Sudan University of Science and Technology

College of graduates study

School of Electronic Engineering

REAL TIME APPROACH RADAR IMAGE TRACKING

تعقب صورة رادار التقرب فى الزمن الحقيقى

Submitted in partial fulfillment of the requirement of M.Sc

Degree in Computer Engineering

SUBMITTED BY:

Mohamed yahia Mohamedai Ahamed

SUPERVISED BY:

Dr. *Abdlrasool Jabbar*

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بسم الله الرحمن الرحيم

الآيـة

"فَتَعَالَى اللَّهُ الْمَلِكُ الْحَقُّ ۗ وَلَا تَعْجَلْ بِالْقُرْآنِ مِن قَبْلِ أَن يُقْضَىٰ إِلَيْكَ وَحْيُهُ ۖ وَقُل رَّبِّ زِدْنِي عِلْمًا"

صدق الله العظيم

سورة طه ـ الآية (114)

Dedication

To …

MY family

To …

MY friends

I dedicate this RESEARCH

,,,,

Acknowledgement

All thanks to Allah Almighty who gave me the strength, Determination and health to successfully complete of this research.

I would like to thank **Dr. Abdlrasool Jabbar** for all his very valuable thoughts, ideas, suggestions and notices which obviously reveal the way to achieve the thesis objectives.

Special thanks to Eng.**Mohand Zagali** and Eng.**Mohamed Kamal** for their support and guidance.

Abstract

This project presents application of share approach radar image between air traffic controller and airport manger or any person responsible for decision making in the field of aviation.

The aim of this project is to provide decision makers in civil aviation real time information about the status of traffic around the airport by the sharing approach radar image.

The design consists of plan position indicator (PPI) represented by two potentiometers as source of parameters, microcontroller (atmega32) used to get radar parameters(azimuth, range) , two x-bee module for wireless transmission, max232 for serial communication and computer Work station which form and display the image of radar.

Simulation and experimental were have been successfully applied and which gave the desired result with accurate position of detected targets displayed on computer through GUI.

تجريد

يقدم هذا المشروع تطبيق لمشاركة صور رادار التقرب بالمطار بين مراقب الحركة الجوية ومدير المطار أو أي شخص أخر مسؤول عن اتخاذ القرارات في مجال الطيران .

ويهدف هذا المشروع لتزويد متخذي القرار في مجال الطيران المدني بمعلومات في الوقت الحقيقي عن حالة المرور في جميع أنحاء المطار عن طريق مشاركة صور رادار التقرب. يحتوى النظام على وحدة عرض صورة الرادار (PPI) ويمثل بمقاومتين متغيرتين كمصدر لمعاملات الرادار، متحكم دقيق (ATMEGA32) و يستخدم للحصول على المعاملات (السمت و المدى) من وحدة العرض، وحدتى ارسال لاسلكية (x-bee) لنقل المعاملات، MAX 232 للاتصال التسلسلي مع الكمبيوتر حيث يُرسم ويُعرض صورة الرادار.

وقد طبقت بنجاح نظام المحاكاة التجريبية واعطت النتيجة المرجوة بعرض الاهداف المكتشفة بصورة دقيقة على جهاز الكمبيوتر من خلال واجهة المستخدم الرسومية.

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Abbreviations

Acronym	Stand for
ADC	Analog to Digital Converter
AREF	Analog Reference
ALU	Arithmetic Logic Unit
ATC	Air traffic control
Bascom	Basic Compiler
Bps	Bit per second
CISC	Complex Instruction Set Computer
CMOS	Complementary Metal Oxide Semiconductor
CONFIG	Configure
CPU	Central Processing Unit
DCE	Data Communication Equipment
DIN	Data Input
DOUT	Data Output
DTE	Data Terminal Equipment
EEPROM	Electrical Erasable Programmable Read Only Memory
EIA	Electronic Industries Association
FFD	Full Function Device
GHz	Gaga Hertz
GND	Ground
GUI	Graphical user interface

I/O	Input/output
IEEE	Institute of Electric and Electronic engineering
Kbps	Kilo bit per second
LCD	Liquid crystal display
m	meter
ms	millisecond
MAC	Medium Access Control
MHz	Mega Hertz
MIPS	Mega Instruction per Second
MCU	Microcontroller
nm	nautical mile
PC	Personal Computer
Pot	potentiometer
PPI	Plan Position Indicator
RADAR	RAdio Detection And Ranging
RF	Radio frequency
RFD	The Reduced Function Device
RISC	Reduced Instruction Set Computer
RPM	Revolutions per minute
RX	Receiver
S	Second
SRAM	Static Random Access Memory
TR	Transmitter

TTL   Transistor-Transistor Logic

USART   Universal synchronous Asynchronous Receiver/Transmitter

WSN   Wireless Network

Chapter One

(Introduction)

Introduction

1.1 Background

Air traffic control radar is the tool that Air traffic control (ATC) uses to obtain real-time, independent surveillance of all flying craft operating in a given volume of airspace. Furthermore, ATC radar also provides ATC with real-time knowledge of specific types of severe and/or hazardous aviation weather (hail, wind shear, etc.) occurring within a given volume of airspace such that ATC can vector aircraft around these events to maintain aviation safety.

There are two general types of airspace: controlled and uncontrolled. Controlled airspace is everything within a given radius of specific airports, specific air routes, and any area that ATC provides service to. ATC services in controlled airspace provide horizontal and vertical separation of aircraft.

ATC radar is used by controllers to maintain real-time knowledge of the airspace and issue appropriate clearances to pilots for coordinating safe and efficient use of controlled airspace [1].

Radar provides the air traffic controller with an accurate, trustworthy on-screen plan view of the aircraft position in real-time. The required separation between aircrafts for safe operation can be greatly reduced compared to procedural separation.

Knowledge of the position of aircraft is essential to an Air Traffic Controller in the provision of most air traffic services [2].

1.2 Problem statement:

In case a big problem happened in the movement of air navigation, an air traffic controller open communication line with airport manager to express the situation and that will not be enough to give him a real evaluation of situation.

1.3 Objectives:

The main purpose of this research is to design a real time approach radar image tracking system. Wireless and Computerized techniques suggest objective and more accurate results and easy manner. Hence, this study aims to give support to civil aviation authority in decision making.

To achieve this objective:-

- Design of system based microcontroller for wireless radar parameters.

- Simulate of the design circuit.

- Implementation of a prototype system will be done.

- Performance evaluation for the system will be run.

1.4 Methodology:

This system used microcontroller (ATMEGA 32) to get continuously the value of radar parameters (range, azimuth) from radar system. After reading parameters MCU display reading values on LCD and the wireless technique (zigbee) system is connected for signal transfer. When parameters received in the other side, firstly goes to Max232 interface to

convert TTL voltages to serial port levels, then a computer get these parameters and use them to specify the target location and display it on the background of radar image through Graphic User Interface (GUI) on computer monitor.

1.5 Research Layout:

This research contains of six chapters as follows:

Chapter one is an introduction, Chapter two deals of Literature review which covered main area of the research including History of the Air Traffic Control System (ATC) and Aviation Radar System.

The Electronic circuit design, explain in details the full connection of the system and how does it work was explained in chapter three. Chapter four deals of Software for the circuit. The results and discussion were illustrated in chapter five, finally conclusions and recommendations presented in chapter six.

Chapter Two

(Literature Review)

2.1 Related Work:

Development of air traffic control decision support tools necessarily requires an Iterative design process to ensure that the tool is effectively integrated into the complex and demanding operational environment [3]. Computer software figures prominently in the present ATC system and will have an even more significant role in the future as the need for new capabilities expands. Many systems related to the safety of flight will be more dependent on computer Programs than is now the case [5]. New tools and capabilities will be added to Air Traffic Control (ATC) displays. Computer displays have become one of the major sources for air traffic controllers to acquire information and control traffic [4, 6].

Several works have been done in the area of radar displaying and tracking among them:

First study undertaken during April 2007 at INTIA Research Institute – INCA Group – Exact Sciences Faculty of the UNCPBA: This work develops a system to visualize the information for radar systems interfaces. It is a flexible, portable software system that allows to be used for radars that have different technologies and that is able to be adapted to the specific needs of each application domain in an efficient way. Replacing the visualization and processing units on existing radar platforms by this new system, a practical and inexpensive improvement is achieved [16].

Another study undertaken at University of Louisiana at Lafayette: This system shows how we can have a control on the minimum range detected

by a software tool (LABVIEW) by simply moving a button instead of having a complicated circuitry for that. Also a display system implemented fully with the same software that can be transformed into FPGA is shown too as a step towards having radar system fully implemented on a chip. The use of software gives the flexibility in design as it can be applied to any radar without the need to change any parameter in the display system at all [17].

This project is intended to provide decision makers in civil aviation with real time information about the status of traffic around the airport by the sharing approach radar image.

2.2 History of the Air Traffic Control System

First attempts to provide a semblance of air traffic control were based on simple "rules of the road" resulting from the European sponsored International Convention for Air Navigation (1919). The United States formulated its first regulations relating to air traffic following the passage of the Air Commerce Act of 1926. With the expansion of commercial aviation in the Thirties, airlines began to press for coordination and tracking of flights beyond airports – along entire air routes. By 1930, radio equipped airport traffic control towers were being established by some local (municipal) authorities. In 1933 instrument flying commenced, and by 1935 several airlines jointly established the first Airway Traffic Control centers to safeguard their aircraft against midair collisions. In 1936 this preliminary effort was transferred to the Federal Government, and the first-generation Air Traffic Control (ATC) System was born. This generation pioneered the development of ATC procedures, rules and regulations, the establishment of a nationwide ATC

system for both civil and military air traffic, and certain new equipment and facilities. more and more technical applications were introduced as standard ATC equipment , like the communication boxes , the headsets, the teletype , the radio locators and the paper flight progress strip boards.

The advent of radar in the early 1950's marked the inauguration of the second-generation system, which carried on, expanded, and improved the accomplishments of the first generation, and brought into operational use radar and direct center/pilot communication capability. In the early 1960's the third generation came into being with the introduction of automation. The familiar features of today's ATC system were all in place: tall control towers astride airports, professional air traffic controllers focused intently on screens with moving "blips" that show planes in flight, pilots talking in jargon to controllers while flipping radio frequencies to maintain contact, and frequently, ground delays before takeoff and flying in holding patterns before landing at congested airports. Since then, many new technologies, such as powerful computers in ATC facilities and collision avoidance systems in aircraft, have made air travel progressively safer and more reliable.

Recognizing the need to develop a more comprehensive approach to solving the requirements of ever increasing air traffic volume, an upgraded third-generation system was postulated in 1969.

In the 90s these tools eased the job of the controller in a positive way but at the same time the traffic increase was more than ever expected: it was doubling at every 10 years! The computes systems were supposed to be able to issue warnings

on the planning of traffic, analyze some traffic situations, offer solutions and minimize the delay of inputs and co-ordinations.

Since the beginning of the Twenty-first century satellite technology was started to be used in ATC, they can help on channeling the pilot-controller communications and reduce radio-telephony occupancy, simplify the aircraft navigation and enhance the surveillance of flights in remote areas or over oceans were no radars can be installed.

Despite the great advances in the ATC devices, but the Radar remains the principal means of aircraft position surveillance.

2.3 The Task of Air Traffic Control (ATC)

The safe and efficient coordination of such a large number of flights is possible by the work of ATC. ATC, both commercial and military, relies on a system based on two important principles. First, that the air traffic controller has real-time knowledge of all flights, operating in a given volume of airspace, and second, that a system of communicating instructions between pilots and air traffic controllers is mutually understood by all who use the airspace. The air traffic controller has the life critical task of coordinating safe and efficient flight in a specific volume of airspace by providing airspace usage instructions to pilots. These instructions from ATC to pilots provide both horizontal and vertical separation of each aircraft from takeoff, through the use of navigational waypoints in the airspace, up to and including approach and landing instruction, as well as other safety-related communications. Pilots operating in this selected airspace must understand and follow ATC instructions in order to maintain safe and efficient flight [1].

2.4 Radar

Historically, the military is primarily credited with developing the radar. The word radar is an abbreviation for **Ra**dio **D**etection **A**nd **R**anging. Originally, it was developed as a means of detecting approaching aircraft at long ranges to enable military defenses to react in sufficient time to counter incoming threats. Most natural and man-made objects reflect radio frequency waves and, depending on the radar's purpose, information can be obtained from objects such as aircraft, ships, ground vehicles, terrain features, weather phenomenon, and even insects [7].

2.4.1 Principle of Operation

Radar is a method whereby radio waves are transmitted into the air in a specific direction and are received when they are reflected by an object in the path of the beam. [11] Oftentimes, radar systems that implement the search function are called surveillance radar. The surveillance radar may detect the same target multiple times [1].

RANGE in RADAR is determined by measuring the time, radio wave takes, from radiation to return of its echo; whereas DIRECTION is determined from the position of antenna at the time of reception of signal.

The distance of an object from a Radar station is called "slant range" or simply "range". Range in Radar is determined by an expression given below.

$$\text{Range} = \frac{c \times t}{2} \quad \text{-------------------(2-1)}$$

Where [c] is speed of radio waves and [t] is the time elapsed from transmission

of radio waves to the reception of echo.

