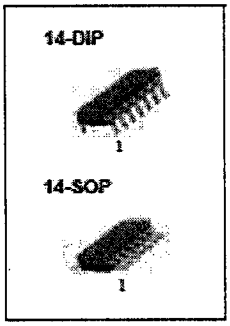
Quad Operational Amplifier

Features

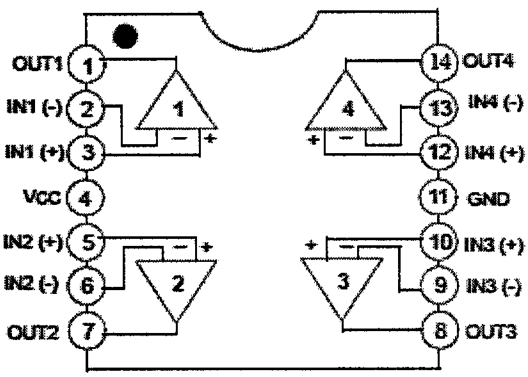
- Internally Frequency Compensated for Unity Gain
- Large DC Voltage Gain: 100dB
- Wide Power Supply Range:
  LM224/LM224A, LM324/LM324A : 3V~32V (or ±1.5 ~ 15V)
  LM2902: 3V~26V (or ±1.5V ~ 13V)
- Input Common Mode Voltage Range Includes Ground
- Large Output Voltage Swing: 0V to V_{CC} -1.5V
- Power Drain Suitable for Battery Operation

Description

The LM324/LM324A,LM2902,LM224/LM224A consist of four independent, high gain, internally frequency compensated operational amplifiers which were designed specifically to operate from a single power supply over a wide voltage range. Operation from split power supplies is also possible so long as the difference between the two supplies is 3 volts to 32 volts. Application areas include transducer amplifier, DC gain blocks and all the conventional OP-AMP circuits which now can be easily implemented in single power supply systems.



Internal Block Diagram



Electrical Characteristics

(V_{CC} = 5.0V, V_{EE} = GND, T_A = 25 °C, unless otherwise specified)

Parameter	Symbol	Conditions	LM224			LM324			LM2902			Unit
			Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	
Input Offset Voltage	V_{IO}	V_{CM} = 0V to V_{CC} -1.5V, $V_{O(P)}$ = 1.4V, R_S = 0Ω	-	1.5	5.0	-	1.5	7.0	-	1.5	7.0	mV
Input Offset Current	I_{IO}	-	-	2.0	30	-	3.0	50	-	3.0	50	nA
Input Bias Current	I_{BIAS}	-	-	40	150	-	40	250	-	40	250	nA
Common-Mode Input Voltage Range	$V_{I(R)}$	Note1	0	-	V_{CC} -1.5	0	V_{CC} -1.5	-	0	-	V_{CC} -1.5	V
Supply Current	I_{CC}	R_L = ∞, V_{CC} = 30V (all Amps)	-	1.0	3	-	1.0	3	-	1.0	3	mA
		R_L = ∞, V_{CC} = 5V (all Amps) (V_{CC} = 26V for LM2902)	-	0.7	1.2	-	0.7	1.2	-	0.7	1.2	mA
Large Signal Voltage Gain	G_V	V_{CC} = 15V, R_L≥2KΩ, $V_{O(P)}$ = 1V to 11V	50	100	-	25	100	-	-	100	-	V/mV
Output Voltage Swing	$V_{O(H)}$	Note1, R_L = 2KΩ	26	-	-	26	-	-	22	-	-	V
		Note1, R_L = 10KΩ	27	28	-	27	28	-	23	24	-	V
	$V_{O(L)}$	V_{CC} = 5V, R_L≥10KΩ	-	5	20	-	5	20	-	5	100	mV
Common-Mode Rejection Ratio	CMRR	-	70	85	-	65	75	-	50	75	-	dB
Power Supply Rejection Ratio	PSRR	-	65	100	-	65	100	-	50	100	-	dB
Channel Separation	CS	f = 1KHz to 20KHz	-	120	-	-	120	-	-	120	-	dB
Short Circuit to GND	I_{SC}	-	-	40	60	-	40	60	-	40	60	mA
Output Current	I_{SOURCE}	$V_{I(+)}$ = 1V, $V_{I(-)}$ = 0V, V_{CC} = 15V, $V_{O(P)}$ = 2V	20	40	-	20	40	-	20	40	-	mA
	I_{SINK}	$V_{I(+)}$ = 0V, $V_{I(-)}$ = 1V, V_{CC} = 15V, $V_{O(P)}$ = 2V	10	13	-	10	13	-	10	13	-	mA
		$V_{I(+)}$ = 0V, $V_{I(-)}$ = 1V, V_{CC} = 15V, $V_{O(R)}$ = 200mV	12	45	-	12	45	-	-	-	-	μA
Differential Input Voltage	$V_{I(DIFF)}$	-	-	-	V_{CC}	-	-	V_{CC}	-	-	V_{CC}	V