2.4.2 Types of ATC Radar

In general there are two types of air traffic surveillance radar the first one is the Primary (approach) Radar, It provides "Range and Bearing" information to the Air Traffic Control Center. It does not need cooperation of the aircraft for it depends upon reflection of the radio waves transmitted by the system itself. The second one is the Secondary Radar It provides "identification and altitude" information to ground ATC. It works with cooperation of the aircraft. The information produced by the Secondary Radar is therefore function of both ground equipment and airborne equipment.

We are now focusing on the primary (approach) radar that will be used in this study.

2.4.3 Primary (approach) Radar

Approach radars continuously scan a specified volume in space searching for targets. They are normally used to extract target information such as range and angular position [8]. Approach radar does not provide the identity or the altitude of the aircraft. However, approach radar does not require any specific equipment on the aircraft. Originally, approach radars were magnetron systems equipped with a single fan-beam antenna mounted on an azimuth rotator. [9, 10]

2.4.3.1 Construction

Practical Primary Radar system is composed of following essential components:

a) Timer or Synchronizer

b) Modulator

c) Transmitter

d) Antenna

e) Duplexer or TR switch

f) Receiver and

g) Indicator or Radar Scope
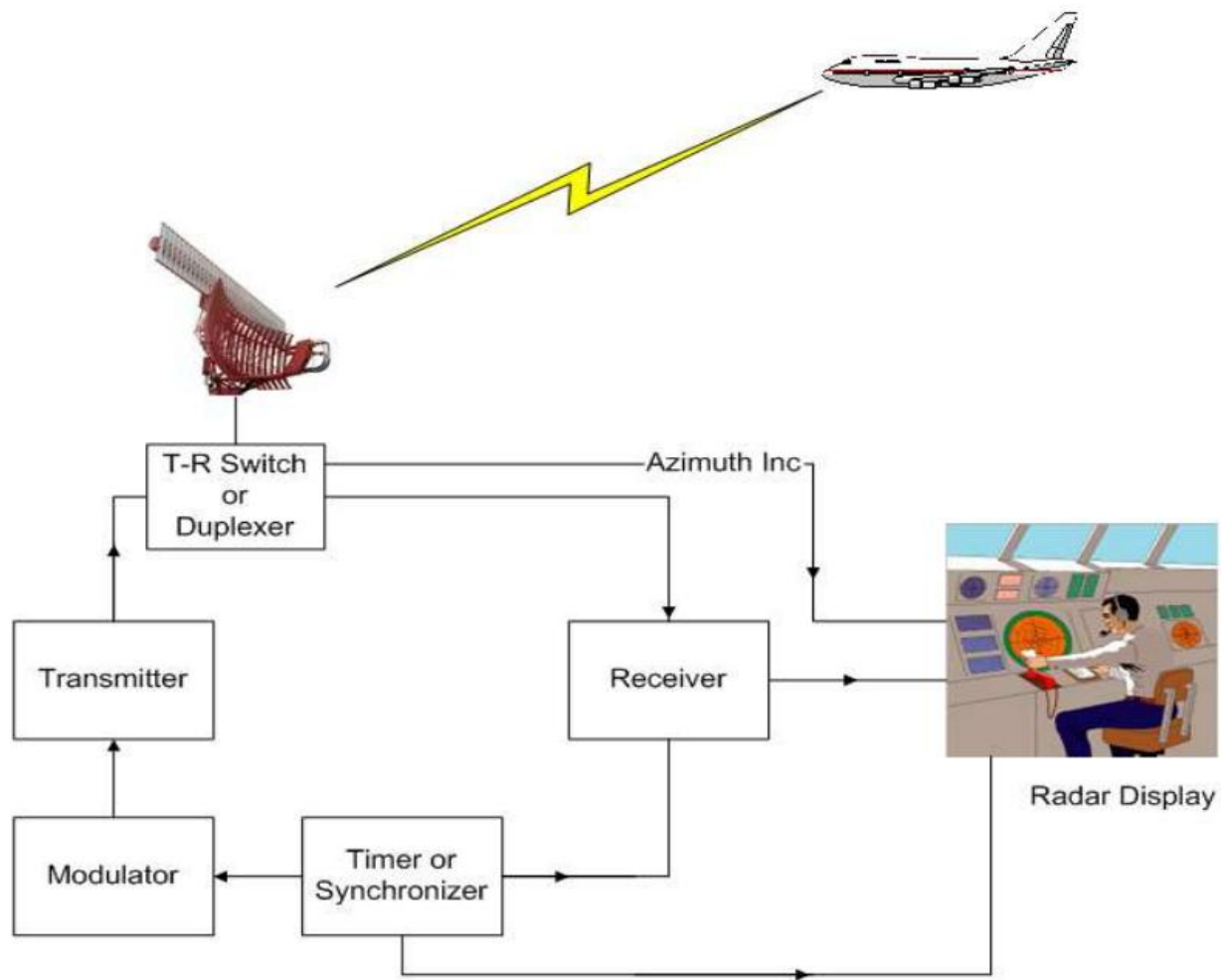
Figure (2-1): Block diagram of Primary (approach) Radar System

2.4.3.2 System Operation

Timer or Synchronizer generates small triggering pulses for start and control of cycle of operation. These pulses are supplied to the Modulator and Indicator units.

Modulator produces larger pulses for excitation of Transmitter The **transmitter** then sends a burst of RF energy to the Duplexer unit. For transmission of RF signal Duplexer will be switched to provide passage to RF energy from transmitter to antenna, which in turn radiates the energy in the specific direction. After the pulse

has been transmitted Duplexer closes transmitter path and allows receiver to pick up echoes.

A small portion of energy reflected back by the object(s) in the path of radar beam

(Called echo) is collected back by the receiver and fed to the Indicator (Display) unit.

The **Radar Display unit**, also called **Radar Scope**, has a dual function:

a) It measures the elapsed time between transmission and reception of radar signal and converts it into the range information; and

b) Displays information into a useable form for ATC purpose.
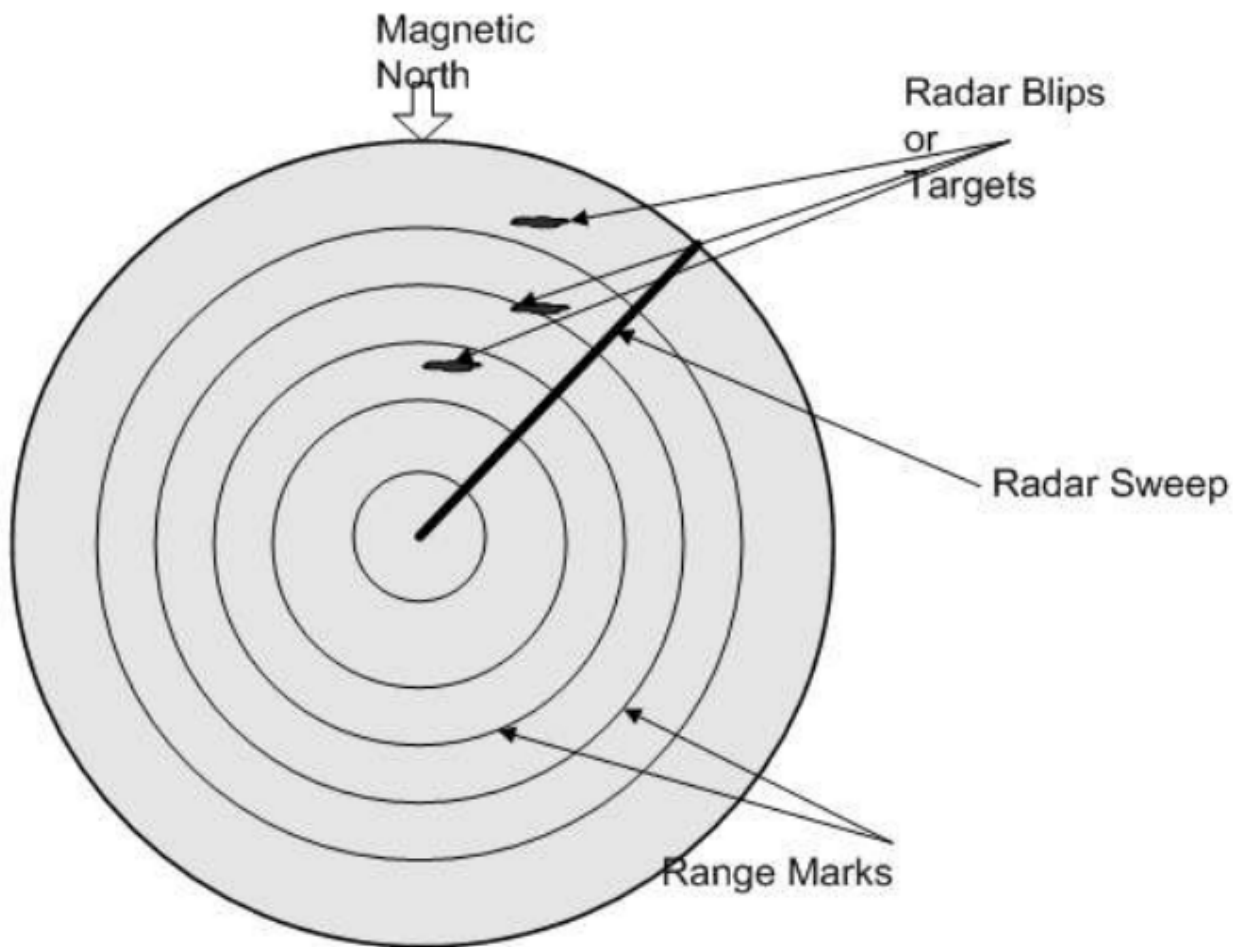
Figure (2-2): Plan Position Indicator (Display)

2.4.3.3 Radar Indicator

Information made available by radar may be presented to an operator in a number of ways. The presentation on an indicator showing all targets within range that are detected as the antenna rotates is called a Plan Position Indicator (PPI).

In PPI the scanning (sweep) starts from the center of the screen and moves outward. The distance between the center and the circumference of the screen represents the maximum range at which the radar is required to provide coverage. When the spot reaches the edge of the screen, it returns to the center extremely fast to start the next scan. This action is known as „Fly back‟.

To display the range of an object, the spot starts its sweep as the pulse is transmitted (by the antenna) and a "blip" is shown at the time when "echo‟ of the transmitted signal is received [11].

Chapter Three

(Electronic Circuit)

3.1 System description

The Real Time Approach Radar Image Tracking System is used to get the radar parameters (range, azimuth) from radar system and transmit them over wireless to manager office computer to form and display target(aircraft). This research will cover the area of control especially microcontroller system .And also the wireless area (X-Bee) should be covered. Proteus software will be used as system simulator.

3.2 System Block Diagram

This design has been divided into two parts Transmitter & Receiver. The Transmitter part is consisting of PPI, Microcontroller, LCD and X-bee module. Receiver part is consisting of X-bee module, Max232 and computer. The figure (3.1) below show the block diagram of real time approach radar image tracking system.

.
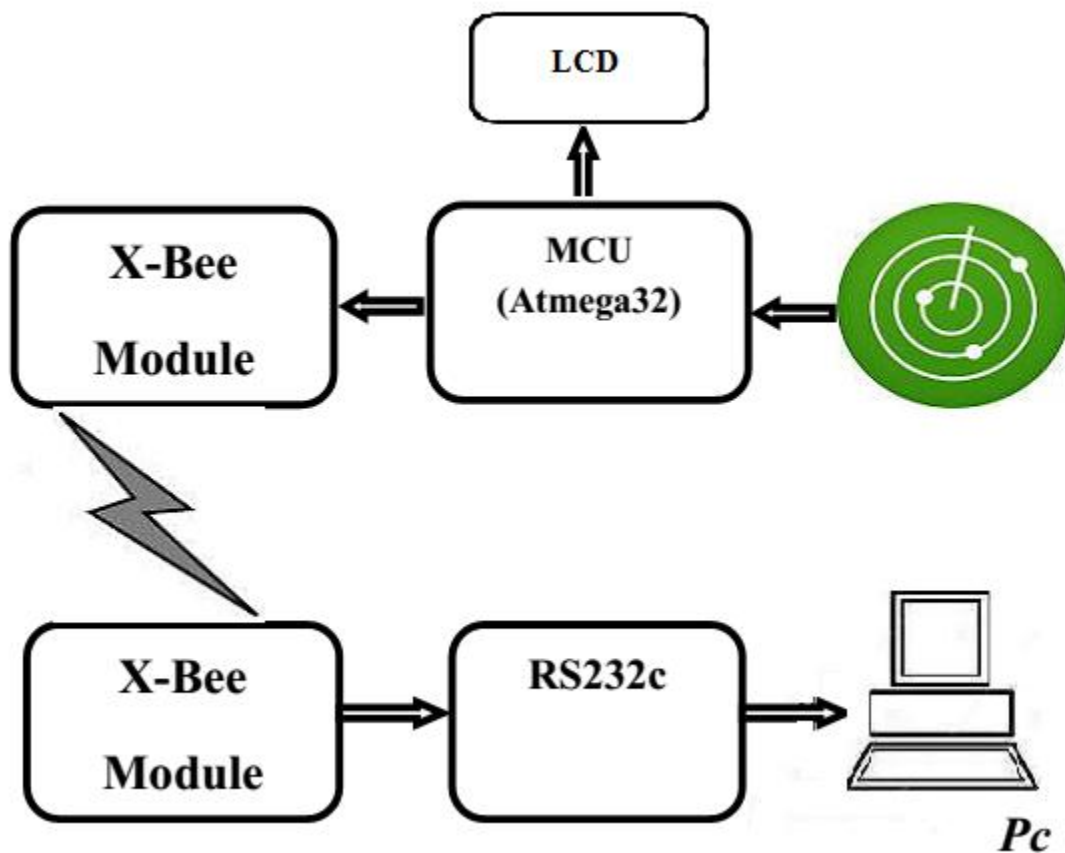
Figure (3.1): Block diagram of real time approach radar image tracking system.

3.3 Electronic Components of the Design

This chapter will give detailed information about the electronic components used in this design.

3.3.1 X-Y potentiometer

Potentiometer is a device with three terminals, two of which are connected to a resistance wire and the third to a brush moving along the wire, so that

a variable potential can be tapped off: used in electronic circuits, especially as a volume control sometimes shortened to **pot.**

Potentiometers are used in many different applications including calibration adjustments, manual control functions, data input, level and sensitivity adjustments, and servo position feedback transducers. The list is almost endless.

Most modern potentiometers are extremely linear and are made with special alloys or precious metal wipers and conductive plastic resistive elements to withstand as many as 100million revolutions. They are usually part of a voltage divider and provide an output voltage proportional to displacement, but they may also drive analog-to-digital converters to feed microprocessor-based instruments directly.

An **x-y potentiometer** is a couple of potentiometers hooked together mechanically in such a manner so that can control both at the same time. Each potentiometer is simply connected to an individual analog input. Notice the three pins on the X-Axis potentiometer? The center pin is routed to an analog input, while one of the side pins is connected to supply voltage, and the other side pin is connected to ground. The other potentiometer (Y-Axis) is connected in the same manner, just to a different analog input.

The double potentiometers can have a single order which positions the two cursors at the same time, or of the separate controls acting each one on the cursor of two resistances. On the figure (3-2 a), a simple potentiometer is equipped with a bipolar switch which is actuated while drawing or by

pushing the control shaft. The double potentiometer, illustrated in the figure (3-2 b)is equipped with two coaxial separate controls for the adjustment independent of two resistances and a unipolar switch which is closed before one of the coaxial orders does not arrive in race end (on only one side).
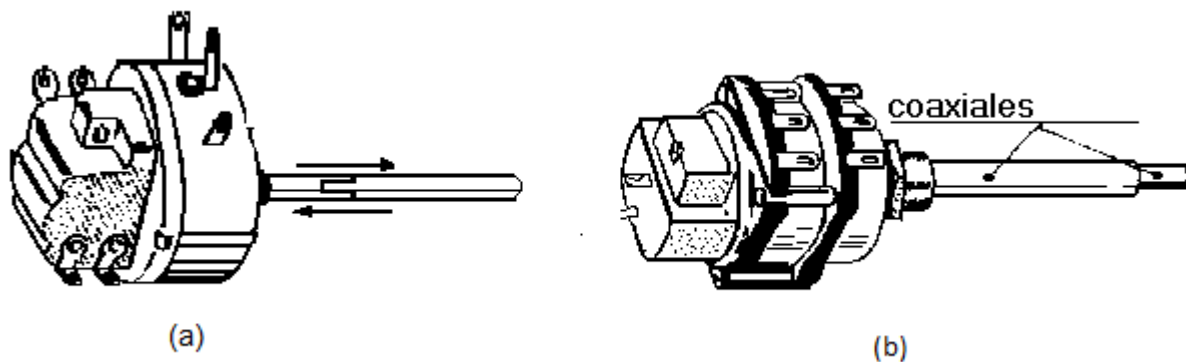
Figure (3- 2) the double potentiometers

The axes of the simple or double potentiometers with single order can be various lengths; there are not adopted universal standards: they are sometimes out of plastic, easily adaptable to the wanted length, and sometimes with a metal stem differently machined for the fixing of the control knob

3.3.2 Microcontroller

The microcontroller may be considered as a specialized computer-on-a-chip or a single-chip computer. The word 'micro' suggests that the device is small, and the word 'controller' suggests that the device may be used to control one or more

functions of objects, processes or events. It is also called an embedded controller as microcontrollers are often embedded in the device or system that they control.

The microcontroller contains a simplified processor, some memory (RAM and ROM), I/O ports and peripheral devices such as counters/timers, analogue-to-digital converters, etc., all integrated on a single chip. It is this feature of the processor and peripheral components available on a single chip that distinguishes it from a microprocessor-based system. While a microprocessor-based system is a general-purpose system that may be programmed to do any of the large number of functions it is capable of doing, microcontrollers are dedicated to one task and run one specific program. This program is stored in ROM and generally does not change.

In this work we use ATmega32 it is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega32 achieves throughputs approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus processing speed.

The AVR core combines a rich instruction set with 32 general purpose working registers. All the 32 registers are directly connected to the Arithmetic Logic Unit (ALU), allowing two independent registers to be accessed in one single instruction executed in one clock cycle. figure (3-3) show the block diagram of the ATmega32 AVR. The resulting architecture is more code efficient of while achieving throughputs up to ten times faster than conventional CISC microcontrollers. The ATmega32 AVR is supported with a full suite of program and system development tools

including: C compilers, macro assemblers, program debugger/simulators, in-circuit emulators, and evaluation kits. The boot program can use any interface to download the application program in the Application Flash memory. Software in the Boot Flash section will continue to run while the Application Flash section is updated, providing true Read-While-Write operation. By combining an 8-bit RISC CPU with In-System Self-Programmable Flash on a monolithic chip, the Atmel ATmega32 is a powerful microcontroller that provides highly-flexible and cost-effective solution to many embedded control applications.
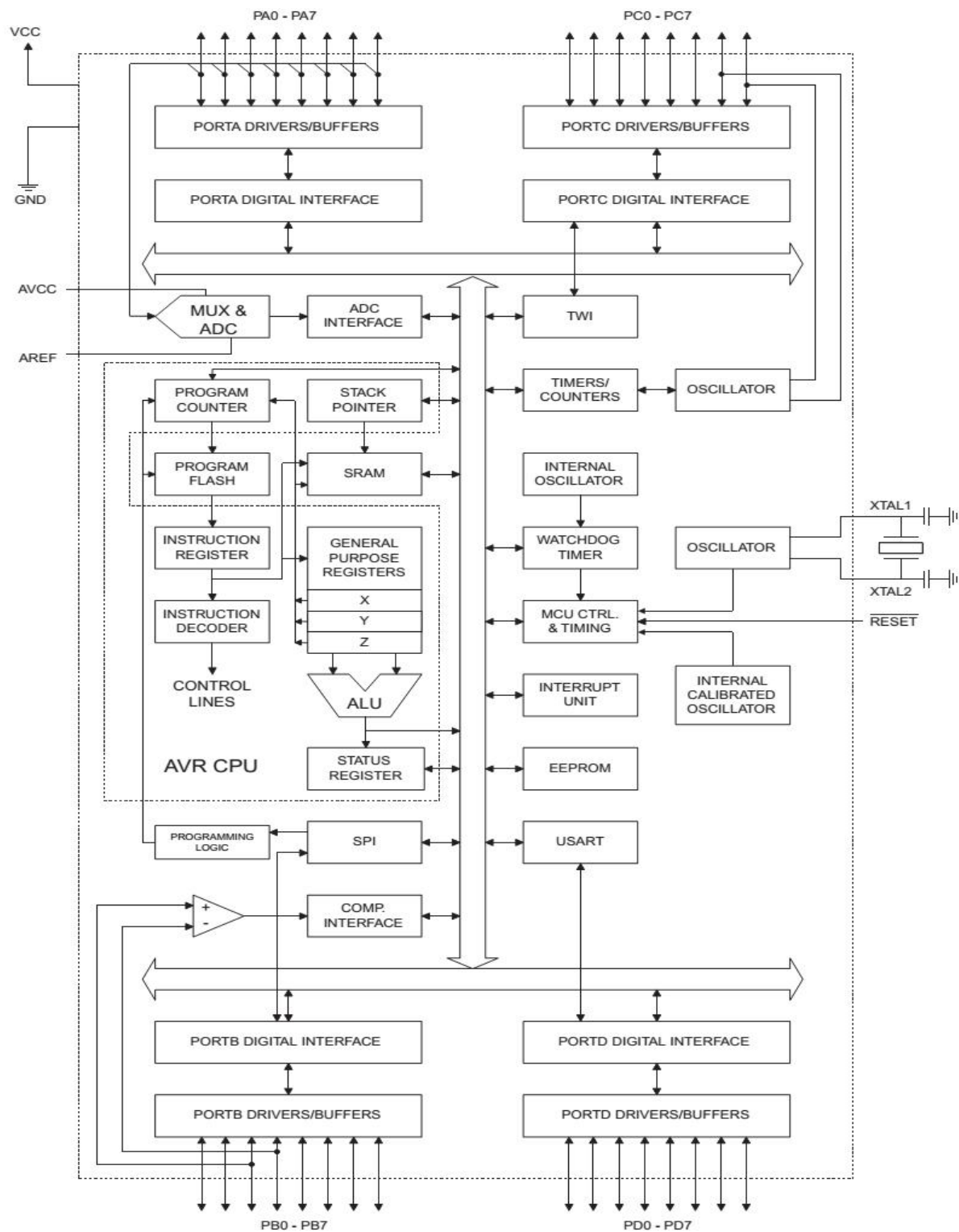
Figure (3-3) block diagram of the ATmega32 AVR

3.3.2.1 Important feature

The ATmega32 provides the following features:

- Advanced RISC Architecture
- 32K bytes of Flash Program memory with Read-While-Write capabilities.
- 1024 bytes EEPROM.
- 2048 bytes SRAM.
- 32 general purpose I/O lines.
- 32 general purpose working registers.
- Three Timer/Counters with compare modes.
- Internal and External Interrupts.
- A serial programmable USART.
- 10-bit ADC.
- Speed Grades   0 - 16 MHz

3.3.2.2 Pin description:

The below figure (3-4) shows pins configuration of ATMEGA32

```
          (XCK/T0) PB0 ▭  1        40 ▭ PA0 (ADC0)
              (T1) PB1 ▭  2        39 ▭ PA1 (ADC1)
        (INT2/AIN0) PB2 ▭  3        38 ▭ PA2 (ADC2)
        (OC0/AIN1) PB3 ▭  4        37 ▭ PA3 (ADC3)
              (SS) PB4 ▭  5        36 ▭ PA4 (ADC4)
            (MOSI) PB5 ▭  6        35 ▭ PA5 (ADC5)
            (MISO) PB6 ▭  7        34 ▭ PA6 (ADC6)
             (SCK) PB7 ▭  8        33 ▭ PA7 (ADC7)
                 RESET ▭  9        32 ▭ AREF
                   VCC ▭ 10        31 ▭ GND
                   GND ▭ 11        30 ▭ AVCC
                 XTAL2 ▭ 12        29 ▭ PC7 (TOSC2)
                 XTAL1 ▭ 13        28 ▭ PC6 (TOSC1)
            (RXD) PD0 ▭ 14        27 ▭ PC5 (TDI)
            (TXD) PD1 ▭ 15        26 ▭ PC4 (TDO)
            (INT0) PD2 ▭ 16        25 ▭ PC3 (TMS)
            (INT1) PD3 ▭ 17        24 ▭ PC2 (TCK)
           (OC1B) PD4 ▭ 18        23 ▭ PC1 (SDA)
           (OC1A) PD5 ▭ 19        22 ▭ PC0 (SCL)
             (ICP) PD6 ▭ 20        21 ▭ PD7 (OC2)
```

Figure (3-4):ATMEGA32 pins configuration

VCC: Digital supply voltage.

GND: Ground.

Port A (PA7...PA0): Port A serves as the analog inputs to the A/D Converter. Port A also serves as an 8-bit bi-directional I/O port, if the A/D Converter is not used. The Port A pins are tri-stated when a reset condition becomes active, even if the clock is not running.

Port B (PB7...PB0): Port B is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port B pins are tri-stated when a reset condition becomes active, even if the clock is not running.

Port C (PC7...PC0): Port C is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port C pins are tri-stated when a reset condition becomes active, even if the clock is not running.

Port D (PD7...PD0): Port D is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port D pins are tri-stated when a reset condition becomes active, even if the clock is not running.

RESET: Reset Input. A low level on this pin for longer than the minimum pulse length will generate a reset, even if the clock is not running.

XTAL1: Input to the inverting Oscillator amplifier and input to the internal clock operating circuit.

XTAL2: Output from the inverting Oscillator amplifier.