Electrical Characteristics (Continued)

(V_{CC} = 5.0V, V_{EE} = GND, unless otherwise specified)
The following specification apply over the range of -25°C ≤ T_A ≤ + 85°C for the LM224; and the 0°C ≤ T_A ≤ +70°C for the LM324 ; and the - 40°C ≤ T_A ≤ +85°C for the LM2902

Parameter	Symbol	Conditions	LM224			LM324			LM2902			Unit
			Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	
Input Offset Voltage	V_{IO}	V_{ICM} = 0V to V_{CC} -1.5V $V_{O(P)}$ = 1.4V, R_S = 0Ω	-	-	7.0	-	-	9.0	-	-	10.0	mV
Input Offset Voltage Drift	$\Delta V_{IO}/\Delta T$	-	-	7.0	-	-	7.0	-	-	7.0	-	µV/°C
Input Offset Current	I_{IO}	-	-	-	100	-	-	150	-	-	200	nA
Input Offset Current Drift	$\Delta I_{IO}/\Delta T$	-	-	10	-	-	10	-	-	10	-	pA/°C
Input Bias Current	I_{BIAS}	-	-	-	300	-	-	500	-	-	500	nA
Common-Mode Input Voltage Range	$V_{I(R)}$	Note1	0	-	V_{CC} -2.0	0	-	V_{CC} -2.0	0	-	V_{CC} -2.0	V
Large Signal Voltage Gain	G_V	V_{CC} = 15V, R_L ≥ 2.0KΩ $V_{O(P)}$ = 1V to 11V	25	-	-	15	-	-	15	-	-	V/mV
Output Voltage Swing	$V_{O(H)}$	Note1, R_L = 2KΩ	26	-	-	26	-	-	22	-	-	V
		Note1, R_L = 10KΩ	27	28	-	27	28	-	23	24	-	V
	$V_{O(L)}$	V_{CC} = 5V, R_L≥10KΩ		5	20	-	5	20	-	5	100	mV
Output Current	I_{SOURCE}	$V_{I(+)}$ = 1V, $V_{I(-)}$ = 0V V_{CC} = 15V, $V_{O(P)}$ = 2V	10	20	-	10	20	-	10	20	-	mA
	I_{SINK}	$V_{I(+)}$ = 0V, $V_{I(-)}$ = 1V V_{CC} = 15V, $V_{O(P)}$ = 2V	10	13	-	5	8	-	5	8	-	mA
Differential Input Voltage	$V_{I(DIFF)}$	-	-	-	V_{CC}	-	-	V_{CC}	-	-	V_{CC}	V

Electrical Characteristics (Continued)

(V_{CC} = 5.0V, V_{EE} = GND, T_A = 25°C, unless otherwise specified)