AVCC: AVCC is the supply voltage pin for Port A and the A/D Converter. It should be externally connected to VCC, even if the ADC is not used. If the ADC is used, it should be connected to VCC through a low-pass filter.

AREF: AREF is the analog reference pin for the A/D Converter.

3.3.3 Liquid Crystal Display (LCD)

LCD (Liquid Crystal Display) screen is an electronic display module and find a wide range of applications. A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits.

These modules are preferred over seven segments and other multi segment LEDs. The reasons being: LCDs are economical; easily programmable; have no limitation of displaying special & even custom characters (unlike in seven segments), animations A 16x2 LCD means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. Figure (3.5): show 16x2 LCD.
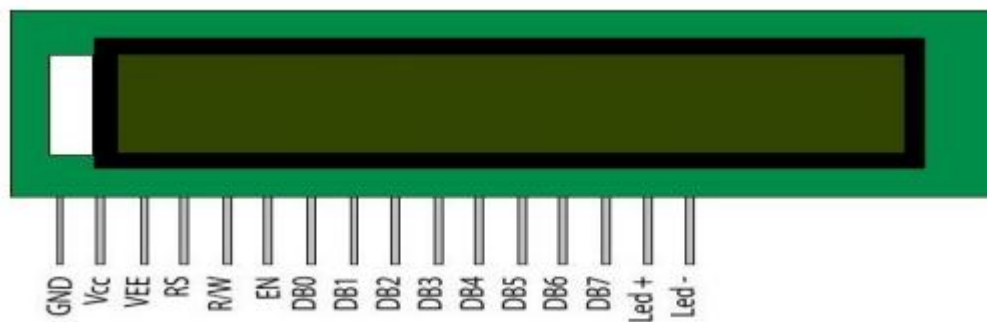
Figure (3-5): Pin Diagram 16x2 LCD

A 16x2 LCD display content of 16 pins, Table (3.1) show the function of each pin.

Table (3-1): Pin Description 16x2 LCD

Pin No	Function	Name
1	Ground (0V)	Ground
2	Supply voltage; 5V (4.7V – 5.3V)	Vcc
3	Contrast adjustment; through a variable resistor	V_{EE}
4	Selects command register when low; and data register when high	Register Select
5	Low to write to the register; High to read from the register	Read/write
6	Sends data to data pins when a high to low pulse is given	Enable
7-14	8-bit data pins	DB0- DB7
15	Backlight V_{CC} (5V)	Led+
16	Backlight Ground (0V)	Led

3.3.3 .1 Features

(1) Interface with 8-bit is available.

(2) 192 kinds off alphabets, numbers, symbols and special characters can be displayed by build-in character generator (ROM).

(3) Other preferred characters can be displayed by characters generator (RAM).

(4) Various functions of instruction are available by programming.

(5) Compact and light weight design which can be easily assembled in devices.

(6) Single power supply +5v drive (exact for extended temp. type).

(7) Low power consumption.

3.3.4 ZigBee

Zigbee is a wireless network standard to create a wireless network using low cost, low power consumption & low data rate connectivity devices. It can beat your Wi-Fi networks hands down for certain applications like industrial automation, medical patient monitoring, etc due to its prominent features[15].

Zigbee is a Wireless Networking standard like WiFi. Zigbee even operates in the same unlicensed frequency spectrum of 2.4 Ghz like Wi-Fi, but the similarity ends there. Zigbee devices form self configuring, self healing wireless networks that use low cost devices (radios, clients) to achieve a limited throughput (250 Kbps). The low bandwidth might surprise you initially, but that is sufficient for many applications.

3.3.4.1 ZigBee Alliance

The ZigBee Alliance is an association of companies working together to define an open global standard for making low-power wireless networks. The intended outcome of ZigBee Alliance is to create a specification defining how to build different network topologies with data security

features and interoperable application profiles. The association includes companies from a wide spectrum of categories, from chip manufactures to system integration companies [14]. Zigbee standard and 802.15.4 is the IEEE Standard for the same. While IEEE 802.15.4 defines the physical and MAC layers, Zigbee itself defines the network and application layers of this wireless network. It means that all Zigbee devices will work with each other, irrespective of the manufacturer [15].

3.3.4.2 Components of the IEEE 802.15.4

IEEE 802.15.4 networks use three types of devices:

•**The network Coordinator** maintains overall network knowledge. It is the most sophisticated one of the three types, and requires the most memory and computing power.

•**The Full Function Device** (FFD) supp orts all IEEE 802.15.4 functions and features specified by the standard. It can function as a network coordinator. Additional memory and computing power make it ideal for network router functions or it could be used in network-edge devices (where the network touches the real world).

•**The Reduced Function Device** (RFD) carries limited (as specified by the standard) functionality to lower cost and complexity. It is generally found in network-edge devices. The RFD can b e used where extremely low power consumption is a necessity [14].

3.3.4.3 Frequencies of Operation and Data Rates

There are three frequency bands in the latest version of IEEE 802.15.4

●868–868.6 MHz (868 MHz band)

●902–928 MHz (915 MHz band)

●2400–2483.5 MHz (2.4 GHz band)

3.3.4.4 XBee

XBee is a brand of radio that supports a variety of communication protocols. XBee is a feature-rich RF module which makes it a very good solution for WSN designers; the implemented protocols on the modules like IEEE 802.15.4 and ZigBee can significantly reduce the work by the programmer for ensuring data communication.

In this thesis we use X-Bee-Pro which is (higher-power) version of the popular XBee! This module is series #1 (802.15.4 protocol) 60mW wireless module, good for point-to-point, multipoint and convertible to a mesh network point. These are much more powerful than the plain XBee modules, great for when you need more range. What we like about the Series 1 modules is that they are so easy to get set up. If you have two in range, they will automatically form a serial link with no configuration, so you can send TTL serial data back and forth. You can also configure the baud rate, as well as sleep modes.

The Figure (3- 6) show X-Bee-Pro modules and pin outs

Figure (3-6a): X-Bee Pro modules
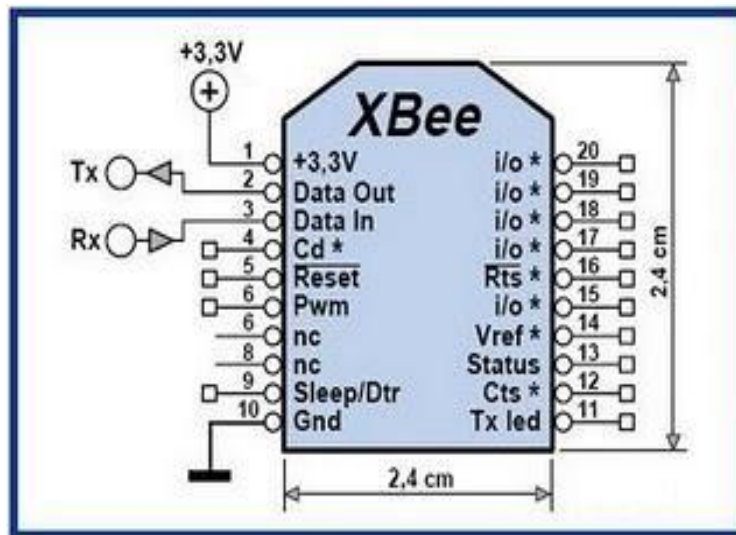
Figure (3-6b): X-Bee Pro Pin outs

3.3.4.4.1 Important feature

- RF Data Rate: 250,000 bps.

- Indoor/Urban Range   Up to 300' (100 m).

- Outdoor RF line-of-sight Range   Up to 1 mile (1500 m).

- Supply Voltage   2.8 – 3.4 V.

- Serial Interface Data Rate (software selectable)   1200 - 115200 bps (non-standard baud rates also supported).

- Operating Frequency   ISM 2.4 GHz.

- Operating Temperature   -40 to 85º C (industrial).

3.3.5 Serial Communication (RS-232):

The RS-232 interface is the Electronic Industries Association (EIA) standard for the interchange of serial binary data between two devices. It was initially developed by the EIA to standardize the connection of computers with telephone

Line modems. The standard allows as many as 20 signals to be defined, but gives complete freedom to the user. Three wires are sufficient: send data, receive data, and signal ground. The remaining lines can be hardwired on or off permanently. The signal transmission is bipolar, requiring two voltages, from 5 to 25 volts, of opposite polarity.

Figure (3-7) illustrates the pin numbering used in the original DB-9 connector normally used in modern computers
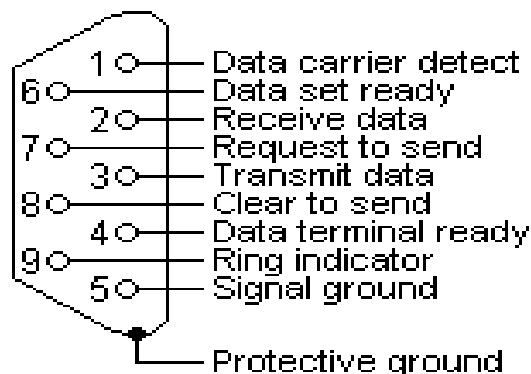
Figure (3-7): DB-9 connector

The RS-232C standard specifies that the maximum length of cable between the transmitter and receiver should not exceed 100 feet.

In theory, a wire cable could be used to connect the Data Terminal Equipment (DTE) to the Data Communication Equipment (DCE). The DTE is a device that is acting as a data source, data sink, or both, e.g. a terminal, peripheral or computer. The DCE is a device that provides the functions required to establish, maintain, and terminate a data-transmission connecting, as well as the signal conversion, and coding required for communication between data terminal equipment and data circuit; e.g. a modem.

The RS-232C specifies the signaling rate between the DTE and DCE, and a digital signal is used on all interchange circuits. The RS-232 standard specifies that logic "1" is to be sent as a voltage in the range -15 to -5 V and that logic "0" is to sent as a voltage in the range +5 to +15 V. The standard specifies that voltages of at least 3 V in amplitude will always be recognized correctly at the receiver according to their polarity, so that appreciable attenuation along the line can be tolerated. The transfer rate is rated > 20 kbps and a distance of < 15m. Greater distance and data rates are possible with good design.

3.4 Transmitter Part

As we mentioned above this part consists of PPI, microcontroller and x-bee module, here we use tow potentiometer (instead of PPI) to work as radar parameters input, first one for azimuth angle and the other for range.

To read these tow parameters by MCU, analog to digital converter (ADC) is needed. ATmega32 has an ADC on chip. An ADC converts an input

voltage into a number. A 10 Bit ADC has a range of 0-1023. (2^10=1024) The ADC also has a Reference voltage (ARef). When input voltage is GND the output is 0 and when input voltage is equal to ARef the output is 1023. So the input range is 0-ARef and digital output is 0-1023.

The ADC in ATmega32 has 8 channels that mean you can take samples from eight different terminals. You can connect up to 8 different analog inputs and get their values separately.

Notice the three pins on the first potentiometer? The center pin is routed to an analog input ADC0, while one of the side pins is connected to +5V, and the other side pin is connected to ground. The other potentiometer is connected in the same manner, just to a different analog input pin ADC1.

By turning the shaft of the potentiometer, we change the amount of resistence on either side of the wiper which is connected to the center pin of the potentiometer. This changes the relative "closeness" of that pin to 5 volts and ground, giving us a different analog input. When the shaft is turned all the way in one direction, there are 0 volts going to the pin, and we read 0. When the shaft is turned all the way in the other direction, there are 5 volts going to the pin and we read 1023. In between, analog Read returns a number between 0 and 1023 that is proportional to the amount of voltage being applied to the pin.

The code would check both of these analog values (which will range from 0-1023), and displayed on LCD.

The x-bee shield allows microcontroller to communicate wirelessly using zigbee .It can be used as serial communication with the jumpers in the x-bee position, the DOUT pin of the x-bee module is connected to Rx pin of the microcontroller, and DIN pin is connected to the TX. So the data can send from the microcontroller wirelessly by the x-bee module, the figure (3-8) show connections of transmitter part.
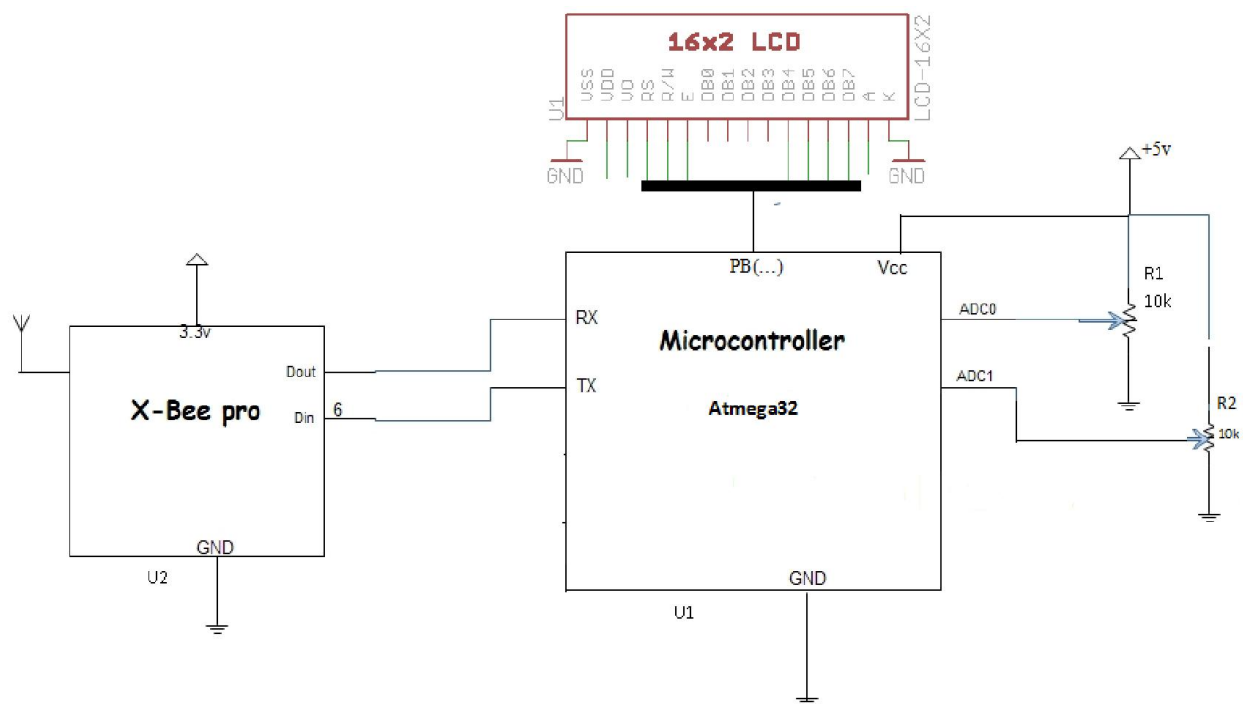
Figure (3-8): Transmitter part

3.5 Receiver part

These part is consists of x-bee module, RS232c and computer work station, here we interfaced x-bee module with a computer through Serial Communication port (RS-232), the figure (3-9) show the interface between three parts of the system.
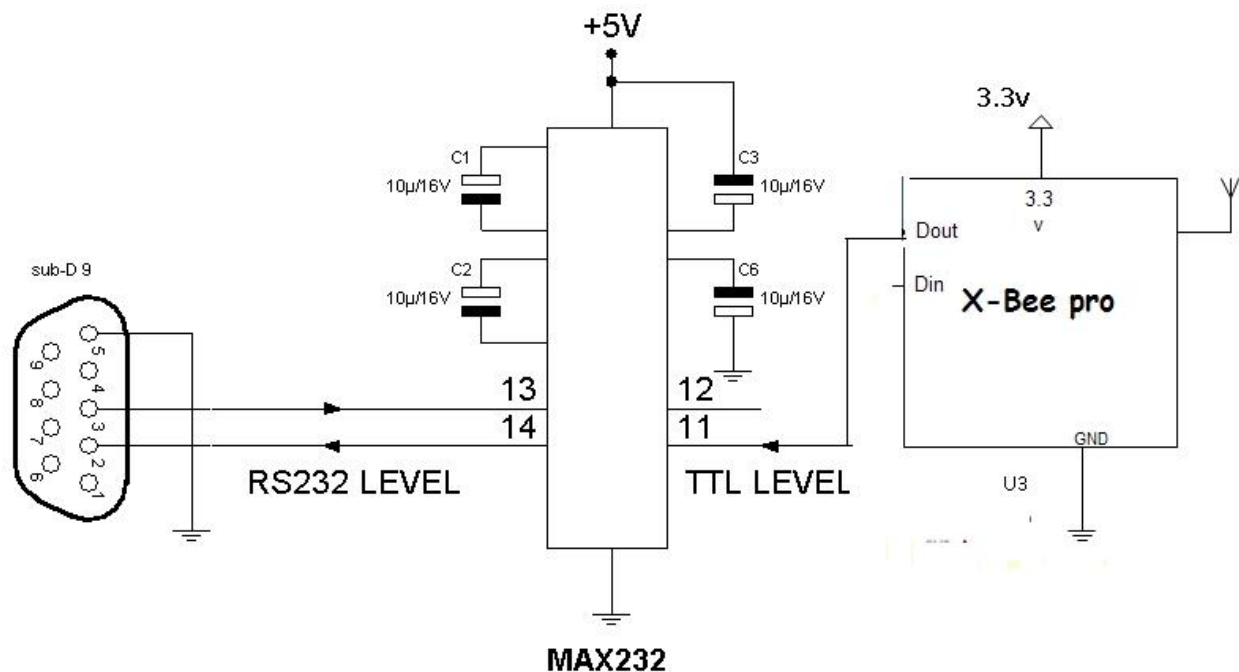
Figure (3-9): Receiver part

Chapter Four

(Software design)

4.1Overview

In this chapter we discuss the software design of the system including bascom and Proteus along with the flow chart.

4.2 Bascom

Bascom means Basic Compiler. Bascom is developed and sold by MCS Electronics. Bascom comes in three variants:

- Bascom-LT for Atmel AT89Cx051 microcontroller.
- Bascom-8051 for 8051 microcontrollers.
- Bascom-AVR for Atmel AVR microcontrollers.

Bascom is a PC application that will allow you to:

- write programs in Basic.
- translate these programs on the PC to machine code (a format the AVR controller can execute).
- simulate the compiled code.

Bascom offered a complete and affordable solution, editor, compiler, simulator and programmer. The reason it became popular was that it included a lot of functionality that was easy to use from BASIC. Using an LCD display was simple, just a configuration line to define the used pins and voila, a working application in minutes. When you needed a different LCD display, you could simply change the CONFIG line. Another reason for its success, no ASM to deal with, simple statements. Of course free updates and support.

When a different processor was needed, you only had to change the name of the definition file. No need for a lot of .h files.

With the many different 8051 variants, it was impossible to support all the chips. Having device definition "DAT" files, made it easy for the user to configure the 8051 variants.

When Atmel launched the AVR chip, the 8051 compiler was rewritten, once again, to support the powerful AVR chips. The result was BASCOM-AVR.

The AVR chip has a lot of internal memory. It uses simple linear memory addressing. The best part is that you can make the chip program itself. No wonder this chip family became so popular.

4.3 Simulate circuits in Proteus

4.3.1 Transmitter Part

The following figure (4-1) illustrates the transmitter part Simulated in proteus.
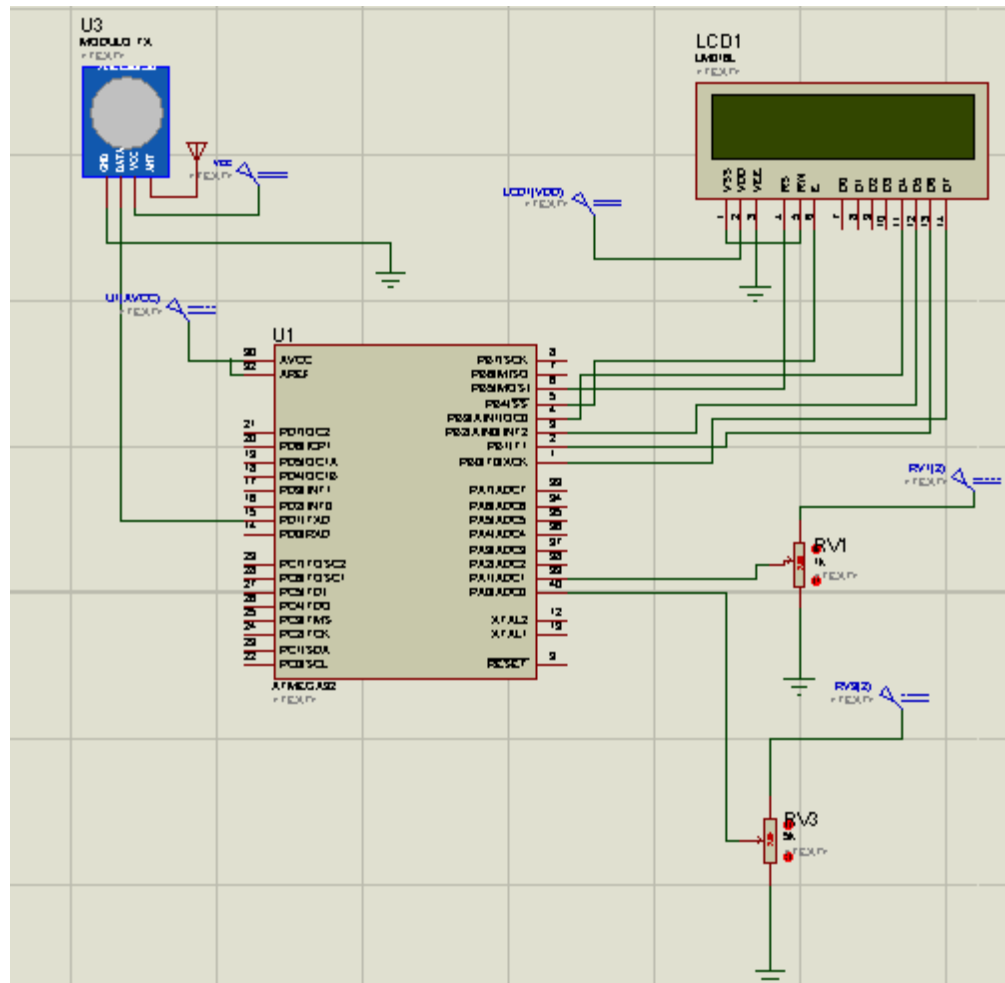
Figure (4-1) the transmitter part

4.3.2 Receiver part

The figure (4-2) below illustrates the receiver part the of design by proteus
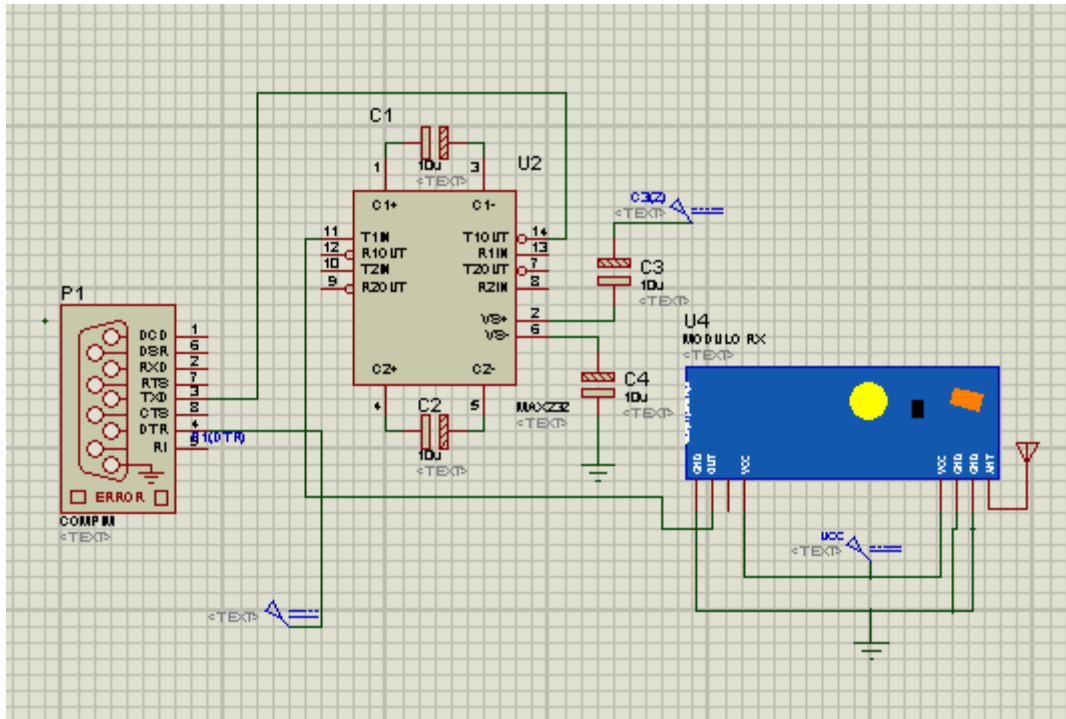
Figure (4-2) receiver part

4.4 Calculation for Software design:

The specifications of approach radar which we use in this study:

- Rotation rate   15 RPM (15 Rotation Per Minute)
- Range   60nm (nautical mile)
- Azimuth   2.8º

From rotation rate of radar we can get:

One rotation time =60/15=4 s

So each rotation of radar antenna (360º) take 4 seconds that means the information of targets refreshed every 4s.

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From third specification azimuth give us the minimum space between targets symbols in display system as degree angle.

Number of radar reading in one rotation time (360º) =360/2.8=128

Microcontroller read 128 once at 4s.