Parameter	Symbol	Conditions		LM224A			LM324A			Unit
				Min.	Typ.	Max.	Min.	Typ.	Max.	
Input Offset Voltage	V_{IO}	V_{CM} = 0V to V_{CC} -1.5V $V_{O(P)}$ = 1.4V, R_S = 0 Ω		-	1.0	3.0	-	1.5	3.0	mV
Input Offset Current	I_{IO}	-		-	2	15	-	3.0	30	nA
Input Bias Current	I_{BIAS}	-		-	40	80	-	40	100	nA
Input Common-Mode Voltage Range	$V_{I(R)}$	V_{CC} = 30V		0	-	V_{CC} -1.5	0	-	V_{CC} -1.5	V
Supply Current (All Amps)	I_{CC}	V_{CC} = 30V		-	1.5	3	-	1.5	3	mA
		V_{CC} = 5V		-	0.7	1.2	-	0.7	1.2	mA
Large Signal Voltage Gain	G_V	V_{CC} = 15V, $R_L \geq$ 2 KΩ $V_{O(P)}$ = 1V to 11V		50	100	-	25	100	-	V/mV
Output Voltage Swing	$V_{O(H)}$	Note1	R_L = 2 KΩ	26	-	-	26	-	-	V
			R_L = 10 KΩ	27	28	-	27	28	-	V
	$V_{O(L)}$	V_{CC} = 5V, $R_L \geq$ 10 KΩ		-	5	20	-	5	20	mV
Common-Mode Rejection Ratio	CMRR	-		70	85	-	65	85	-	dB
Power Supply Rejection Ratio	PSRR	-		65	100	-	65	100	-	dB
Channel Separation	CS	f = 1KHz to 20KHz		-	120	-	-	120	-	dB
Short Circuit to GND	I_{SC}	-		-	40	60	-	40	60	mA
Output Current	I_{SOURCE}	$V_{I(+)}$ = 1V, $V_{I(-)}$ = 0V V_{CC} = 15V		20	40	-	20	40	-	mA
	I_{SINK}	$V_{I(+)}$ = 0V, $V_{I(-)}$ = 1V V_{CC} = 15V, $V_{O(P)}$ = 2V		10	20	-	10	20	-	mA
		$V_{I(+)}$ = 0v, $V_{I(-)}$ = 1V V_{CC} = 15V, $V_{O(P)}$ = 200mV		12	50	-	12	50	-	µA
Differential Input Voltage	$V_{I(DIFF)}$	-		-	-	V_{CC}	-	-	V_{CC}	V

Electrical Characteristics (Continued)

(V_{CC} = 5.0V, V_{EE} = GND, unless otherwise specified)
The following specification apply over the range of -25°C ≤ T_A ≤ + 85°C for the LM224A; and the 0°C ≤ T_A ≤ +70°C for the LM324A

Parameter	Symbol	Conditions		LM224A Min.	LM224A Typ.	LM224A Max.	LM324A Min.	LM324A Typ.	LM324A Max.	Unit
Input Offset Voltage	V_{IO}	V_{CM} = 0V to V_{CC} -1.5V, $V_{O(P)}$ = 1.4V, R_S = 0Ω		-	-	4.0	-	-	5.0	mV
Input Offset Voltage Drift	$\Delta V_{IO}/\Delta T$	-		-	7.0	20	-	7.0	30	µV/°C
Input Offset Current	I_{IO}	-		-	-	30	-	-	75	nA
Input Offset Current Drift	$\Delta I_{IO}/\Delta T$	-		-	10	200	-	10	300	pA/°C
Input Bias Current	I_{BIAS}	-		-	40	100	-	40	200	nA
Common-Mode Input Voltage Range	$V_{I(R)}$	V_{CC} = 30V		0	-	V_{CC} -2.0	0	-	V_{CC} -2.0	V
Large Signal Voltage Gain	G_V	V_{CC} = 15V, R_L≥ 2.0KΩ		25	-	-	15	-	-	V/mV
Output Voltage Swing	$V_{O(H)}$	V_{CC} = 30V	R_L = 2KΩ	26	-	-	26	-	-	V
			R_L = 10KΩ	27	28	-	27	28	-	
	$V_{O(L)}$	V_{CC} = 5V, R_L≥ 10KΩ		-	5	20	-	5	20	mA
Output Current	I_{SOURCE}	$V_{I(+)}$ = 1V, $V_{I(-)}$ = 0V, V_{CC} = 15V		10	20	-	10	20	-	mA
	I_{SINK}	$V_{I(+)}$ = 0V, $V_{I(-)}$ = 1V, V_{CC} = 15V		5	8	-	5	8	-	mA
Differential Input Voltage	$V_{I(DIFF)}$	-		-	-	V_{CC}	-	-	V_{CC}	V