 Time to take one reading =4/128 =31.25ms

Or take one reading after 31.25ms

In the simulation we use potentiometer R1 to represent as azimuth angle input, so any reading by microcontroller from pot R1 must by divide by factor (Z) to get the actual value because the ADC Read returns a number between 0 and 1023 that is proportional to the amount of voltage being applied to the pin and we need maximum value 360.

$$Z= 1024/360 = 2.8$$

Also the pot R2 which represent the range returns a number between 0 and 1023 , and the actual maximum range 60nm, so each reading by pot R2 must divide by factor (R) to get the real range.

$$R=1024/60 = 17$$

4.5 Flow Chart

4.5.1 Flow Chart of transmitter part:

After the analog parameters input and digital output has been defined the microcontroller keeps monitoring input of ADC (0) and ADC (1) in order to capture valid data.

Then the microcontroller transmit the parameters value to the receiver part using x-bee transceiver unit and Then microcontroller will return to read new data from ADC channels. Figure (4-3) shows the flow Chart of transmitter part.

```
                    ┌─────────────┐
                    │    Start    │
                    └─────────────┘
                           │
                           ▼
                 ╭───────────────────╮
                 │ -Set basic parameters │
                 │ -Define serial baud   │
                 │  rate                 │
                 ╰───────────────────╯
                           │
                           ▼
                 ╱───────────────────╲
                │  Mcu read data from  │
                │  ADC (0), ADC (1)    │
                 ╲───────────────────╱
                           │
                           ▼
                 ┌───────────────────┐
                 │ Azimuth=ADC0/2.8  │
                 │ Range=ADC1/17     │
                 │ Display data on LCD│
                 └───────────────────┘
                           │
                           ▼
                 ╱───────────────────╲
                │  MCU transmit data   │
                │  through serial port │
                │  to x-bee module     │
                 ╲───────────────────╱
                           │
                           ▼
                 ╱───────────────────╲
                │  X-bee get the data  │
                │  from Mcu and        │
                │  retransmit it       │
                 ╲───────────────────╱
                           │
                           ▼
                       ╱───────╲
                      ╱ MCU read ╲  Yes
                      ╲ new value ╱─────┐
                       ╲───────╱        │
                           │ No         │
                           ▼            │
                    ┌─────────────┐     │
                    │    End      │     │
                    └─────────────┘     │
```
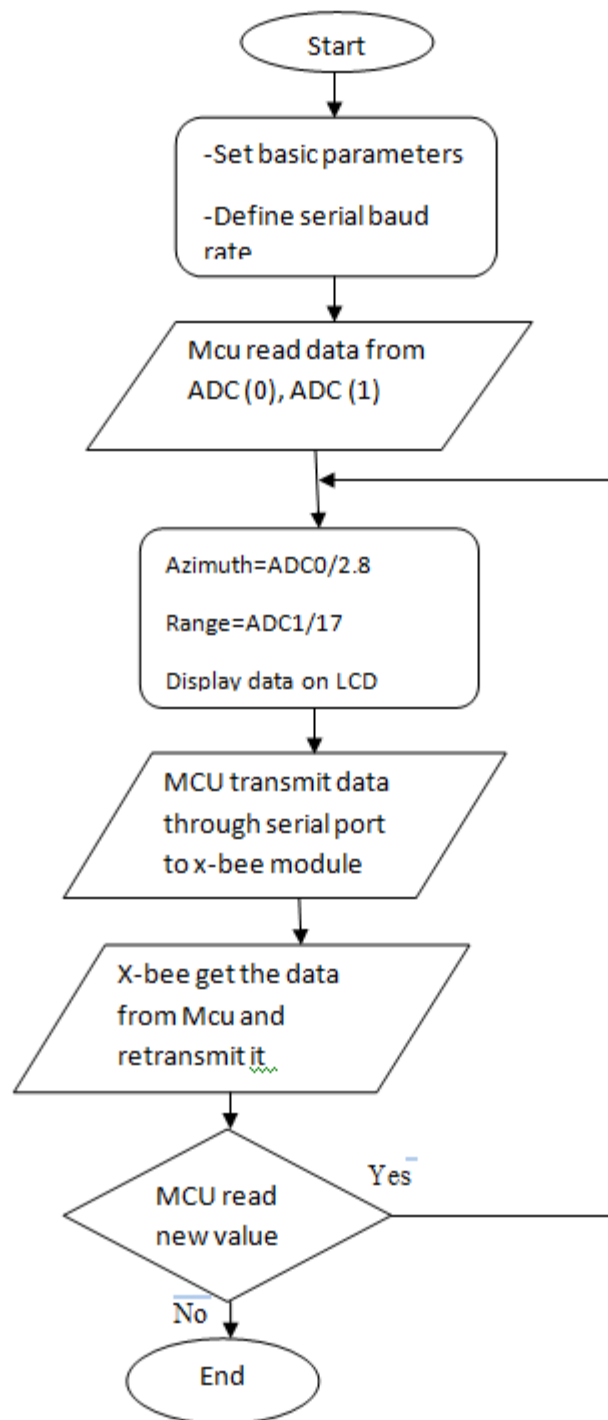
Figure (4-3) Flow Chart of transmitter part

4.5.2 Flow Chart of receiver part:

The X-bee transceiver unit in receiver part get the data wirelessly and resend it to max232 which convert of TTL voltage levels (i.e. logic 1 = +5V and logic 0 = 0V) to serial port's voltage level (logic 1 = -15V and logic 0 = +15V), after that a computer get the data through serial port.

Figure (4-4) Flow Chart of receiver part

4.6 Graphical user interface:

Finally, the data (parameters) will be used to specify the target position and displayed on the (GUI) in a computer; the code is written in visual c# programming language the following figure (4-5) illustrates the (GUI).
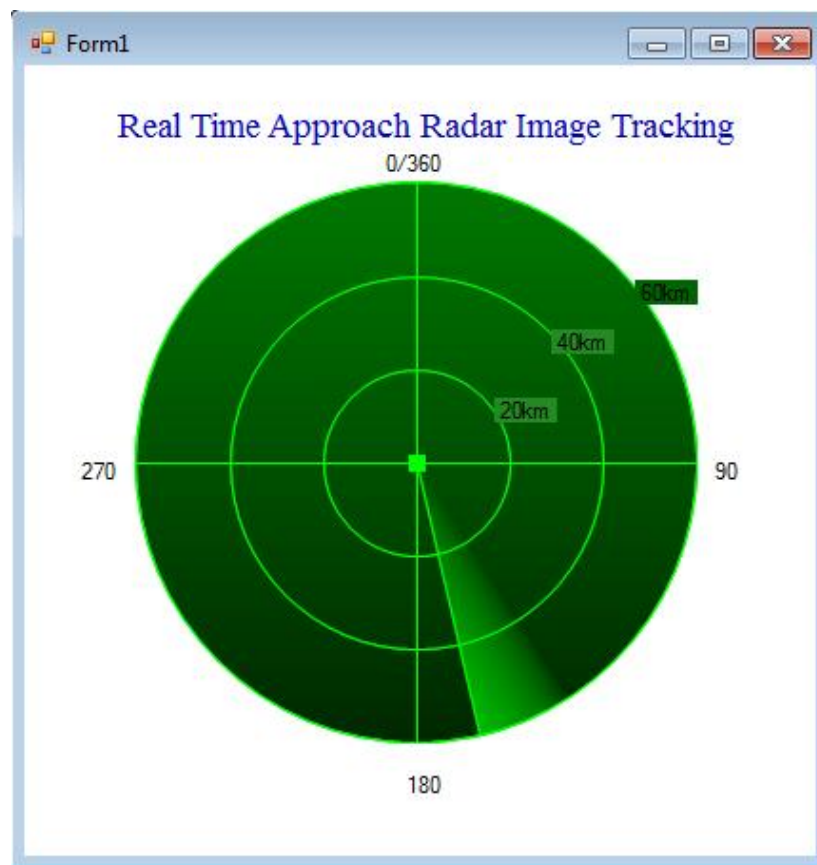
Figure (4-5): GUI

Chapter Five

(Result and Discussion)

Result and Discussion

5.1 Introduction

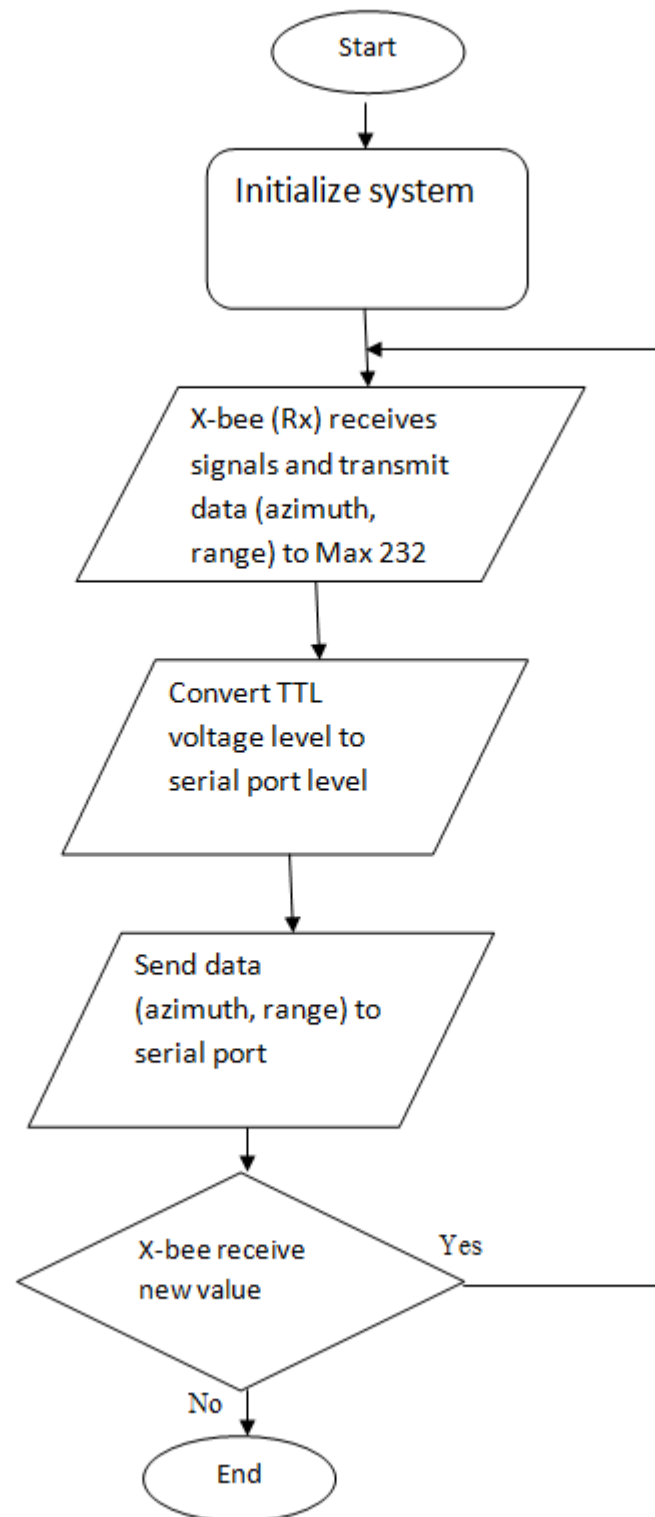This chapter starts with a description of the way of performing the experiments, the experiments itself has been described in addition to snapshots of simulation circuit and the Graphic User Interface (GUI). Covers the results obtained from the design in several values of parameters input.

5.2 Description of Experiments

When the system start to run microcontroller read parameters value from two potentiometers feed to ADC0& ADC1. An ADC converts an input voltage into a number. A 10 Bit ADC has a range of 0-1023. (2^10=1024) When input voltage is GND the output is 0 and when input voltage is equal to ARef the output is 1023. In between, analog Read returns a number between 0 and 1023 that is proportional to the amount of voltage being applied to the pin, then the parameters value will be displayed on the LCD and send wirelessly by the x-bee module to receiver side and through RS232 computer get parameters.

In the computer monitor GUI show the target location as small green bright square displayed on the radar image background.