LM1558/LM1458 Dual Operational Amplifier

General Description

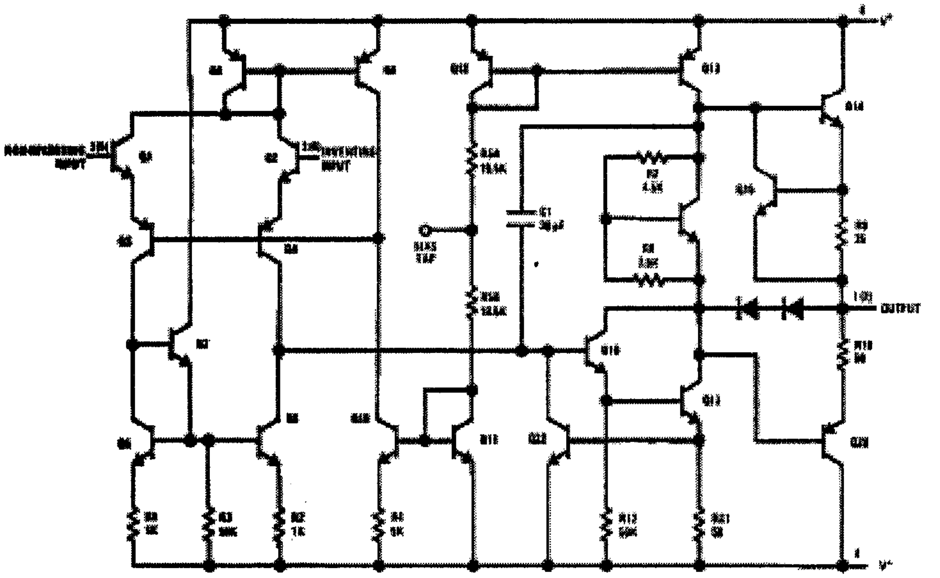
The LM1558 and the LM1458 are general purpose dual operational amplifiers. The two amplifiers share a common bias network and power supply leads. Otherwise, their operation is completely independent.

The LM1458 is identical to the LM1558 except that the LM1458 has its specifications guaranteed over the temperature range from 0°C to +70°C instead of −55°C to +125°C.

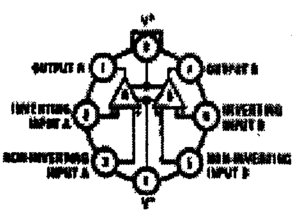
Features

- No frequency compensation required
- Short-circuit protection
- Wide common-mode and differential voltage ranges
- Low-power consumption
- 8-lead can and 8-lead mini DIP
- No latch up when input common mode range is exceeded

Schematic and Connection Diagrams



Metal Can Package

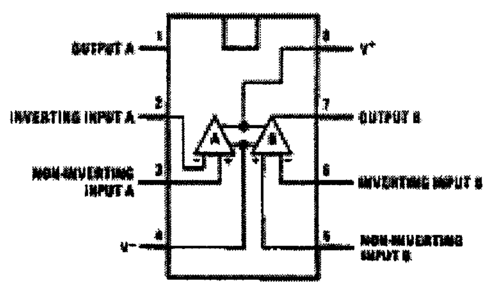


Top View

Order Number LM1558H, LM1558H/883 or LM1458H

See NS Package Number H08C

Dual-In-Line Package



Top View

Order Number LM1558J, LM1558J/883, LM1458J, LM1458M or LM1458N

See NS Package Number J08A, M08A or N08E

Electrical Characteristics (Note 3)

Parameter	Conditions	LM1558			LM1458			Units
		Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage	$T_A = 25°C$, $R_S \le 10 k\Omega$		1.0	5.0		1.0	6.0	mV
Input Offset Current	$T_A = 25°C$		80	200		80	200	nA
Input Bias Current	$T_A = 25°C$		200	500		200	500	nA
Input Resistance	$T_A = 25°C$	0.3	1.0		0.3	1.0		MΩ
Supply Current Both Amplifiers	$T_A = 25°C$, $V_S = \pm 15V$		3.0	5.0		3.0	5.6	mA
Large Signal Voltage Gain	$T_A = 25°C$, $V_S = \pm 15V$ $V_{OUT} = \pm 10V$, $R_L \ge 2 k\Omega$	50	160		20	160		V/mV
Input Offset Voltage	$R_S \le 10 k\Omega$			6.0			7.5	mV
Input Offset Current				500			300	nA
Input Bias Current				1.5			0.8	μA
Large Signal Voltage Gain	$V_S = \pm 15V$, $V_{OUT} = \pm 10V$ $R_L \ge k\Omega$	25			15			V/mV
Output Voltage Swing	$V_S = \pm 15V$, $R_L = 10 k\Omega$	±12	±14		±12	±14		V
	$R_L = 2 k\Omega$	±10	±13		±10	±13		V
Input Voltage Range	$V_S = \pm 15V$	±12			±12			V
Common Mode Rejection Ratio	$R_S \le 10 k\Omega$	70	90		70	90		dB
Supply Voltage Rejection Ratio	$R_S \le 10 k\Omega$	77	96		77	96		dB

MOC3010 MOC3011 MOC3012

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
INPUT LED					
Reverse Leakage Current (V_R = 3 V)	I_R	—	0.05	100	μA
Forward Voltage (I_F = 10 mA)	V_F	—	1.15	1.5	Volts
OUTPUT DETECTOR (I_F = 0 unless otherwise noted)					
Peak Blocking Current, Either Direction (Rated V_{DRM}(1))	I_{DRM}	—	10	100	nA
Peak On–State Voltage, Either Direction (I_{TM} = 100 mA Peak)	V_{TM}	—	1.8	3	Volts
Critical Rate of Rise of Off–State Voltage (Figure 7, Note 2)	dv/dt	—	10	—	V/μs
COUPLED					
LED Trigger Current, Current Required to Latch Output (Main Terminal Voltage = 3 V(3))	I_{FT}				mA
MOC3010		—	8	15	
MOC3011		—	5	10	
MOC3012		—	3	5	
Holding Current, Either Direction	I_H	—	100	—	μA

1. Test voltage must be applied within dv/dt rating.
2. This is static dv/dt. See Figure 7 for test circuit. Commutating dv/dt is a function of the load–driving thyristor(s) only.
3. All devices are guaranteed to trigger at an I_F value less than or equal to max I_{FT}. Therefore, recommended operating I_F lies between max I_{FT} (15 mA for MOC3010, 10 mA for MOC3011, 5 mA for MOC3012) and absolute max I_F (60 mA).