5.2.1Experiment no (1)

Figure (5-1) shows the target location when the input parameters are zero that means there is no target detected by radar or target arrives to destination (runway).
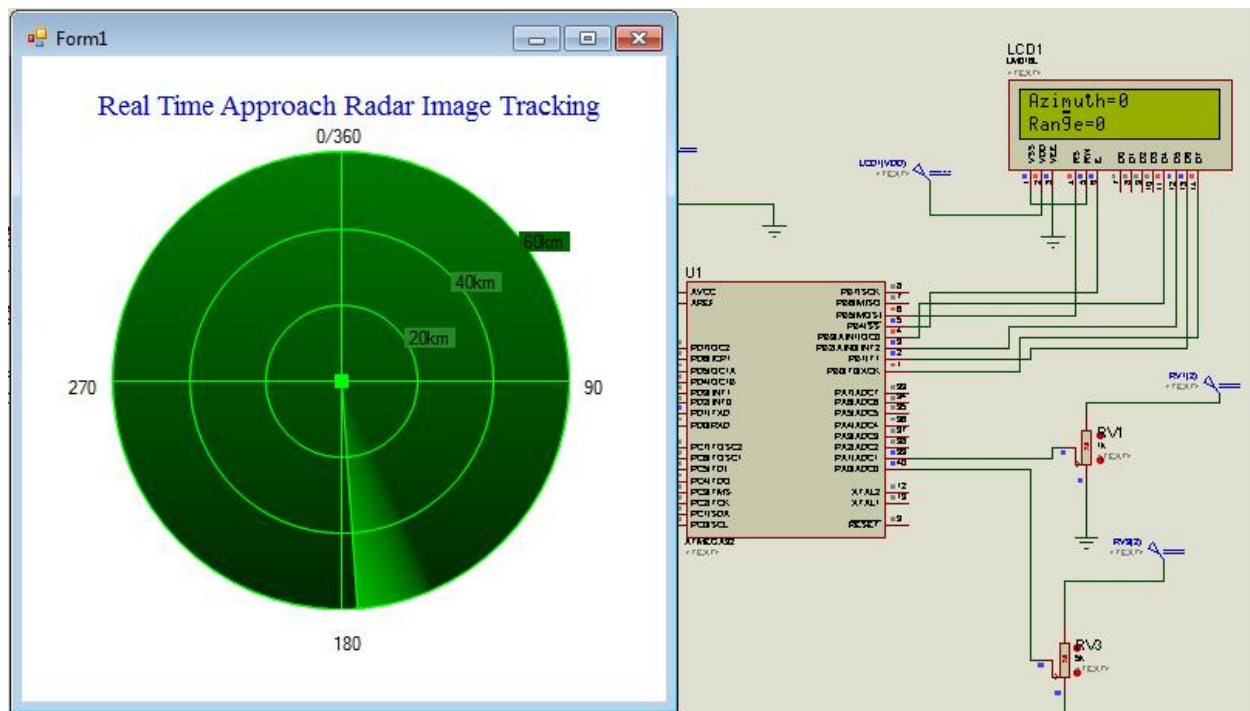
Figure (5-1) snapshot of experiment no.1

5.2.2Experiment no (2)

The figure (5-2) illustrates the value of inputs on LCD as exactly location showing on GUI.
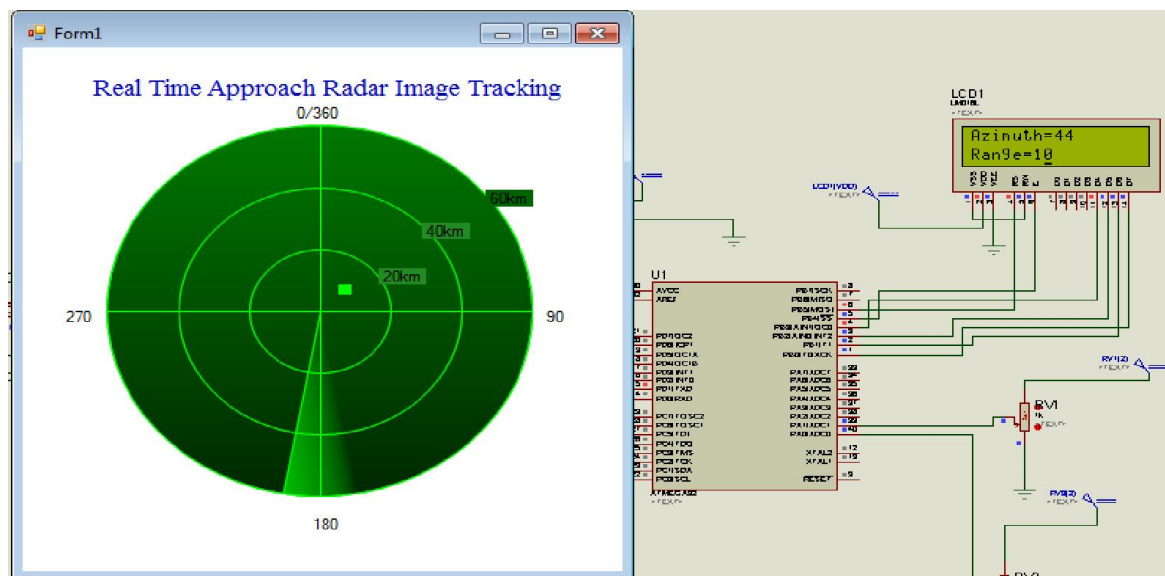
Figure (5-2) snapshot of experiment no.2

5.2.3 Experment no (3)

The figure (5-3) also illustrates another value of parameters on the LCD in transmitter side and its actual location in GUI.
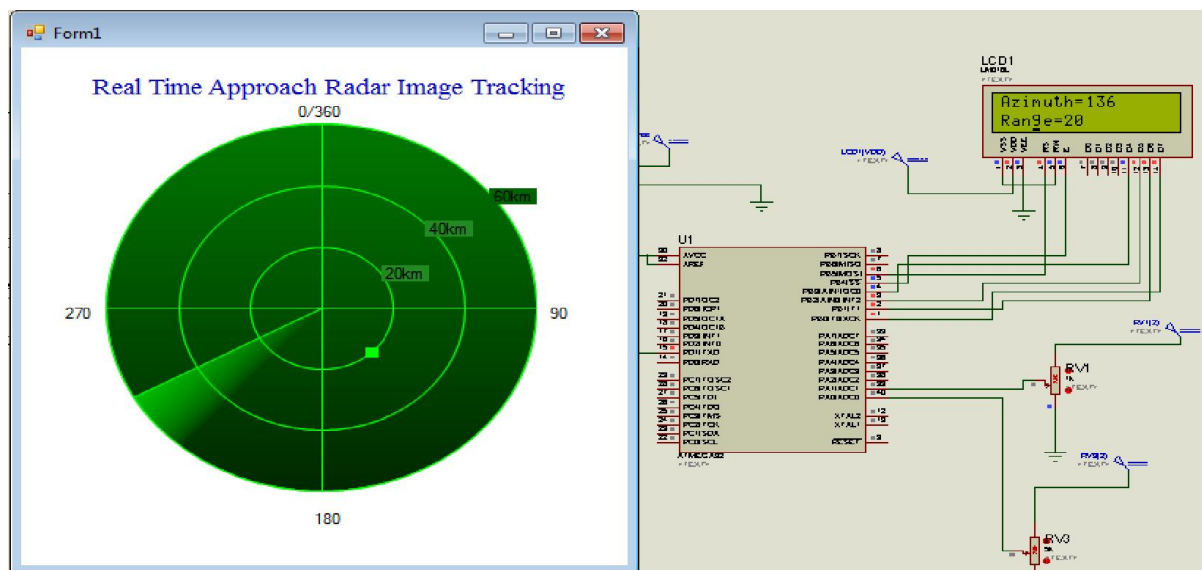
Figure (5-3) snapshot of experiment no.3

5.2.4 Experment no (4)

The figures (5-4) shows the target location when it's coming from south direction.
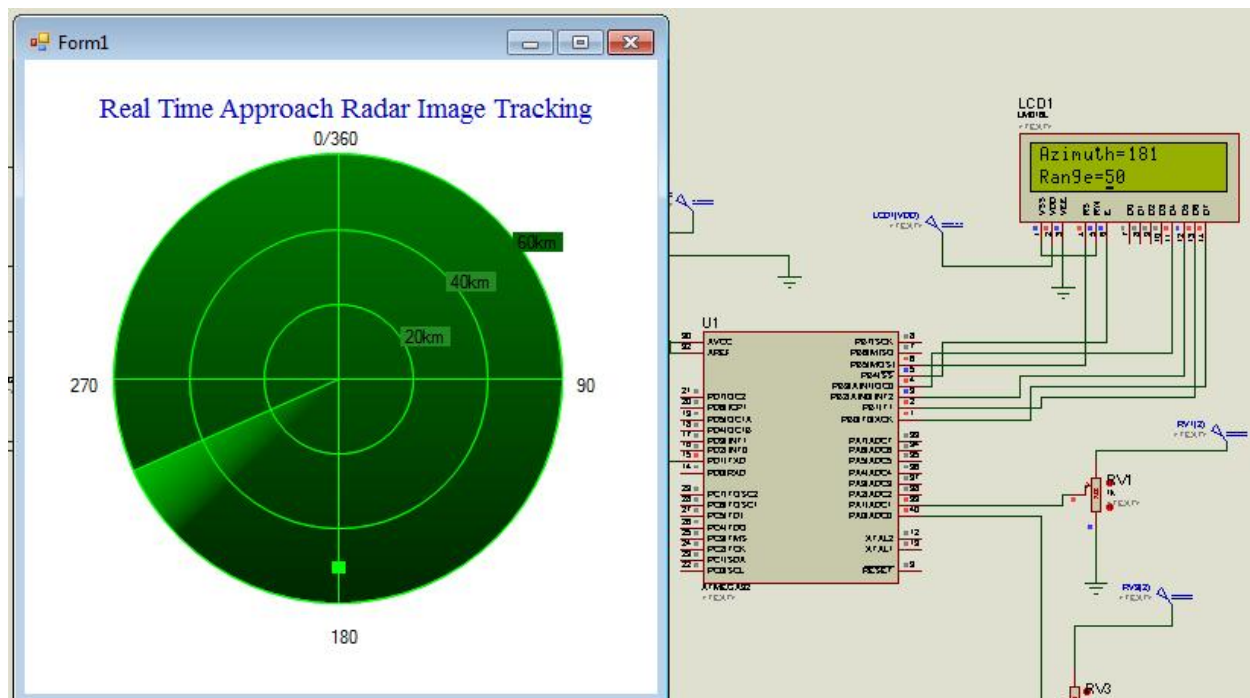
Figure (5-4) snapshot of experiment no.4

5.2.5 Experment no(5)

Figure (5-5) shows other different values of parameters with their locations on GUI.
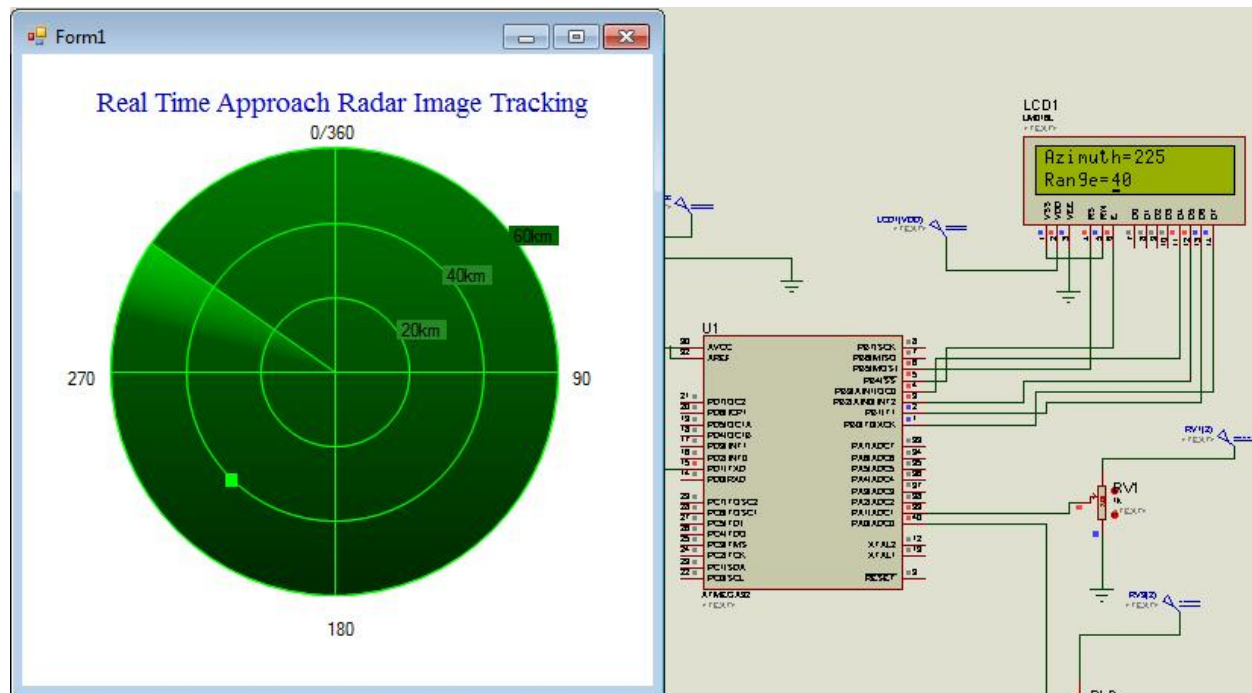
Figure (5-5) snapshot of experiment no.5

5.3 Discussion

From the result, this system is very effective to monitor targets in all location. The GUI will display the same position as reading at the LCD from potentiometers. Any changes of azimuth and range reading will update the location of target in GUI.

Chapter Six

(Conclusion and Recommendation)

Conclusion and Recommendation

6.1 Conclusion

The aim of this project to track and monitor the targets that detected by approach radar. The designed was successfully applied to one target.

Radar parameters were read by MCU and displayed on LCD for comparison then transmitted through X-bee modules and received in other side and interfaced to computer which used to display target location on computer through GUI written in visual C# program.

The result of simulation gave the desired result with accurate position of detected targets on GUI with comparison to values displayed on LCD.

6.2 Recommendation

The recommended approach is to develop a system which could detect and display more than one target in the same time mark target by different color to easy tracking.