TYPICAL ELECTRICAL CHARACTERISTICS
T_A = 25°C

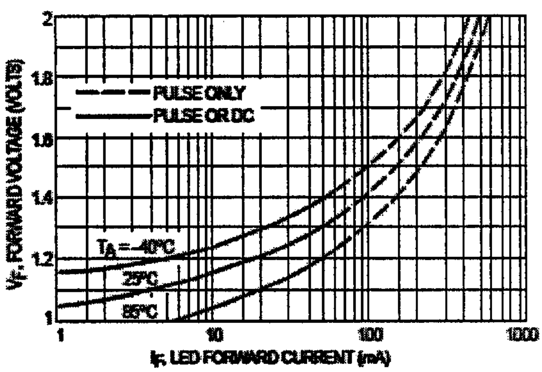


Figure 1. LED Forward Voltage versus Forward Current

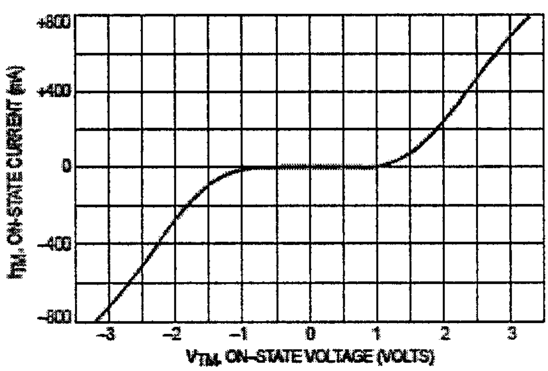


Figure 2. On–State Characteristics

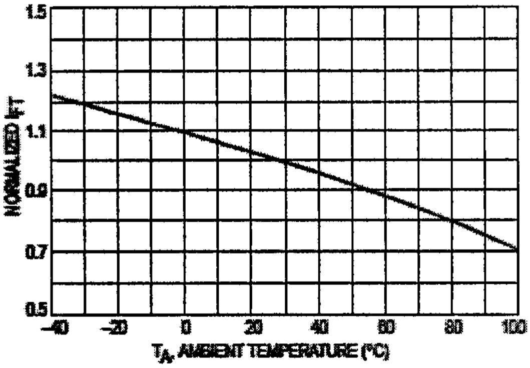


Figure 3. Trigger Current versus Temperature

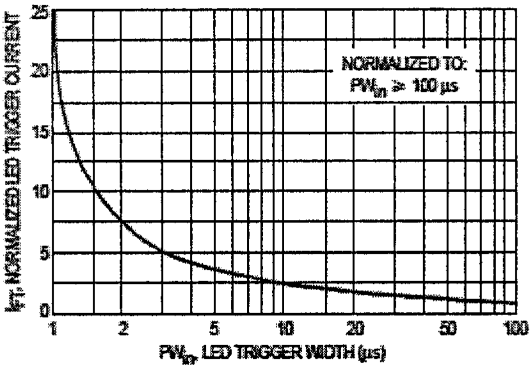


Figure 4. LED Current Required to Trigger versus LED Pulse Width

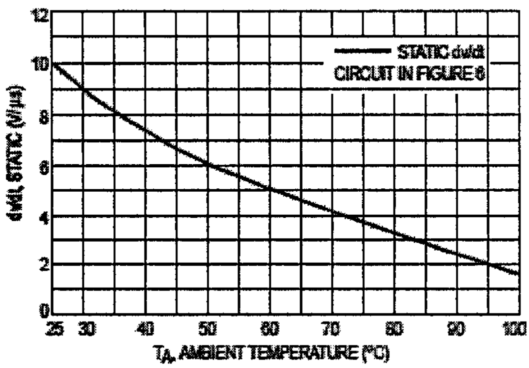
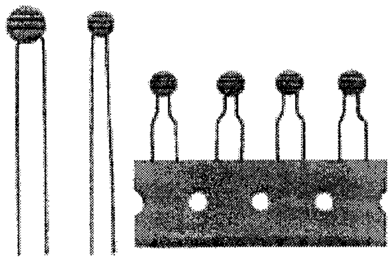


Figure 5. dv/dt versus Temperature

Disc Type NTC Thermistors

Type: **ERTD**



Disc type negative temperaturecoefficient thermistors. Resistance values from 8 Ω to 150 kΩ and B Values are from 3000 K to5000 K.

Features

- Wide selection of temperature coefficients
- Excellent electrical and thermal stability

Recommended Applications

- Temperature detection
- Temperature compensation for measuring instruments
- Temperature compensation for deflection coil in TV

Explanation of Part Numbers

1	2	3	4	5	6	7	8	9	10	11	12
E	R	T	D								

Product Code	
ERT	NTC Thermistors

Shape	
D	Disc Type

Disc Dim	
2	ϕ6.0 mm
3	ϕ7.5 mm

Lead Style	
F	Straight Lead
Z	"Z" Crimped Lead

Center B Value (K)	
E	2501–3000
F	3001–3500
G	3501–4000
H	4001–4500
I	4501–5000

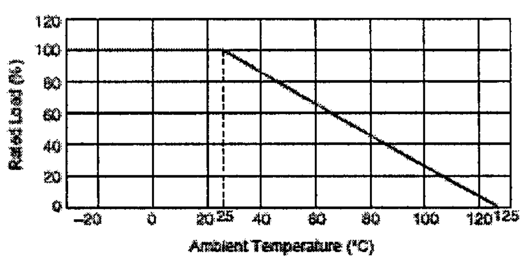
Resistance Tolerance	
J	± 5 %
K	±10 %
L	±15 %

Resistance R_{25} (Ω)
The first two digits are significant figures of resistance and the third one denotes number of zeros following them. Decimal point is expressed by R as 1,4 =1R4.

Option	
S	Standard
T	Taping Type

Derating Curve for the NTC Thermistor

For the NTC Thermistor operated in ambient temperature above 25 °C, power rating should be derated in accordance with the right figure.



■ Ratings and Characteristics

Part No.	Zero-Power Resistance at 25 °C(Ω)	B Value** (K)	Maximum Permissible Power(W)	Heat Dissipation Constant (mW/°C)	Thermal Time Constant (s)	Resistance Ratio R_{25}/R_{50}
ERTD2FE□*200S	20	3000	0.4	4.5	20	2.18
ERTD2FF□*400S	40	3200				2.30
ERTD2FG□*750S	75	3700				2.62
ERTD2FF□*101S	100	3500				2.48
ERTD2FG□*101S	100	3700				2.62
ERTD2FG□*171S	170	3700				2.62
ERTD2FF□*251S	250	3500				2.48
ERTD2FG□*251S	250	3900				2.76
ERTD2FG□*301S	300	3900				2.76
ERTD2FF□*351S	350	3500				2.48
ERTD2FG□*601S	600	4000				2.83
ERTD2FG□*801S	800	3900				2.76
ERTD2FG□*102S	1000	3700				2.61
ERTD2FG□*142S	1400	3900				2.76
ERTD2FG□*202S	2000	4000				2.83
ERTD2FG□*332S	3300	4000				2.83
ERTD2FH□*462S	4600	4100				2.90
ERTD2FH□*802S	8000	4100				2.90
ERTD2FH□*103S	10000	4100				2.90
ERTD2FH□*153S	15000	4200				2.98
ERTD2FH□*333S	33000	4500				3.22
ERTD2FH□*503S	50000	4500				3.22
ERTD2FI□*154S	150000	4800				3.48
ERTD3FE□*8R0S	8	3000	0.6	7.0	27	2.18
ERTD3FF□*130S	13	3200				2.30
ERTD3FF□*160S	16	3200				2.30
ERTD3FF□*200S	20	3200				2.30
ERTD3FF□*300S	30	3200				2.30
ERTD3FF□*400S	40	3200				2.30
ERTD3FG□*750S	75	3700				2.62
ERTD3FG□*800S	80	3700				2.62
ERTD3FG□*131S	130	3700				2.62
ERTD3FG□*501S	500	4000				2.83
ERTD3FH□*402S	4000	4100				2.90
ERTD3FH□*203S	20000	4500				3.22
ERTD3FI□*803S	80000	5000				3.70

*Resistance Tolerance Code

J	K	L
±5 %	±10 %	±15 %

**Tolerance of "B value": ±10 %

$$B=\frac{\ln(R_{25}/R_{50})}{1/298.15-1/323.15}$$

R_{25}=Resistance at 25.0 °C

R_{50}=Resistance at 50.0 °C

● Operating Temperature Range: −30 to +125 °C