Information displayed on approach radars was simple, including aircraft position, but Secondary Radar has a display containing aircraft position, ID, speed, heading etc, so the second recommended is to join primary and secondary radar parameters in the same image to give full information about target.

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Appendixes

Appendix A Software Code (Bascom)

```
$regfile = "m32def.dat"

$crystal = 8000000

$baud = 9600

Config Adc = Single , Prescaler = Auto

Config Lcdpin = Pin , Db4 = Portb.3 , Db5 = Portb.2 , Db6 = Portb.1 , Db7 =
Portb.0 , E = Portb.4 , Rs = Portb.5

Dim Adc_1 As Word

Dim Adc_2 As Word

Dim Azimuth As Word

Dim Range As Word

Dim D As Byte

Dim X As Byte

Dim Y As Word

Dim Z As Byte

X = 255

Do

Adc_1 = Getadc(0)

Y = Adc_1 / 2.8

Azimuth = Y * 2

D = Y / 2

Locate 1 , 1

Lcd "Azimuth="
```

Lcd Azimuth

'--------------------Range

Adc_2 = Getadc(1)

Range = Adc_2 / 17

Locate 2 , 1

Lcd "Range="

Lcd Range

'------------ SEND to Wirless

Printbin X

Printbin D
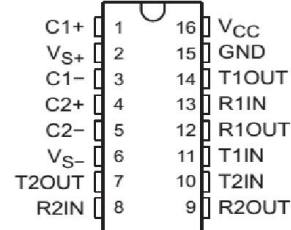
Printbin Range

'Waitms 31.25

Loop

Appendix B

MAX232, MAX232I
DUAL EIA-232 DRIVERS/RECEIVERS

SLLS047L – FEBRUARY 1989 – REVISED MARCH 2004

- Meets or Exceeds TIA/EIA-232-F and ITU Recommendation V.28
- Operates From a Single 5-V Power Supply With 1.0-μF Charge-Pump Capacitors
- Operates Up To 120 kbit/s
- Two Drivers and Two Receivers
- ±30-V Input Levels
- Low Supply Current . . . 8 mA Typical
- ESD Protection Exceeds JESD 22
  − 2000-V Human-Body Model (A114-A)
- Upgrade With Improved ESD (15-kV HBM) and 0.1-μF Charge-Pump Capacitors is Available With the MAX202
- Applications
  − TIA/EIA-232-F, Battery-Powered Systems, Terminals, Modems, and Computers

MAX232 . . . D, DW, N, OR NS PACKAGE
MAX232I . . . D, DW, OR N PACKAGE
(TOP VIEW)

C1+	1	16	V_{CC}
V_{S+}	2	15	GND
C1−	3	14	T1OUT
C2+	4	13	R1IN
C2−	5	12	R1OUT
V_{S-}	6	11	T1IN
T2OUT	7	10	T2IN
R2IN	8	9	R2OUT

description/ordering information

The MAX232 is a dual driver/receiver that includes a capacitive voltage generator to supply TIA/EIA-232-F voltage levels from a single 5-V supply. Each receiver converts TIA/EIA-232-F inputs to 5-V TTL/CMOS levels. These receivers have a typical threshold of 1.3 V, a typical hysteresis of 0.5 V, and can accept ±30-V inputs. Each driver converts TTL/CMOS input levels into TIA/EIA-232-F levels. The driver, receiver, and voltage-generator functions are available as cells in the Texas Instruments LinASIC™ library.

ORDERING INFORMATION

T_A	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING
0°C to 70°C	PDIP (N)	Tube of 25	MAX232N	MAX232N
	SOIC (D)	Tube of 40	MAX232D	MAX232
		Reel of 2500	MAX232DR	
	SOIC (DW)	Tube of 40	MAX232DW	MAX232
		Reel of 2000	MAX232DWR	
	SOP (NS)	Reel of 2000	MAX232NSR	MAX232
−40°C to 85°C	PDIP (N)	Tube of 25	MAX232IN	MAX232IN
	SOIC (D)	Tube of 40	MAX232ID	MAX232I
		Reel of 2500	MAX232IDR	
	SOIC (DW)	Tube of 40	MAX232IDW	MAX232I
		Reel of 2000	MAX232IDWR	

† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.

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LinASIC is a trademark of Texas Instruments.

TEXAS INSTRUMENTS

POST OFFICE BOX 655303 ● DALLAS, TEXAS 75265

1

MAX232, MAX232I
DUAL EIA-232 DRIVERS/RECEIVERS

SLLS047L − FEBRUARY 1989 − REVISED MARCH 2004

Function Tables

EACH DRIVER

INPUT TIN	OUTPUT TOUT
L	H
H	L

H = high level, L = low level

EACH RECEIVER

INPUT RIN	OUTPUT ROUT
L	H
H	L

H = high level, L = low level

logic diagram (positive logic)
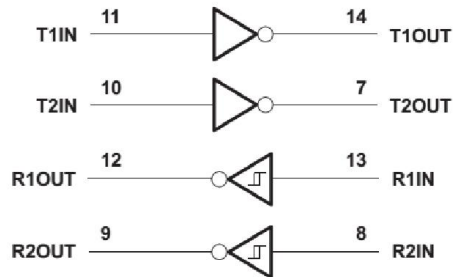
T1IN — 11 — 14 — T1OUT

T2IN — 10 — 7 — T2OUT

R1OUT — 12 — 13 — R1IN

R2OUT — 9 — 8 — R2IN

TEXAS
INSTRUMENTS

POST OFFICE BOX 655303 ● DALLAS, TEXAS 75265

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Input supply voltage range, V_{CC} (see Note 1)	−0.3 V to 6 V
Positive output supply voltage range, V_{S+}	V_{CC} − 0.3 V to 15 V
Negative output supply voltage range, V_{S-}	−0.3 V to −15 V
Input voltage range, V_I: Driver	−0.3 V to V_{CC} + 0.3 V
Receiver	±30 V
Output voltage range, V_O: T1OUT, T2OUT	V_{S-} − 0.3 V to V_{S+} + 0.3 V
R1OUT, R2OUT	−0.3 V to V_{CC} + 0.3 V
Short-circuit duration: T1OUT, T2OUT	Unlimited
Package thermal impedance, θ_{JA} (see Notes 2 and 3): D package	73°C/W
DW package	57°C/W
N package	67°C/W
NS package	64°C/W
Operating virtual junction temperature, T_J	150°C
Storage temperature range, T_{stg}	−65°C to 150°C

† Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTES: 1. All voltages are with respect to network GND.
2. Maximum power dissipation is a function of T_J(max), θ_{JA}, and T_A. The maximum allowable power dissipation at any allowable ambient temperature is $P_D = (T_J(max) − T_A)/\theta_{JA}$. Operating at the absolute maximum T_J of 150°C can affect reliability.
3. The package thermal impedance is calculated in accordance with JESD 51-7.

recommended operating conditions

			MIN	NOM	MAX	UNIT
V_{CC}	Supply voltage		4.5	5	5.5	V
V_{IH}	High-level input voltage (T1IN,T2IN)		2			V
V_{IL}	Low-level input voltage (T1IN, T2IN)				0.8	V
R1IN, R2IN	Receiver input voltage				±30	V
T_A	Operating free-air temperature	MAX232	0		70	°C
		MAX232I	−40		85	

electrical characteristics over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted) (see Note 4 and Figure 4)

PARAMETER		TEST CONDITIONS	MIN	TYP‡	MAX	UNIT
I_{CC}	Supply current	V_{CC} = 5.5 V, All outputs open, T_A = 25°C		8	10	mA

‡ All typical values are at V_{CC} = 5 V and T_A = 25°C.
NOTE 4: Test conditions are C1−C4 = 1 µF at V_{CC} = 5 V ± 0.5 V.

Appendix: C

LCD-016M002B
Vishay

16 x 2 Character LCD

FEATURES

- 5 x 8 dots with cursor
- Built-in controller (KS 0066 or Equivalent)
- + 5V power supply (Also available for + 3V)
- 1/16 duty cycle
- B/L to be driven by pin 1, pin 2 or pin 15, pin 16 or A.K (LED)
- N.V. optional for + 3V power supply

MECHANICAL DATA

ITEM	STANDARD VALUE	UNIT
Module Dimension	80.0 x 36.0	mm
Viewing Area	66.0 x 16.0	mm
Dot Size	0.56 x 0.66	mm
Character Size	2.96 x 5.56	mm

ABSOLUTE MAXIMUM RATING

ITEM	SYMBOL	STANDARD VALUE			UNIT
		MIN.	TYP.	MAX.	
Power Supply	VDD-VSS	- 0.3	–	7.0	V
Input Voltage	VI	- 0.3	–	VDD	V

NOTE: VSS = 0 Volt, VDD = 5.0 Volt

ELECTRICAL SPECIFICATIONS

ITEM	SYMBOL	CONDITION		STANDARD VALUE			UNIT
				MIN.	TYP.	MAX.	
Input Voltage	VDD	VDD = + 5V		4.7	5.0	5.3	V
		VDD = + 3V		2.7	3.0	5.3	V
Supply Current	IDD	VDD = 5V		–	1.2	3.0	mA
Recommended LC Driving Voltage for Normal Temp. Version Module	VDD - V0	- 20 °C		–	–	–	V
		0°C		4.2	4.8	5.1	
		25°C		3.8	4.2	4.6	
		50°C		3.6	4.0	4.4	
		70°C		–	–	–	
LED Forward Voltage	VF	25°C		–	4.2	4.6	V
LED Forward Current	IF	25°C	Array	–	130	260	mA
			Edge	–	20	40	
EL Power Supply Current	IEL	Vel = 110VAC:400Hz		–	–	5.0	mA

DISPLAY CHARACTER ADDRESS CODE:

Display Position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
DD RAM Address	00	01														0F
DD RAM Address	40	41														4F

LCD-016M002B

Vishay   16 x 2 Character LCD   **VISHAY**

PIN NUMBER	SYMBOL	FUNCTION
1	Vss	GND
2	Vdd	+ 3V or + 5V
3	Vo	Contrast Adjustment
4	RS	H/L Register Select Signal
5	R/W̄	H/L Read/Write Signal
6	E	H →L Enable Signal
7	DB0	H/L Data Bus Line
8	DB1	H/L Data Bus Line
9	DB2	H/L Data Bus Line
10	DB3	H/L Data Bus Line
11	DB4	H/L Data Bus Line
12	DB5	H/L Data Bus Line
13	DB6	H/L Data Bus Line
14	DB7	H/L Data Bus Line
15	A/Vee	+ 4.2V for LED/Negative Voltage Output
16	K	Power Supply for B/L (OV)

DIMENSIONS in millimeters
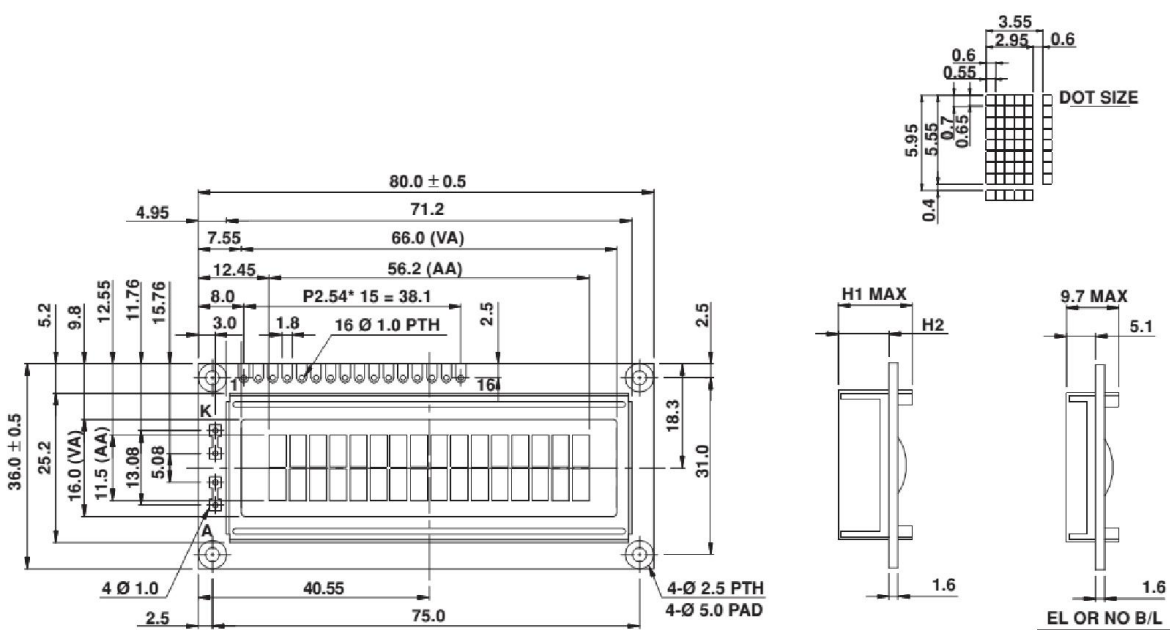
LED - H/L B/L		
	HIGH	LOW
H1	13.2	12.1
H2	8.6	7.5